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

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
18 January 2018 (18.01.2018)

WIPO | PCT

(10) International Publication Number
WO 2018/013596 A1

(51) International Patent Classification:
H04B 7/06 (2006.01) *H04B 7/08* (2006.01)

(21) International Application Number:
PCT/US2017/041576

(22) International Filing Date:
11 July 2017 (11.07.2017)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
PCT/CN2016/089666 11 July 2016 (11.07.2016) CN
62/377,296 19 August 2016 (19.08.2016) US
PCT/CN2016/097600 31 August 2016 (31.08.2016) CN
62/382,089 31 August 2016 (31.08.2016) US

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

(72) Inventors: **CHANG, Wenting**; 8F, Raycom Infotech Park A., No. 2, KeXueYuan South Road, Beijing 100190 (CN). **NIU, Huaning**; 6806 Bluffwood Ct., San Jose, California 95120 (US). **ZHU, Yuan**; Room 605, Building 16, Mo Li Yuan, Bei Yuan Jia Yuan, Chao Yang District, Beijing 100012 (CN). **ZHANG, Yushu**; 8F, Raycom Infotech Park A., No. 2, KeXueYuan South Road, Haidian District, Beijing 100190 (CN). **TANG, Yang**; 5752 Owens Drive, Apt. 301, Pleasanton, California 94588 (US). **PAWAR, Sameer**; 444 Saratoga Avenue, Apt. 24-H, Santa Clara, California 95050 (US). **MIAO, Honglei**; Aindorferstrasse 2, 80686 Munich (DE). **XIONG, Gang**; 16682 NW Arizona Drive, Beaverton, Oregon 97006 (US).

(74) Agent: **NICHOLSON, JR., Wesley E.**; Green, Howard & Mughal, LLP, 5 Centerpointe Drive, Suite 400, Lake Oswego, Oregon 97035 (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, DJ, DK, DM, DO,

(54) Title: SYSTEM AND METHOD FOR CONFIRMATION OF BEAM SWITCHING

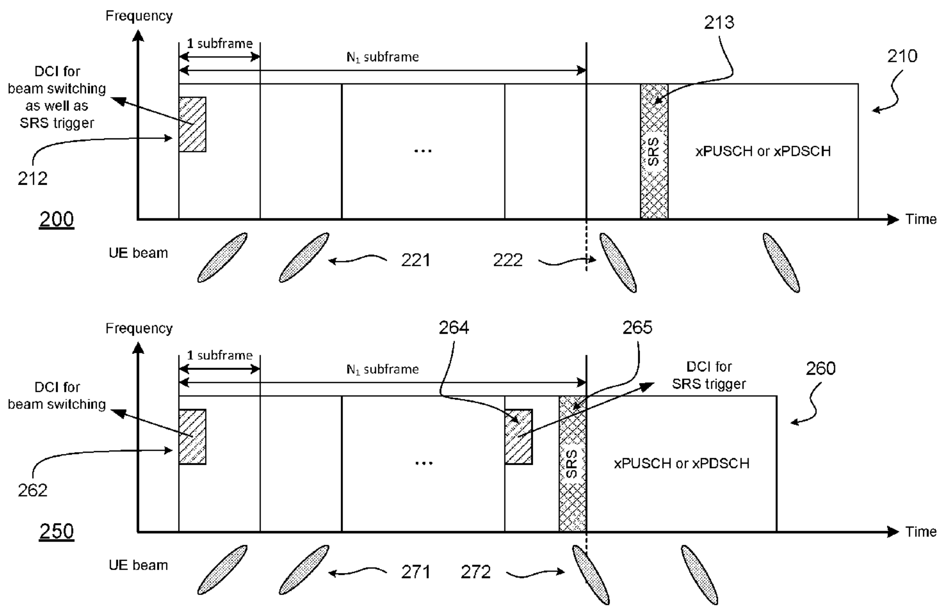

Fig. 2

(57) Abstract: Described is an apparatus of a User Equipment (UE). The apparatus may comprise a first circuitry and a second circuitry. The first circuitry may be operable to process a Downlink Control Information (DCI) received via a first UE beam, the DCI carrying an indicator for switching to a second UE beam. The second circuitry may be operable to generate a confirmation transmission for the second UE beam based on a trigger indicator. The apparatus may also comprise an interface for inputting the DCI to one or more processors of the apparatus and for outputting the confirmation transmission to a transmission circuitry.

WO 2018/013596 A1

[Continued on next page]

DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JO, JP, KE, KG, KH, KN, KP, KR, KW, 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))*

Published:

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

SYSTEM AND METHOD FOR CONFIRMATION OF BEAM SWITCHING

CLAIM OF PRIORITY

[0001] The present application claims priority to Patent Cooperation Treaty International Patent Application Number PCT/CN2016/097600 filed August 31, 2016, and claims priority to United States Provisional Patent Application Serial Number 62/382,089 filed August 31, 2016, and claims priority to Patent Cooperation Treaty International Patent Application Number PCT/CN2016/089666 filed July 11, 2016, and claims priority to United States Provisional Patent Application Serial Number 62/377,296 filed August 19, 2016, which are herein incorporated by reference in their entirety.

BACKGROUND

[0002] A variety of wireless cellular communication systems have been implemented, including a 3rd Generation Partnership Project (3GPP) Universal Mobile Telecommunications System, a 3GPP Long-Term Evolution (LTE) system, and a 3GPP LTE-Advanced (LTE-A) system. Next-generation wireless cellular communication systems based upon LTE and LTE-A systems are being developed, such as a fifth generation (5G) wireless system / 5G mobile networks system. Next-generation wireless cellular communication systems may provide support for higher data rates.

BRIEF DESCRIPTION OF THE DRAWINGS

[0003] The embodiments of the disclosure will be understood more fully from the detailed description given below and from the accompanying drawings of various embodiments of the disclosure. However, while the drawings are to aid in explanation and understanding, they are only an aid, and should not be taken to limit the disclosure to the specific embodiments depicted therein.

[0004] **Fig. 1** illustrates synchronous beam switching, in accordance with some embodiments of the disclosure.

[0005] **Fig. 2** illustrates Sounding Reference Signal (SRS) transmission for confirmation of beam switching, in accordance with some embodiments of the disclosure.

[0006] **Fig. 3** illustrates Channel State Information Reference Signal (CSI-RS) transmission for confirmation of beam switching, in accordance with some embodiments of the disclosure.

[0007] **Fig. 4** illustrates Physical Random Access Channel (PRACH) transmission for confirmation of beam switching, in accordance with some embodiments of the disclosure.

[0008] **Fig. 5** illustrates User Equipment (UE) transmission of SR signal, in accordance with some embodiments of the disclosure.

[0009] **Fig. 6** illustrates UE transmission of SRS along with 2 bits of side information, in accordance with some embodiments of the disclosure.

[0010] **Fig. 7** illustrates initial beam acquisition, in accordance with some embodiments of the disclosure.

[0011] **Fig. 8** illustrates beam management based on omnidirectional Beam Refinement Reference Signal (BRRS) and beamformed SRS, in accordance with some embodiments of the disclosure.

[0012] **Fig. 9** illustrates beam management based on omnidirectional SRS and beamformed BRRS, in accordance with some embodiments of the disclosure.

[0013] **Fig. 10** illustrates a multiple narrow-beam layout, in accordance with some embodiments of the disclosure.

[0014] **Fig. 11** illustrates beam numbering with respect to Zenith Angle of Departure (ZoD) and Azimuth Angle of Departure (AoD), in accordance with some embodiments of the disclosure.

[0015] **Fig. 12** illustrates beam mapping onto Orthogonal Frequency-Division Multiplexing (OFDM) time and frequency resources, in accordance with some embodiments of the disclosure.

[0016] **Fig. 13** illustrates beam mapping for implicitly indicating inter-subset beam correlation, in accordance with some embodiments of the disclosure.

[0017] **Fig. 14** illustrates relative performance of coherent combination of correlated inter-subset beams, in accordance with some embodiments of the disclosure.

[0018] **Fig. 15** illustrates beam mapping for implicitly indicating inter-subset beam correlation, in accordance with some embodiments of the disclosure.

[0019] **Fig. 16** illustrates beam mapping for implicitly indicating inter-subset beam correlation, in accordance with some embodiments of the disclosure.

[0020] **Fig. 17** illustrates a correlation association between intra-subset beams and inter-subset beams, in accordance with some embodiments of the disclosure.

[0021] **Fig. 18** illustrates an Evolved Node B (eNB) and a UE, in accordance with some embodiments of the disclosure.

[0022] **Fig. 19** illustrates hardware processing circuitries for a UE for confirmation of beam-forming, in accordance with some embodiments of the disclosure.

[0023] **Fig. 20** illustrates hardware processing circuitries for an eNB for confirmation of beam-forming, in accordance with some embodiments of the disclosure.

[0024] **Fig. 21** illustrates methods for a UE for confirmation of beam-forming, in accordance with some embodiments of the disclosure.

[0025] **Fig. 22** illustrates methods for an eNB for confirmation of beam-forming, in accordance with some embodiments of the disclosure.

[0026] **Fig. 23** illustrates example components of a device, in accordance with some embodiments of the disclosure.

[0027] **Fig. 24** illustrates example interfaces of baseband circuitry, in accordance with some embodiments of the disclosure.

DETAILED DESCRIPTION

[0028] Various wireless cellular communication systems have been implemented or are being proposed, including a 3rd Generation Partnership Project (3GPP) Universal Mobile Telecommunications System (UMTS), a 3GPP Long-Term Evolution (LTE) system, a 3GPP LTE-Advanced system, and a 5th Generation wireless system / 5th Generation mobile networks (5G) system / 5th Generation new radio (NR) system.

[0029] With respect to various embodiments, in coming 5G systems, high frequency bands may be adopted to support higher user-experienced data rates. In high frequency bands, beam-forming may include transmit-side (Tx) beam-forming and receive-side (Rx) beam-forming, and may be applied to increase beam-forming gain. In turn, increased beam-forming gain may advantageously compensate for severe pathloss that may be associated with high frequency bands, and may also advantageously suppress mutual user interference.

[0030] In a beam-forming system, a Tx beam and an Rx beam may be paired and aligned to the same channel cluster. For a wireless link between eNB and UE, multiple channel clusters may exist, which may be due to reflection, diffraction, or both. On an Evolved Node-B (eNB) side of the link, a Tx beam may align with an Azimuth Angle of Departure (AoD) and/or a Zenith Angle of Departure (ZoD) of a strongest channel cluster. Similarly, on a User Equipment (UE) side of the link, an Rx beam may align with an Azimuth Angle of Arrival (AoA) and/or Zenith Angle of Arrival (ZoA) of a strongest channel cluster. Movement of the UE, or rotation of the UE, or a surrounding environment change may lead the strongest channel cluster to change. Subsequently, the Tx beam and Rx beam pair may be disposed to being switched, which may advantageously help realize transmission on the strongest channel cluster.

[0031] A beam-forming switching indicator or Beam Refinement Reference Signal (BRRS) may be configured by the eNB to realize synchronous switching of an eNB beam and a UE beam. However, such switching information may be lost due to, for example, a failed detection of Downlink Control Information (DCI), or a failed demodulation of an indicator or a BRRS. If smooth beam switching is performed, an eNB and a UE may still communicate with each other based on a slightly deteriorated channel. However, in situations involving abrupt beam switching, link quality may decrease severely, and (more seriously) the link may break.

[0032] Discussed herein are mechanisms and methods for confirmation of beam switching. In some embodiments, Sounding Reference Signal (SRS) may be a confirming signal. For some embodiments, Channel State Information Reference Signal (CSI-RS) may be a confirming signal. In some embodiments, Physical Random Access Channel (PRACH) may be a confirming signal.

[0033] With respect to various embodiments, in a cellular communications system, a Scheduling Request (SR) may be used by a UE to request Uplink (UL) shared channel (UL-SCH) resources for a new transmission. An SR channel may be designed for a cellular system operating in mid-to-high frequency bands. In a high frequency band communication system (for example, a millimeter-wave (mmWave) system), designing an SR channel may be challenging since both UL transmission and UL reception may be disposed to being beam-formed, which may advantageously overcome significant path loss commonly that may be experienced at those higher frequencies. For example, with respect to SR transmission, although a UE can use an acquired Rx beam, assuming channel reciprocity, from Downlink (DL) beam acquisition signals (such as synchronization signals or beam-refinement signals), an eNB may not know the UL Rx beam to detect the SR channel.

[0034] Discussed herein are mechanisms and methods for efficiently and reliably detecting SR's from multiple UE's, even when the eNB does not know the UL Rx beam (or beams) for the SR channel, while simultaneously supporting a low-latency operation.

[0035] In high frequency band communication systems, both Tx beam-forming and Rx beam-forming during UL channel transmission, such as SR channel, may facilitate successful communication. In various embodiments, a UE-specific sub-carrier sub-sampling may be carefully selected for SR channel. Frequency domain subsampling may result in a replicated time-domain signal for each transmitting UE. Multiple time-domain replicas may provide an eNB with an opportunity to perform beam-scanning using multiple Rx beams and find an appropriate Rx beam. Sub-carrier subsampling may further provide additional UE multiplexing resource, thus supporting eNB Rx beam-scanning without being wasteful of UL resources.

[0036] The mechanisms and methods may be compatible with other forms of UE multiplexing, such as code division multiplexing (CDM), using orthogonal sequences over time or cyclic shift based multiplexing in frequency domain, and so forth. The mechanisms and methods may apply to systems based upon Guard Interval Discrete Fourier Transform spread Orthogonal Frequency-Division Multiplexing (GI-DFT-s-OFDM). The mechanisms and methods may also apply to systems based upon other types of multi-carrier waveforms, such as systems based upon Orthogonal Frequency-Division Multiplexing (OFDM), or systems based upon Zero-Tail Discrete Fourier Transform spread OFDM (ZT-DFT-s-OFDM), for example. In some embodiments, the methods and mechanisms may also be applied to SR design for mid-to-high band mmWave systems, with GI-DFT-s-OFDM waveforms and/or implicit beam training (e.g., eNB Rx beam training through UL Random Access Channel (RACH) and/or SRS signaling without an explicit UE Beamforming Reference Signal Received Power (BRS-RP) feedback).

[0037] With respect to various embodiments, mobile communications have evolved significantly from early voice systems to current integrated communication platforms. 5G systems may provide access to information and sharing of data anywhere, anytime by various users and applications. 5G may provide unified networks and/or systems targeting vastly different and sometime conflicting performance dimensions and services. Such diverse multi-dimensional requirements are driven by different services and applications.

[0038] In general, 5G systems may evolve from 3GPP LTE-A systems with additional potential new Radio Access Technologies (RATs) to facilitate simpler and seamless wireless connectivity solutions. 5G may enable many services connected by wireless technology and may deliver fast, rich content and services.

[0039] In high frequency band wireless systems, beam-forming including an eNB side and a UE side may be performed to compensate for severe pathloss. On a DL side, a beam may be associated with a Beamforming Reference Signal (BRS), and a beam related indicator may be referred to a BRS index number. However, for some systems, BRS may not exist.

[0040] Discussed herein are mechanisms and methods for beam acquisition and management without BRS. Some embodiments may comprise initial beam acquisition based on synchronization signal and PRACH. Some embodiments may comprise beam management based on BRRS and SRS.

[0041] With respect to various embodiments, in order to compensate for severe pathloss, beam-forming may be applied. Multiple beams with narrow beam widths may cover an area. Among these beams, adjacent beams may have high correlation with each other, which may enable a UE to realize fast beam acquisition based on better link reliability. This characteristic may be utilized to divide beams into multiple subsets, which may enable hierarchical beam search and may reduce latency of beam acquisition. In addition to subset division, a beam pattern of NW beams may be further improved to support a beam correlation that may be implicitly configured by a beam pattern. In this way, a coherent beam combination may be supported, and a BRS-RP report according to an instantaneous value change between highly correlated beams may advantageously be avoided.

[0042] Discussed herein are mechanisms and methods for informing a UE of a correlation between different beams based on beam pattern design. In some embodiments, a beam pattern layout may indicate inter-subset beam correlation. For some embodiments, a beam pattern layout may indicate intra-subset beam correlation.

[0043] In the following description, numerous details are discussed to provide a more thorough explanation of embodiments of the present disclosure. It will be apparent to one skilled in the art, however, that embodiments of the present disclosure may be practiced without these specific details. In other instances, well-known structures and devices are shown in block diagram form, rather than in detail, in order to avoid obscuring embodiments of the present disclosure.

[0044] Note that in the corresponding drawings of the embodiments, signals are represented with lines. Some lines may be thicker, to indicate a greater number of constituent signal paths, and/or have arrows at one or more ends, to indicate a direction of information flow. Such indications are not intended to be limiting. Rather, the lines are used in connection with one or more exemplary embodiments to facilitate easier understanding of a circuit or a logical unit. Any represented signal, as dictated by design needs or preferences, may actually comprise one or more signals that may travel in either direction and may be implemented with any suitable type of signal scheme.

[0045] Throughout the specification, and in the claims, the term "connected" means a direct electrical, mechanical, or magnetic connection between the things that are connected, without any intermediary devices. The term "coupled" means either a direct electrical, mechanical, or magnetic connection between the things that are connected or an indirect connection through one or more passive or active intermediary devices. The term "circuit" or "module" may refer to one or more passive and/or active components that are arranged to cooperate with one another to provide a desired function. The term "signal" may refer to at least one current signal, voltage signal, magnetic signal, or data/clock signal. The meaning of "a," "an," and "the" include plural references. The meaning of "in" includes "in" and "on."

[0046] The terms "substantially," "close," "approximately," "near," and "about" generally refer to being within +/- 10% of a target value. Unless otherwise specified the use of the ordinal adjectives "first," "second," and "third," etc., to describe a common object, merely indicate that different instances of like objects are being referred to, and are not intended to imply that the objects so described must be in a given sequence, either temporally, spatially, in ranking, or in any other manner.

[0047] It is to be understood that the terms so used are interchangeable under appropriate circumstances such that the embodiments of the invention described herein are, for example, capable of operation in other orientations than those illustrated or otherwise described herein.

[0048] The terms "left," "right," "front," "back," "top," "bottom," "over," "under," and the like in the description and in the claims, if any, are used for descriptive purposes and not necessarily for describing permanent relative positions.

[0049] For the purposes of the present disclosure, the phrases "A and/or B" and "A or B" mean (A), (B), or (A and B). For the purposes of the present disclosure, the phrase "A, B, and/or C" means (A), (B), (C), (A and B), (A and C), (B and C), or (A, B and C).

[0050] In addition, the various elements of combinatorial logic and sequential logic discussed in the present disclosure may pertain both to physical structures (such as AND gates, OR gates, or XOR gates), or to synthesized or otherwise optimized collections of devices implementing the logical structures that are Boolean equivalents of the logic under discussion.

[0051] In addition, for purposes of the present disclosure, the term "eNB" may refer to a legacy LTE capable eNB, a next-generation or 5G capable eNB (which may be referred to as a gNB), a millimeter-wave (mmWave) capable eNB or an mmWave small cell, an Access Point (AP), and/or another base station (BS) for a wireless communication system. For purposes of the present disclosure, the term "UE" may refer to a legacy LTE capable UE, a next-generation or 5G capable UE, an mmWave capable UE, a Station (STA), and/or another mobile equipment for a wireless communication system.

[0052] Various embodiments of eNBs and/or UEs discussed below may process one or more transmissions of various types. Some processing of a transmission may comprise demodulating, decoding, detecting, parsing, and/or otherwise handling a transmission that has been received. In some embodiments, an eNB or UE processing a transmission may determine or recognize the transmission's type and/or a condition associated with the transmission. For some embodiments, an eNB or UE processing a transmission may act in accordance with the transmission's type, and/or may act conditionally based upon the transmission's type. An eNB or UE processing a transmission may also recognize one or more values or fields of data carried by the transmission. Processing a transmission may comprise moving the transmission through one or more layers of a protocol stack (which may be implemented in, e.g., hardware and/or software-configured elements), such as by moving a transmission that has been received by an eNB or a UE through one or more layers of a protocol stack.

[0053] Various embodiments of eNBs and/or UEs discussed below may also generate one or more transmissions of various types. Some generating of a transmission may comprise modulating, encoding, formatting, assembling, and/or otherwise handling a transmission that is to be transmitted. In some embodiments, an eNB or UE generating a transmission may establish the transmission's type and/or a condition associated with the transmission. For some embodiments, an eNB or UE generating a transmission may act in accordance with the transmission's type, and/or may act conditionally based upon the transmission's type. An eNB or UE generating a transmission may also determine one or more values or fields of data carried by the transmission. Generating a transmission may comprise moving the transmission through one or more layers of a protocol stack (which may be implemented in, e.g., hardware and/or software-configured elements), such as by moving a transmission to be sent by an eNB or a UE through one or more layers of a protocol stack.

[0054] In various embodiments, resources may span various Resource Blocks (RBs), Physical Resource Blocks (PRBs), and/or time periods (e.g., frames, subframes, and/or slots) of a wireless communication system. In some contexts, allocated resources (e.g., channels, Orthogonal Frequency-Division Multiplexing (OFMD) symbols, subcarrier frequencies, resource elements (REs), and/or portions thereof) may be formatted for (and prior to) transmission over a wireless communication link. In other contexts, allocated resources (e.g., channels, OFDM symbols, subcarrier frequencies, REs, and/or portions thereof) may be detected from (and subsequent to) reception over a wireless communication link.

[0055] **Fig. 1** illustrates synchronous beam switching, in accordance with some embodiments of the disclosure. A scenario 100 may comprise a set of traffic 110 over a wireless communications link between an eNB and a UE. Traffic 110 may comprise a DCI 112. Based on a beam switching indicator carried by DCI 112, the UE may transition from a first UE beam 121 to a second UE beam 122 after a number of subframes N_1, which may be a predetermined number. (First UE beam 121 and/or second UE beam 122 may be UE Tx beams, UE Rx beams, or both.) DCI 112 may be configured by the eNB.

[0056] A scenario 150 may comprise a set of traffic 160 over a wireless communications link between an eNB and a UE. Traffic 160 may comprise a DCI 162 and/or a BRRS 163. Based on BRRS 163, the UE may transition from a first UE beam 171 to a second UE beam 172 after a number of subframes N_1, which may be a predetermined number. (First UE beam 121 and/or second UE beam 122 may be UE Tx beams, UE Rx beams, or both.) BRRS 163 may be configured by the eNB.

[0057] Accordingly, a beam-forming switching indicator (e.g., via DCI) and/or BRRS may be configured by an eNB to realize beam switching synchronously. The DCI or BRRS may be configured by the eNB, and a UE may switch from a first beam to a new, second beam after N_1 subframes, where reserving N_1 subframes may enable the UE to have sufficient processing time.

[0058] **Fig. 2** illustrates SRS transmission for confirmation of beam switching, in accordance with some embodiments of the disclosure. A scenario 200 may comprise a set of traffic 210 over a wireless communications link between an eNB and a UE. Traffic 210 may comprise a DCI 212, which may configure or otherwise indicate that SRS may be used as a confirming signal, and may also include a trigger for the SRS. An SRS 213 (which may be a 5G SRS (xSRS)) may follow DCI 212.

[0059] A number of subframes N_1 after DCI 212, the UE may transition from a first UE beam 221 to a second UE beam 222, and may transmit SRS 213 after switching beams. (First UE beam 221 and/or second UE beam 222 may be UE Tx beams, UE Rx beams, or both.) In this way, SRS (which may be duplicated) may be transmitted based on a new UE beam, which may enable the eNB to optimize a receiving beam when the new UE beam is applied.

[0060] A scenario 250 may comprise a set of traffic 260 over a wireless communications link between an eNB and a UE. Traffic 260 may comprise a first DCI 262, which may configure or otherwise indicate that an SRS may be used as a confirming signal.

Traffic 260 may also comprise a second DCI 264, which may include a trigger for the SRS. An SRS 265 (which may be a 5G SRS (xSRS)) may follow second DCI 264.

[0061] Second DCI 264 may be transmitted within N_1 subframes of the subframe in which first DCI 262 is transmitted. The UE may transition from a first UE beam 271 to a second UE beam 272, and may transmit SRS 265 after switching beams. (First UE beam 271 and/or second UE beam 272 may be UE Tx beams, UE Rx beams, or both.) In this way, SRS (which may be duplicated) may be transmitted based on a new UE beam, which may enable the eNB to optimize a receiving beam when the new UE beam is applied.

[0062] For some embodiments of scenario 200 and/or scenario 250, N_1 may be a predetermined number. In various embodiments of scenario 200 and/or scenario 250, the eNB may estimate Channel State Information (CSI), may utilize channel reciprocity to derive Channel Quality Information (CQI), and/or may assign an appropriate Modulation and Coding Scheme (MCS) for the UE, which may advantageously save a CQI report overhead.

[0063] **Fig. 3** illustrates CSI-RS transmission for confirmation of beam switching, in accordance with some embodiments of the disclosure. A scenario 300 may comprise a set of traffic 310 over a wireless communications link between an eNB and a UE. Traffic 310 may comprise a DCI 312, which may configure or otherwise indicate that a CQI report may be used as confirmation, and may also include a trigger for the CQI report. A CSI-RS 313 may follow DCI 312, and a CQI report 315 may follow CSI-RS 313.

[0064] A number of subframes N_1 after DCI 312, the UE may transition from a first UE beam 321 to a second UE beam 322, and may transmit CQI report 315 after switching beams. (First UE beam 321 and/or second UE beam 322 may be UE Tx beams, UE Rx beams, or both.) In this way, a CQI report may be transmitted based on a new UE beam, which may enable the eNB to optimize a receiving beam when the new UE beam is applied. CSI-RS may be transmitted via a Tx beam corresponding to a current optimal Rx beam.

[0065] A scenario 350 may comprise a set of traffic 360 over a wireless communications link between an eNB and a UE. Traffic 360 may comprise a first DCI 362, which may configure or otherwise indicate that a CQI report may be used as a confirmation. Traffic 360 may also comprise a second DCI 364, which may include a trigger for the CQI report. A CSI-RS 365 may follow second DCI 364, and a CQI report 367 may follow CSI-RS 365.

[0066] Second DCI 364 may be transmitted within N_1 subframes of the subframe in which first DCI 362 is transmitted. The UE may transition from a first UE beam 371 to a second UE beam 372, and may transmit CQI report 367 after switching beams. (First UE beam 371 and/or second UE beam 372 may be UE Tx beams, UE Rx beams, or both.) In this way, CQI report 367 may be transmitted based on a new UE beam, which may enable the eNB to optimize a receiving beam when the new UE beam is applied.

[0067] In scenario 300 and/or scenario 500, a UE may measure CSI-RS using a new Rx beam direction, and may feedback CQI to eNB. In this way, successful CQI feedback may serve as a confirmation for beam pair switching. An eNB may subsequently schedule data transmission using the new beam direction.

[0068] **Fig. 4** illustrates PRACH transmission for confirmation of beam switching, in accordance with some embodiments of the disclosure. A scenario 400 may comprise a set of traffic 410 over a wireless communications link between an eNB and a UE. Traffic 410 may comprise a DCI 412, which may configure or otherwise indicate that a PRACH transmission may be used as confirmation. A PRACH 413 (which may be a 5G PRACH (xPRACH)) may follow DCI 412.

[0069] The UE may then transition from a first UE beam 421 to a second UE beam 422. (First UE beam 421 and/or second UE beam 422 may be UE Tx beams, UE Rx beams, or both.) A time and/or frequency position for PRACH 413 may be associated with a preferred Tx beam. For example, if a current receiving beam on the UE side is matched with a first Tx beam (e.g., an eNB Tx beam), then a time and/or frequency position for PRACH 413 may be derived based on a time and/or frequency position associated with the first Tx beam. This identification may advantageously permit avoidance of additional control signaling for triggering acknowledgement and/or confirmation. The UE may then switch to a new receiving beam after transmitting PRACH 413 (which may postpone beam switching).

[0070] With respect to various embodiments, in a cellular communications system, an SR may be used by a UE for requesting UL Shared Channel (SCH) resources for a new transmission. In a high-frequency-band communication system, both Tx beam-forming and Rx beam-forming during UL channel transmission may facilitate successful communication. Hence, for transmission of a scheduling request, and assuming channel reciprocity, a UE may utilize a most-recent best DL receive beam acquired thus far for Tx beam-forming. Although this may address the process for Tx beam-forming, an eNB may not know the best Rx beam to employ for SR reception, and may be disposed to Rx beam sweeping. In order to facilitate an Rx beam sweep at the eNB, multiple copies of an SR may be transmitted by a UE within an OFDM symbol. The eNB may then scan multiple Rx beams, and may attempt to detect all transmitted SR (because more than one UE may transmit SR at a given time). Replication of a transmitted SR signal may be achieved by sub-sampling of available sub-carriers. In some embodiments, Zadoff-Chu (ZC) sequences may be used for transmitting SR.

[0071] **Fig. 5** illustrates UE transmission of SR signal, in accordance with some embodiments of the disclosure. In a scenario 500 of a UE transmitting SR signal, an N_{ZC} length ZC sequence may be used in transmitting SR signal. A total number of sub-carriers for the transmission may be a number N_{SC} greater than or equal to N_{ZC}. A sub-carrier mapping circuitry 512 may load the ZC symbols on every 4th sub-carrier 514 (sub-sampling) to achieve 4 repetitions of an SR signal in one symbol duration 516 (e.g., an OFDM symbol duration).

[0072] For GI-DFT-s-OFDM waveforms and/or ZT-DFTs- OFDM waveforms, no further modifications might be employed. For cyclic prefix based transmissions such as OFDM or DFT-s-OFDM, a cyclic prefix may be added to this symbol to get a final symbol with CP. The eNB may then attempt four different Rx beams to detect SR signal.

[0073] A Buffer Status Report (BSR) or other additional scheduling-request related information may be transmitted along with SR signal, which may advantageously reduce a transmission latency, by using a modulated ZC sequence with constellation symbols (e.g., Quadrature Phase-Shift Keying (QPSK), 16 Quadrature Amplitude Modulation (16-QAM), and so on). Note that when additional information is transmitted along with SR signal, a Demodulation Reference Signal (DMRS) may be transmitted for coherent demodulation of data. Sub-carriers used by the data modulated ZC sequence and the DMRS may be identical.

[0074] **Fig. 6** illustrates UE transmission of SRS along with 2 bits of side information, in accordance with some embodiments of the disclosure. In a scenario 600, a UE may transmit 2 bits of side information along with SR signal. An N_{ZC} length ZC sequence may be used to transmit SR signal. A total of number of sub-carriers for the transmission may be a number N_{SC} greater than or equal to N_{ZC}. A sub-carrier mapping circuitry 612 may load the ZC symbols on every 4th sub-carrier (sub-sampling) 614 to achieve 4 repetitions of an SR signal in one symbol duration 616 (e.g., an OFDM symbol duration).

[0075] DMRS signal may occupy the same set of sub-carriers as the data (e.g., every 4th sub-carrier). A sub-carrier mapping circuitry 622 may load the corresponding symbols on every 4th sub-carrier (sub-sampling) 624 to achieve 4 repetitions of a DMRS signal in one symbol duration 626 (e.g., an OFDM symbol duration). In some embodiments, symbol duration 626 may be the same OFDM symbol as symbol duration 616. The eNB may then attempt four different Rx beams to detect SR signal and decode additional information coherently.

[0076] In general, sub-carriers used for SR signal transmission might not be at the edge of a system bandwidth. An offset in occupied sub-carriers for SR signal transmission may result in a known phase ramp in the time-domain SR signal, which may be compensated by the eNB appropriately. Similarly, the sub-sampling factor (e.g., 4 as in scenario 500 and scenario 600), a number of times an SR signal may repeat per OFDM symbol, may be configured by an eNB using control messaging.

[0077] With respect to multiplexing of UEs within an SR channel, scheduling requests from multiple UEs may be multiplexed together in one SR channel using various orthogonal resources. In a first set of embodiments, frequency division multiplexing may use cossets (which may be, e.g., a set of subcarriers). SR information (with or without BSR) may occupy sub-sampled sub-carriers. The eNB can configure multiple cossets corresponding to the sets of the sub-carrier. For example, in scenario 500 and/or scenario 600, there may be 4 potential cossets, where: cosset $Ci = \{\text{subcarriers } N_{SC} \mid i = \text{mod}(N_{SC}, 4)\}$, for $i = 0,1,2,3$. The UE may occupy cosset-0.

[0078] In a second set of embodiments comprising cyclic shifts of ZC sequences, ZC sequences may have perfect zero-auto correlation (e.g., with their cyclic shifted versions). In a given symbol, multiple UEs may be multiplexed by using the same ZC sequence, but with different cyclic shifts to modulate their SR data. A number of cyclic shifts supported may be configured by eNB.

[0079] In a third set of embodiments comprising code division multiplexing in time, SR information may span multiple OFDM symbols if advantageous and/or configured. In this case, additional orthogonal UE multiplexing may be achieved by modulating different OFDM symbols with orthogonal spreading codes. The frequency cosset hopping across OFDM symbols may provide additional diversity gain.

[0080] In some embodiments, a method of wireless communications may comprise a communication between a UE and a base station (e.g., an mmWave base station), comprising the generating by the UE of an SR signal for requesting uplink resource when needed. For some embodiments, the method may comprise the UE identifying a transmit beam direction for the SR signal, based on DL reference signals such as primary synchronization signals (PSS) and secondary synchronization signals (SSS) or DL beam refinement signals. In some embodiments, the generated SR signal may be repetitive in the time-domain to facilitate performing receive beam-scan at the BS to identify the best possible Rx beam for receiving the transmitted SR signal. For some embodiments, the UE may generate a repeated time-domain SR signal using sub-sampled sub-carriers as configured by the BS.

[0081] In some embodiments, the UE may use a ZC sequence to generate SR. For some embodiments, the SR may consist of additional related information such as a BSR, which may be transmitted by modulating the ZC sequence. In some embodiments, a DMRS may be accompanied with SR when transmitting BSR for coherent demodulation of BSR. For some embodiments, the DMRS signal may occupies the same set of sub-carriers as the modulated BSR. In some embodiments, the DMRS signal may be generated using a ZC sequence. For some embodiments, for UL, different UEs may be assigned different sets of sub-sampled sub-carriers (e.g., cossets), cyclically shifted and cyclically extended versions of the same base ZC sequence and/or orthogonal spreading code across multiple OFDM symbols used for SR and BSR transmission.

[0082] In some embodiments, an apparatus to construct and transmit one or more signals such as the signals discussed herein may be part of a UE implementation. The apparatus may comprise circuitry operable to identify an appropriate direction for transmitting SR signal based on channel reciprocity assumptions and using most recent best available DL receive beam. The apparatus may additionally comprise circuitry operable to load appropriately assigned ZC sequences or modulated ZC sequences on the assigned cosset of sub-carriers. The apparatus may also comprise circuitry operable to accompany the SR signal transmission with DMRS signal occupying the same cosset of sub-carriers for coherent demodulation of the SR and/or BSR. The apparatus may further comprise circuitry operable to perform cosset hopping if configured by the base station.

[0083] For some embodiments, an apparatus to receive a signal such as the signals discussed herein may be part of a base station implementation. The apparatus may comprise circuitry operable to perform receive beam scan to identify the best receive beam for the SR and/or BSR. The apparatus may additionally comprise circuitry operable to perform time and/or frequency filtering and correlation to distinguish SR signal from multiple UEs. The apparatus may also comprise circuitry operable to perform channel estimation based on the transmitted DMRS with the SR signal and use it for coherent demodulation and/or decoding of the BSR and other information transmitted by UE as a part of the SR signal.

[0084] With respect to various embodiments, **Fig. 7** illustrates initial beam acquisition, in accordance with some embodiments of the disclosure. In an action 710, PSS and/or SSS may be repeatedly transmitted by multiple Transmission Points (TPs), which may provide additional SFN gain (e.g., Single Frequency Network gain). A UE may then obtain timing information and may derive a UE beam based on a repeated synchronous signal. In an action 720, based on the derived UE beam, the UE may repeatedly transmit PRACH (which may be 5G PRACH (xPRACH)), which may enable the eNB to calculate an eNB beam. In an action 720, eNB may then send a Random Access Response (RAR) based on the calculated eNB beam, and the UE may receive the RAR based on the derived UE beam.

[0085] In some embodiments, PSS transmitted by different TPs may be overlapped, which may improve the Signal-to-Interference-plus-Noise Ratio (SINR) for synchronous signals. However, in doing so for UE beam sweeping for a particular TP, PSS from different TPs may cause interference to each other.

[0086] For some embodiments, an omni-directional BRRS may be utilized for UE side beam training, and the BRRS may contain a repeated signal with the same Tx beam. Since different TPs may transmit BRRS orthogonally in time and/or frequency and/or code domains, corresponding interference may be reduced or avoided, which may enable a UE to derive an accurate UE beam for a particular TP.

[0087] **Fig. 8** illustrates beam management based on omnidirectional BRRS and beamformed SRS, in accordance with some embodiments of the disclosure. In a first action 810, an eNB may transmit an omni-directional beamed BRRS. The UE may perform beam sweeping against the omni-directional beamed BRRS. Then, in a second action 820, the UE may transmit SRS (which may be an xSRS) based on an active UE beam and/or candidate UE beam. The UE may accordingly derive an active UE beam and/or a candidate UE beam according to channel conditions.

[0088] In some embodiments, the UE may report to the eNB that one UE beam (e.g., an active beam, or an active UE beam and a candidate UE beam) may be detected. For some embodiments, a reduced BRRS report may be introduced. For example, two bits may be reported, where a first value (e.g., “00”) may indicate one UE beam is detected, a second value (e.g., “01”) may indicate two non-simultaneous UE beams, a third value (e.g., “10”) may indicate two simultaneous UE beams, and/or a fourth value (e.g. “11”) may be reserved. For some embodiments, according to the reported number of detected candidate UE beams, the eNB may schedule one or two SRS resources to the UE.

[0089] In some embodiments, the UE may transmit SRS based on an active UE beam and/or a candidate UE beam, where the SRS may contain repeated signals with the same Tx beam. This may enable the eNB to calculate a paired eNB beam.

[0090] For some embodiments, if two non-simultaneous UE beams are measured, two SRS resources may be configured in different time resources, where each SRS resource may correspond to eNB measurement of one UE beam.

[0091] In some embodiments, if two simultaneous UE beams are measured, two SRS resources may be configured in different time and/or frequency and/or code resources, where each SRS resource may correspond to eNB measurement of one UE beam.

[0092] For some embodiments, SRS may be designed as either a repeated signal within one OFDM symbol, or as covering multiple OFDM symbols, with one signal per OFDM symbol.

[0093] In some embodiments, a repeated number of OFDM symbols for SRS may be configured by the eNB.

[0094] For some embodiments, instead of an omni-directional BRRS, another cell-specific repeated omni-directional reference signal may be utilized (e.g., an SSS and/or a DMRS of a Physical Broadcast Channel (PBCH) and/or an ESS).

[0095] In some embodiments, a cell-specific omni-directional CSI-RS may be transmitted for UE beam training. For some embodiments, CSI-RS measurement might not be reported.

[0096] **Fig. 9** illustrates beam management based on omnidirectional SRS and beamformed BRRS, in accordance with some embodiments of the disclosure. In a first action 910, a UE may transmit an omnidirectional SRS (which may be an xSRS). The SRS may be a repeated signal, which may enable an eNB to determine one active eNB beam and/or one candidate eNB beam based on the omnidirectional SRS. Then, in a second action 920, the eNB may transmit BRRS for the active eNB beam and/or the candidate eNB beam for UE-side beam training. Since different UEs may transmit SRS orthogonally in the time domain and/or frequency domain and/or code domain, a corresponding interference may advantageously be reduced or avoided, which may then enable the eNB to derive a more accurate eNB beam.

[0097] In some embodiments, if a UE is equipped with two panels, two SRS resources (which may be orthogonal to each in terms of time domain and/or frequency domain and/or code domain) may be configured for the UE. In some embodiments, the eNB may transmit BRRS with the active eNB beam and/or candidate eNB beam, and may configure the BRRS format for the UE so that the UE may prepare to train one or two UE beams.

[0098] For some embodiments, a new BRRS format may be introduced, which may be indicated by BRRS format. For example, a 2-bit indicator may be adopted, where a first value (e.g., "00") may indicate one beam training, a second value (e.g., "01") may indicate non-simultaneous UE beam training, a third value (e.g., "10") may indicate simultaneous UE beam training, and a fourth value (e.g., "11") may be reserved.

[0099] In some embodiments, if the BRRS is for non-simultaneous UE beam training, different BRRS formats may be configured at different time resources; otherwise, for some embodiments, different BRRS formats may be configured at different time domain and/or frequency domain and/or code domain resources.

[00100] For some embodiments, the UE may report one or two BRRS reports to the eNB, so that the eNB may maintain a paired active eNB/UE beam and/or candidate eNB/UE beam.

[00101] In some embodiments, a trigger for omni-SRS may be configured by the eNB. Alternatively, the trigger for omni-SRS may be requested through SR (via the UE), or through PRACH (which may be an xPRACH) via the UE, or via an anchor network.

[00102] With respect to various embodiments, **Fig. 10** illustrates a multiple narrow-beam layout, in accordance with some embodiments of the disclosure. A plurality of beams 1000 with narrow beam width may cover an area with horizontal angular span from 0 degrees to 120 degrees, and vertical angular span from 45 degrees to 135 degrees, where each beam may have a relatively narrow beam width orientated toward different azimuth angles and/or zenith angles. An eNB may apply these beams on a specific reference signal (e.g., BRS) so that a UE may acquire one or more preferred beam candidates.

[00103] **Fig. 11** illustrates beam numbering with respect to ZoD and AoD, in accordance with some embodiments of the disclosure. A plurality of beams 1110 may correspond with a plurality of beam subsets 1120. Beams 1110 may have different ZoD and/or AoD.

[00104] In **Fig. 11**, three beams subsets may be generated, for example by an eNB. Any beam may be contained by one subset, and each subset may cover the full space (e.g., the space around an eNB) with sparse spatial granularity. A UE may then adopt one Rx beam to sweep one subset, instead of all Narrow-Width (NW) beams.

[00105] **Fig. 12** illustrates beam mapping onto OFDM time and frequency resources, in accordance with some embodiments of the disclosure. A plurality of beams 1210 may correspond with a plurality of beam subsets 1220. Beams 1210 may correspond to various

frequency domain resources (e.g., one or more subcarriers) and/or time domain resources (e.g., one or more OFDM symbols).

[00106] In mapping beams into frequency domain resources and/or time domain resource, each subset may cover four consecutive OFDM symbols, and four beams within the same subset may be configured on one OFDM symbol (based upon four panels). As depicted in various figures herein, one BRS antenna port (AP) may occupy one frequency sub-band, and different BRS APs may be multiplexed in a Frequency-Division Multiplexing (FDM) manner; the proposed design may also be straightforwardly extended to cases in which BRS APs are transmitted in a blocked interleaved manner.

[00107] **Fig. 13** illustrates beam mapping for implicitly indicating inter-subset beam correlation, in accordance with some embodiments of the disclosure. A plurality of beams 1310 may correspond with a plurality of beam subsets 1320. Beams 1310 may correspond to various frequency domain resources (e.g., one or more subcarriers) and/or time domain resources (e.g., one or more OFDM symbols).

[00108] In some embodiments, beams belonging to different subsets with high correlation may be associated with each other, which may advantageously facilitate a UE's performance of coherent combination for those beams.

[00109] For some embodiments, the association may be implicitly indicated. For inter-subset beam subset, beams on the same subcarriers but different OFDM symbols with fixed OFDM offset (e.g., beams in analogous sub-carrier and frequency positions within different subsets) may be highly correlated beams. As depicted in **Fig. 13**, for example, beam number 1 in subset 1, beam #27 in subset 2, and beam #12 in subset 3 may be highly correlated with each other.

[00110] **Fig. 14** illustrates relative performance of coherent combination of correlated inter-subset beams, in accordance with some embodiments of the disclosure. A first performance 1410 may correspond with beamformed transmission and omnidirectional reception, while a second performance 1420 may correspond with combined beamformed transmission and omnidirectional reception.

[00111] The performance of coherent combination of inter-subset beams may be simulated and evaluated. For example, as illustrated in **Fig. 14**, coherent combination may provide approximate 2 decibels (dB) of beam energy gain.

[00112] **Fig. 15** illustrates beam mapping for implicitly indicating inter-subset beam correlation, in accordance with some embodiments of the disclosure. A plurality of beams 1510 may correspond with a plurality of beam subsets 1520. Beams 1510 may correspond to

various frequency domain resources (e.g., one or more subcarriers) and/or time domain resources (e.g., one or more OFDM symbols).

[00113] In some embodiments, correlated beams belonging to different subsets may be mapped to shifted Resource Blocks (RBs) and/or portions of resource blocks (e.g., subsets) to obtain potential frequency diversity.

[00114] For some embodiments, an OFDM offset, and a frequency offset may be predefined in the specification or otherwise predetermined, or may be configured by higher layers via a Master Information Block (MIB), a 5G MIB (xMIB), a System Information Block (SIB), and/or a 5G SIB (xSIB). This may also be determined by synchronization signals, such as PSS or SSS.

[00115] **Fig. 16** illustrates beam mapping for implicitly indicating inter-subset beam correlation, in accordance with some embodiments of the disclosure. A plurality of beams 1610 may correspond with a plurality of beam subsets 1620. Beams 1610 may correspond to various frequency domain resources (e.g., one or more subcarriers) and/or time domain resources (e.g., one or more OFDM symbols).

[00116] During BRS measurement, BRS-RP of instantaneous beams may be dynamically changed. For highly correlated beams, this phenomenon may be more frequent. For example, in one subframe, BRS-RP of a first beam (e.g., beam #20 in subset 1) may be better than BRS-RP of a highly correlated second beam (e.g., beam #46 in subset 1), while in the next subframe, the instantaneous value of the second beam maybe better than the first beam. As a result, a correlation of beams may be configured, which may advantageously reduce or eliminate frequent BRS-RP reports due to changes in beam energy among highly correlated beams.

[00117] In some embodiments, beams within the same subset may be configured at an adjacent frequency or adjacent time resource. As depicted in **Fig. 16**, beam #20 and beam #46, which may be correlated intra-subset beams, may be assigned to adjacent frequency resources. For purposes of this disclosure, intra-subset beam correlation may be between beams in the same subset.

[00118] For some embodiments, a correlation rule among intra-subset beams may be predefined in the specification, or otherwise predetermined, or may be configured by higher layers via MIB, xMIB, SIB, and/or xSIB. This may also be determined by synchronization signals, such as PSS and/or SSS.

[00119] **Fig. 17** illustrates a correlation association between intra-subset beams and inter-subset beams, in accordance with some embodiments of the disclosure. A plurality of beams 1710 may correspond with a plurality of beam subsets 1720. Beams 1710 may have different ZoD and/or AoD.

[00120] In some embodiments, for adjacent configured intra-subset beams, highly correlated inter-subset beams of one beam may be inferred to be highly correlated inter-subset beams of another beam. As depicted in **Fig. 17**, beam #13 and beam #27, which may be highly correlated inter-subset beams of beam #1, may also be highly correlated inter-subset beams to beam #39 (which may be an adjacent configured intra-subset beam of beam #1). For purposes of this disclosure, inter-subset beam correlation may be between beams in different subsets.

[00121] For some embodiments, an indicator may be configured by an eNB to inform a UE, for one specific beam, of inter-subset beams which may be associated to its intra-subset beams, may also be inferred as its own highly correlated beam.

[00122] **Fig. 18** illustrates an eNB and a UE, in accordance with some embodiments of the disclosure. **Fig. 18** includes block diagrams of an eNB 1810 and a UE 1830 which are operable to co-exist with each other and other elements of an LTE network. High-level, simplified architectures of eNB 1810 and UE 1830 are described so as not to obscure the embodiments. It should be noted that in some embodiments, eNB 1810 may be a stationary non-mobile device.

[00123] eNB 1810 is coupled to one or more antennas 1805, and UE 1830 is similarly coupled to one or more antennas 1825. However, in some embodiments, eNB 1810 may incorporate or comprise antennas 1805, and UE 1830 in various embodiments may incorporate or comprise antennas 1825.

[00124] In some embodiments, antennas 1805 and/or antennas 1825 may comprise one or more directional or omni-directional antennas, including monopole antennas, dipole antennas, loop antennas, patch antennas, microstrip antennas, coplanar wave antennas, or other types of antennas suitable for transmission of RF signals. In some MIMO (multiple-input and multiple output) embodiments, antennas 1805 are separated to take advantage of spatial diversity.

[00125] eNB 1810 and UE 1830 are operable to communicate with each other on a network, such as a wireless network. eNB 1810 and UE 1830 may be in communication with each other over a wireless communication channel 1850, which has both a downlink path from eNB 1810 to UE 1830 and an uplink path from UE 1830 to eNB 1810.

[00126] As illustrated in **Fig. 18**, in some embodiments, eNB 1810 may include a physical layer circuitry 1812, a MAC (media access control) circuitry 1814, a processor 1816, a memory 1818, and a hardware processing circuitry 1820. A person skilled in the art will appreciate that other components not shown may be used in addition to the components shown to form a complete eNB.

[00127] In some embodiments, physical layer circuitry 1812 includes a transceiver 1813 for providing signals to and from UE 1830. Transceiver 1813 provides signals to and from UEs or other devices using one or more antennas 1805. In some embodiments, MAC circuitry 1814 controls access to the wireless medium. Memory 1818 may be, or may include, a storage media/medium such as a magnetic storage media (e.g., magnetic tapes or magnetic disks), an optical storage media (e.g., optical discs), an electronic storage media (e.g., conventional hard disk drives, solid-state disk drives, or flash-memory-based storage media), or any tangible storage media or non-transitory storage media. Hardware processing circuitry 1820 may comprise logic devices or circuitry to perform various operations. In some embodiments, processor 1816 and memory 1818 are arranged to perform the operations of hardware processing circuitry 1820, such as operations described herein with reference to logic devices and circuitry within eNB 1810 and/or hardware processing circuitry 1820.

[00128] Accordingly, in some embodiments, eNB 1810 may be a device comprising an application processor, a memory, one or more antenna ports, and an interface for allowing the application processor to communicate with another device.

[00129] As is also illustrated in **Fig. 18**, in some embodiments, UE 1830 may include a physical layer circuitry 1832, a MAC circuitry 1834, a processor 1836, a memory 1838, a hardware processing circuitry 1840, a wireless interface 1842, and a display 1844. A person skilled in the art would appreciate that other components not shown may be used in addition to the components shown to form a complete UE.

[00130] In some embodiments, physical layer circuitry 1832 includes a transceiver 1833 for providing signals to and from eNB 1810 (as well as other eNBs). Transceiver 1833 provides signals to and from eNBs or other devices using one or more antennas 1825. In some embodiments, MAC circuitry 1834 controls access to the wireless medium. Memory 1838 may be, or may include, a storage media/medium such as a magnetic storage media (e.g., magnetic tapes or magnetic disks), an optical storage media (e.g., optical discs), an electronic storage media (e.g., conventional hard disk drives, solid-state disk drives, or flash-memory-based storage media), or any tangible storage media or non-transitory storage media. Wireless interface 1842 may be arranged to allow the processor to communicate with another device. Display 1844 may provide a visual and/or tactile display for a user to interact with UE 1830, such as a touch-screen display. Hardware processing circuitry 1840 may comprise logic devices or circuitry to perform various operations. In some embodiments, processor 1836 and memory 1838 may be arranged to perform the operations of hardware processing circuitry 1840, such as operations described herein with reference to logic devices and circuitry within UE 1830 and/or hardware processing circuitry 1840.

[00131] Accordingly, in some embodiments, UE 1830 may be a device comprising an application processor, a memory, one or more antennas, a wireless interface for allowing the application processor to communicate with another device, and a touch-screen display.

[00132] Elements of **Fig. 18**, and elements of other figures having the same names or reference numbers, can operate or function in the manner described herein with respect to any such figures (although the operation and function of such elements is not limited to such descriptions). For example, **Figs. 19-20 and 23-24** also depict embodiments of eNBs, hardware processing circuitry of eNBs, UEs, and/or hardware processing circuitry of UEs, and the embodiments described with respect to **Fig. 18** and **Figs. 19-20 and 23-24** can operate or function in the manner described herein with respect to any of the figures.

[00133] In addition, although eNB 1810 and UE 1830 are each described as having several separate functional elements, one or more of the functional elements may be combined and may be implemented by combinations of software-configured elements and/or other hardware elements. In some embodiments of this disclosure, the functional elements can refer to one or more processes operating on one or more processing elements. Examples of software and/or hardware configured elements include Digital Signal Processors (DSPs), one or more microprocessors, DSPs, Field-Programmable Gate Arrays (FPGAs), Application Specific Integrated Circuits (ASICs), Radio-Frequency Integrated Circuits (RFICs), and so on.

[00134] **Fig. 19** illustrates hardware processing circuitries for a UE for confirmation of beam-forming, in accordance with some embodiments of the disclosure. With reference to **Fig. 18**, a UE may include various hardware processing circuitries discussed herein (such as hardware processing circuitry 1900 of **Fig. 19**), which may in turn comprise logic devices and/or circuitry operable to perform various operations. For example, in **Fig. 18**, UE 1830 (or various elements or components therein, such as hardware processing circuitry 1840, or combinations of elements or components therein) may include part of, or all of, these hardware processing circuitries.

[00135] In some embodiments, one or more devices or circuitries within these hardware processing circuitries may be implemented by combinations of software-configured elements and/or other hardware elements. For example, processor 1836 (and/or one or more other processors which UE 1830 may comprise), memory 1838, and/or other elements or components of UE 1830 (which may include hardware processing circuitry 1840) may be arranged to perform the operations of these hardware processing circuitries, such as operations described herein with reference to devices and circuitry within these hardware processing circuitries. In some embodiments, processor 1836 (and/or one or more other processors which UE 1830 may comprise) may be a baseband processor.

[00136] Returning to **Fig. 19**, an apparatus of UE 1830 (or another UE or mobile handset), which may be operable to communicate with one or more eNBs on a wireless network, may comprise hardware processing circuitry 1900. In some embodiments, hardware processing circuitry 1900 may comprise one or more antenna ports 1905 operable to provide various transmissions over a wireless communication channel (such as wireless communication channel 1850). Antenna ports 1905 may be coupled to one or more antennas 1907 (which may be antennas 1825). In some embodiments, hardware processing circuitry 1900 may incorporate antennas 1907, while in other embodiments, hardware processing circuitry 1900 may merely be coupled to antennas 1907.

[00137] Antenna ports 1905 and antennas 1907 may be operable to provide signals from a UE to a wireless communications channel and/or an eNB, and may be operable to provide signals from an eNB and/or a wireless communications channel to a UE. For example, antenna ports 1905 and antennas 1907 may be operable to provide transmissions from UE 1830 to wireless communication channel 1850 (and from there to eNB 1810, or to another eNB). Similarly, antennas 1907 and antenna ports 1905 may be operable to provide transmissions from a wireless communication channel 1850 (and beyond that, from eNB 1810, or another eNB) to UE 1830.

[00138] Hardware processing circuitry 1900 may comprise various circuitries operable in accordance with the various embodiments discussed herein. With reference to **Fig. 19**, hardware processing circuitry 1900 may comprise a first circuitry 1910 and/or a second circuitry 1920. First circuitry 1910 may be operable to process a DCI received via a first UE beam, the DCI carrying an indicator for switching to a second UE beam. Second circuitry 1920 may be operable to generate a confirmation transmission for the second UE beam based on a trigger indicator. First circuitry 1910 may be operable to transmit an indicator or other information regarding the second UE beam to second circuitry 1920 via an interface 1915. Hardware processing circuitry 1900 may also comprise an interface for inputting the DCI to one or more processors of hardware processing circuitry 1900 and for outputting the confirmation transmission to a transmission circuitry. The confirmation transmission may be one of: an SRS transmission, a CQI report transmission, or a PRACH transmission.

[00139] For some embodiments, the DCI may carry the trigger indicator. In some embodiments, the DCI may be a first DCI, and first circuitry 1910 may be operable to process a second DCI received via the first UE beam. For some embodiments, the second DCI may carry the trigger indicator.

[00140] In some embodiments, the confirmation transmission may be an SRS transmission. For some embodiments, the confirmation transmission may be generated at a subframe that is offset from a subframe in which the DCI was received by a number of subframes N.

[00141] For some embodiments, the DCI may be a first DCI, and first circuitry 1910 may be operable to process a second DCI received via the first UE beam within a number of subframes N of a subframe in which the first DCI was received. In some embodiments, the second DCI may carry the trigger indicator. For some embodiments, the confirmation transmission may be an SRS transmission.

[00142] In some embodiments, first circuitry 1910 may be operable to process a CSI-RS transmission received via the first UE beam. For some embodiments, the confirmation transmission may be a CQI report transmission carrying a report corresponding to the CSI-RS transmission. In some embodiments, the CSI-RS transmission may be received via the second UE receive beam at a subframe that is offset from a subframe in which the DCI was received by a number of subframes N.

[00143] For some embodiments, the DCI may be a first DCI, and first circuitry 1910 may be operable to process a second DCI received via the first UE beam within a number of subframes N of a subframe in which the first DCI was received. First circuitry 1910 may also be operable to process a CSI-RS transmission received via the first UE beam. In some embodiments, the second DCI may carry the trigger indicator. For some embodiments, the confirmation transmission may be a CQI report transmission carrying a report of the CSI-RS transmission.

[00144] In some embodiments, the confirmation transmission may be a PRACH transmission. For some embodiments, the first UE beam may encompass a plurality of eNB beams partially overlapping with each other. In some embodiments, the plurality of eNB beams have a respectively corresponding plurality of AODs. For some embodiments, the plurality of eNB beams may have a respectively corresponding plurality of ZODs.

[00145] In some embodiments, first circuitry 1910 and/or second circuitry 1920 may be implemented as separate circuitries. In other embodiments, first circuitry 1910 and/or second circuitry 1920 may be combined and implemented together in a circuitry without altering the essence of the embodiments.

[00146] **Fig. 20** illustrates hardware processing circuitries for an eNB for confirmation of beam-forming, in accordance with some embodiments of the disclosure. With reference to **Fig. 18**, an eNB may include various hardware processing circuitries discussed herein (such as hardware processing circuitry 2000 of **Fig. 20**), which may in turn comprise logic devices and/or circuitry operable to perform various operations. For example, in **Fig. 18**, eNB 1810 (or various elements or components therein, such as hardware processing circuitry 1820, or combinations of elements or components therein) may include part of, or all of, these hardware processing circuitries.

[00147] In some embodiments, one or more devices or circuitries within these hardware processing circuitries may be implemented by combinations of software-configured elements and/or other hardware elements. For example, processor 1816 (and/or one or more other processors which eNB 1810 may comprise), memory 1818, and/or other elements or components of eNB 1810 (which may include hardware processing circuitry 1820) may be arranged to perform the operations of these hardware processing circuitries, such as operations described herein with reference to devices and circuitry within these hardware processing circuitries. In some embodiments, processor 1816 (and/or one or more other processors which eNB 1810 may comprise) may be a baseband processor.

[00148] Returning to **Fig. 20**, an apparatus of eNB 1810 (or another eNB or base station), which may be operable to communicate with one or more UEs on a wireless network, may comprise hardware processing circuitry 2000. In some embodiments, hardware processing circuitry 2000 may comprise one or more antenna ports 2005 operable to provide various transmissions over a wireless communication channel (such as wireless communication channel 1850). Antenna ports 2005 may be coupled to one or more antennas 2007 (which may be antennas 1805). In some embodiments, hardware processing circuitry 2000 may incorporate antennas 2007, while in other embodiments, hardware processing circuitry 2000 may merely be coupled to antennas 2007.

[00149] Antenna ports 2005 and antennas 2007 may be operable to provide signals from an eNB to a wireless communications channel and/or a UE, and may be operable to provide signals from a UE and/or a wireless communications channel to an eNB. For example, antenna ports 2005 and antennas 2007 may be operable to provide transmissions from eNB 1810 to wireless communication channel 1850 (and from there to UE 1830, or to another UE). Similarly, antennas 2007 and antenna ports 2005 may be operable to provide transmissions from a wireless communication channel 1850 (and beyond that, from UE 1830, or another UE) to eNB 1810.

[00150] Hardware processing circuitry 2000 may comprise various circuitries operable in accordance with the various embodiments discussed herein. With reference to **Fig. 20**, hardware processing circuitry 2000 may comprise a first circuitry 2010 and/or a second circuitry 2020. First circuitry 2010 may be operable to generate a DCI for a first UE beam, the DCI carrying an indicator for switching to a second UE beam. Second circuitry 2020 may be operable to process a confirmation transmission from the second UE beam based on a trigger indicator. First circuitry 2010 may be operable to provide an indicator of the second UE beam to second circuitry 2020 via an interface 2015. Hardware processing circuitry 2000 may also comprise an interface for outputting the DCI from one or more processors of hardware processing circuitry 2000 and for inputting the confirmation transmission from a receiving circuitry. The confirmation transmission may be one of: an SRS transmission, a CQI report transmission, or a PRACH transmission.

[00151] For some embodiments, the DCI may carry the trigger indicator. In some embodiments, the DCI may be a first DCI, and first circuitry 2010 may be operable to generate a second DCI received for the first UE beam. For some embodiments, the second DCI may carry the trigger indicator.

[00152] In some embodiments, the confirmation transmission may be an SRS transmission. For some embodiments, the confirmation transmission may be generated at a subframe that is offset from a subframe in which the DCI was received by a number of subframes N.

[00153] For some embodiments, the DCI may be a first DCI, and first circuitry 2010 may be operable to generate a second DCI for the first UE beam within a number of subframes N of a subframe in which the first DCI was received. In some embodiments, the second DCI may carry the trigger indicator. For some embodiments, the confirmation transmission may be an SRS transmission.

[00154] In some embodiments, first circuitry 2010 may be operable to generate a CSI-RS transmission for the first UE beam. For some embodiments, the confirmation transmission may be a CQI report transmission carrying a report corresponding to the CSI-RS transmission. In some embodiments, the CSI-RS transmission may be received via the second UE receive beam at a subframe that is offset from a subframe in which the DCI was received by a number of subframes N.

[00155] For some embodiments, the DCI may be a first DCI, and first circuitry 2010 may be operable to generate a second DCI for the first UE beam within a number of subframes N of a subframe in which the first DCI was received. First circuitry 2010 may also be operable to generate a CSI-RS transmission for the first UE beam. In some embodiments, the second DCI may carry the trigger indicator. For some embodiments, the confirmation transmission may be a CQI report transmission carrying a report of the CSI-RS transmission.

[00156] In some embodiments, the confirmation transmission may be a PRACH transmission. For some embodiments, the first UE beam may encompass a plurality of eNB beams partially overlapping with each other. In some embodiments, the plurality of eNB beams may have a respectively corresponding plurality of AODs. For some embodiments, the plurality of eNB beams may have a respectively corresponding plurality of ZODs.

[00157] In some embodiments, first circuitry 2010 and/or second circuitry 2020 may be implemented as separate circuitries. In other embodiments, first circuitry 2010 and/or second circuitry 2020 may be combined and implemented together in a circuitry without altering the essence of the embodiments.

[00158] **Fig. 21** illustrates methods for a UE for confirmation of beam-forming, in accordance with some embodiments of the disclosure. With reference to **Fig. 18**, methods that may relate to UE 1830 and hardware processing circuitry 1840 are discussed herein. Although the actions in the method 2100 of **Fig. 21** are shown in a particular order, the order of the actions can be modified. Thus, the illustrated embodiments can be performed in a different order, and some actions may be performed in parallel. Some of the actions and/or operations listed in **Fig. 21** are optional in accordance with certain embodiments. The numbering of the actions presented is for the sake of clarity and is not intended to prescribe an order of operations in which the various actions must occur. Additionally, operations from the various flows may be utilized in a variety of combinations.

[00159] Moreover, in some embodiments, machine readable storage media may have executable instructions that, when executed, cause UE 1830 and/or hardware processing circuitry 1840 to perform an operation comprising the methods of **Fig. 21**. Such machine readable storage media may include any of a variety of storage media, like magnetic storage media (e.g., magnetic tapes or magnetic disks), optical storage media (e.g., optical discs), electronic storage media (e.g., conventional hard disk drives, solid-state disk drives, or flash-memory-based storage media), or any other tangible storage media or non-transitory storage media.

[00160] In some embodiments, an apparatus may comprise means for performing various actions and/or operations of the methods of **Fig. 21**.

[00161] Returning to **Fig. 21**, various methods may be in accordance with the various embodiments discussed herein. A method 2100 may comprise a processing 2110 and a generating 2115. Method 2100 may also comprise a processing 2120, a processing 2130, a processing 2140, a processing 2150, and/or a processing 2155.

[00162] In processing 2110, a DCI may be received via a first UE beam. The DCI may carry an indicator for switching to a second UE beam. In generating 2115, a confirmation transmission for the second UE beam may be generated based on a trigger indicator. The confirmation transmission may be one of: an SRS transmission, a CQI report transmission, or a PRACH transmission.

[00163] For some embodiments, the DCI may carry the trigger indicator. In some embodiments, the DCI may be a first DCI, and in processing 2120, a second DCI received via the first UE beam may be processed. For some embodiments, the second DCI may carry the trigger indicator.

[00164] In some embodiments, the confirmation transmission may be an SRS transmission. For some embodiments, the confirmation transmission may be generated at a subframe that is offset from a subframe in which the DCI was received by a number of subframes N.

[00165] For some embodiments, the DCI may be a first DCI, and in processing 2130, a second DCI received via the first UE beam may be processed within a number of subframes N of a subframe in which the first DCI was received. In some embodiments, the second DCI may carry the trigger indicator. For some embodiments, the confirmation transmission may be an SRS transmission.

[00166] In some embodiments, in processing 2140, a CSI-RS transmission received via the first UE beam may be processed. For some embodiments, the confirmation transmission may be a CQI report transmission carrying a report corresponding to the CSI-RS transmission. In some embodiments, the CSI-RS transmission may be received via the second UE receive beam at a subframe that is offset from a subframe in which the DCI was received by a number of subframes N.

[00167] For some embodiments, the DCI may be a first DCI, and in processing 2150, a second DCI received via the first UE beam may be processed within a number of subframes

N of a subframe in which the first DCI was received. In some embodiments, in processing 2155, a CSI-RS transmission received via the first UE beam may be processed. For some embodiments, the second DCI may carry the trigger indicator. In some embodiments, the confirmation transmission may be a CQI report transmission carrying a report of the CSI-RS transmission.

[00168] In some embodiments, the confirmation transmission may be a PRACH transmission. For some embodiments, the first UE beam may encompass a plurality of eNB beams partially overlapping with each other. In some embodiments, the plurality of eNB beams have a respectively corresponding plurality of AODs. For some embodiments, the plurality of eNB beams may have a respectively corresponding plurality of ZODs.

[00169] **Fig. 22** illustrates methods for an eNB for confirmation of beam-forming, in accordance with some embodiments of the disclosure. With reference to **Fig. 18**, various methods that may relate to eNB 1810 and hardware processing circuitry 1820 are discussed herein. Although the actions in method 2200 of **Fig. 22** are shown in a particular order, the order of the actions can be modified. Thus, the illustrated embodiments can be performed in a different order, and some actions may be performed in parallel. Some of the actions and/or operations listed in **Fig. 22** are optional in accordance with certain embodiments. The numbering of the actions presented is for the sake of clarity and is not intended to prescribe an order of operations in which the various actions must occur. Additionally, operations from the various flows may be utilized in a variety of combinations.

[00170] Moreover, in some embodiments, machine readable storage media may have executable instructions that, when executed, cause eNB 1810 and/or hardware processing circuitry 1820 to perform an operation comprising the methods of **Fig. 22**. Such machine readable storage media may include any of a variety of storage media, like magnetic storage media (e.g., magnetic tapes or magnetic disks), optical storage media (e.g., optical discs), electronic storage media (e.g., conventional hard disk drives, solid-state disk drives, or flash-memory-based storage media), or any other tangible storage media or non-transitory storage media.

[00171] In some embodiments, an apparatus may comprise means for performing various actions and/or operations of the methods of **Fig. 22**.

[00172] Returning to **Fig. 22**, various methods may be in accordance with the various embodiments discussed herein. A method 2200 may comprise a generating 2210 and a processing 2215. In some embodiments, a method 2200 may also comprise a generating 2220, a generating 2230, a generating 2240, a generating 2250, and/or a generating 2255.

[00173] In generating 2210, a DCI for a first UE beam may be generated. The DCI may carry an indicator for switching to a second UE beam. In processing 2215, a confirmation transmission from the second UE beam may be processed based on a trigger indicator. In some embodiments, the confirmation transmission may be one of: an SRS transmission, a CQI report transmission, or a PRACH transmission.

[00174] For some embodiments, the DCI may carry the trigger indicator. In some embodiments, the DCI may be a first DCI, and in generating 2220, a second DCI may be generated for the first UE beam. For some embodiments, the second DCI may carry the trigger indicator.

[00175] In some embodiments, the confirmation transmission may be an SRS transmission. For some embodiments, the confirmation transmission may be generated at a subframe that is offset from a subframe in which the DCI was received by a number of subframes N.

[00176] For some embodiments, the DCI may be a first DCI, and in generating 2230, a second DCI for the first UE beam may be generated within a number of subframes N of a subframe in which the first DCI was received. In some embodiments, the second DCI may carry the trigger indicator. For some embodiments, the confirmation transmission may be an SRS transmission.

[00177] In some embodiments, in generating 2240, a CSI-RS transmission for the first UE beam may be generated. For some embodiments, the confirmation transmission may be a CQI report transmission carrying a report corresponding to the CSI-RS transmission. In some embodiments, the CSI-RS transmission may be received via the second UE receive beam at a subframe that is offset from a subframe in which the DCI was received by a number of subframes N.

[00178] For some embodiments, the DCI may be a first DCI, and in generating 2250, a second DCI for the first UE beam may be generated within a number of subframes N of a subframe in which the first DCI was received. In generating 2255, a CSI-RS transmission may be generated for the first UE beam. For some embodiments, the second DCI may carry the trigger indicator. In some embodiments, the confirmation transmission may be a CQI report transmission carrying a report of the CSI-RS transmission.

[00179] In some embodiments, the confirmation transmission may be a PRACH transmission. For some embodiments, the first UE beam may encompass a plurality of eNB beams partially overlapping with each other. In some embodiments, the plurality of eNB beams have a respectively corresponding plurality of AODs. For some embodiments, the plurality of eNB beams may have a respectively corresponding plurality of ZODs.

[00180] **Fig. 23** illustrates example components of a device, in accordance with some embodiments of the disclosure. In some embodiments, the device 2300 may include application circuitry 2302, baseband circuitry 2304, Radio Frequency (RF) circuitry 2306, front-end module (FEM) circuitry 2308, one or more antennas 2310, and power management circuitry (PMC) 2312 coupled together at least as shown. The components of the illustrated device 2300 may be included in a UE or a RAN node. In some embodiments, the device 2300 may include less elements (e.g., a RAN node may not utilize application circuitry 2302, and instead include a processor/controller to process IP data received from an EPC). In some embodiments, the device 2300 may include additional elements such as, for example, memory/storage, display, camera, sensor, or input/output (I/O) interface. In other embodiments, the components described below may be included in more than one device (e.g., said circuitries may be separately included in more than one device for Cloud-RAN (C-RAN) implementations).

[00181] The application circuitry 2302 may include one or more application processors. For example, the application circuitry 2302 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 or may include memory/storage and may be configured to execute instructions stored in the memory/storage to enable various applications or operating systems to run on the device 2300. In some embodiments, processors of application circuitry 2302 may process IP data packets received from an EPC.

[00182] The baseband circuitry 2304 may include circuitry such as, but not limited to, one or more single-core or multi-core processors. The baseband circuitry 2304 may include one or more baseband processors or control logic to process baseband signals received from a receive signal path of the RF circuitry 2306 and to generate baseband signals for a transmit signal path of the RF circuitry 2306. Baseband processing circuity 2304 may interface with the application circuitry 2302 for generation and processing of the baseband signals and for controlling operations of the RF circuitry 2306. For example, in some embodiments, the baseband circuitry 2304 may include a third generation (3G) baseband processor 2304A, a fourth generation (4G) baseband processor 2304B, a fifth generation (5G) baseband processor 2304C, or other baseband processor(s) 2304D for other existing generations, generations in development or to be developed in the future (e.g., second generation (2G), sixth generation (6G), etc.). The baseband circuitry 2304 (e.g., one or more of baseband processors 2304A-D) may handle various radio control functions that enable communication with one or more radio networks via the RF circuitry 2306. In other embodiments, some or all of the functionality of baseband processors 2304A-D may be included in modules stored in the memory 2304G and executed via a Central Processing Unit (CPU) 2304E. 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 2304 may include Fast-Fourier Transform (FFT), precoding, or constellation mapping/demapping functionality. In some embodiments, encoding/decoding circuitry of the baseband circuitry 2304 may include convolution, tail-biting convolution, turbo, Viterbi, 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.

[00183] In some embodiments, the baseband circuitry 2304 may include one or more audio digital signal processor(s) (DSP) 2304F. The audio DSP(s) 2304F 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 2304 and the application circuitry 2302 may be implemented together such as, for example, on a system on a chip (SOC).

[00184] In some embodiments, the baseband circuitry 2304 may provide for communication compatible with one or more radio technologies. For example, in some embodiments, the baseband circuitry 2304 may support communication with an evolved universal terrestrial radio access network (EUTRAN) 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 2304 is configured to support radio communications of more than one wireless protocol may be referred to as multi-mode baseband circuitry.

[00185] RF circuitry 2306 may enable communication with wireless networks using modulated electromagnetic radiation through a non-solid medium. In various embodiments, the RF circuitry 2306 may include switches, filters, amplifiers, etc. to facilitate the communication with the wireless network. RF circuitry 2306 may include a receive signal path which may include circuitry to down-convert RF signals received from the FEM circuitry 2308 and provide baseband signals to the baseband circuitry 2304. RF circuitry 2306 may also include a transmit signal path which may include circuitry to up-convert baseband signals provided by the baseband circuitry 2304 and provide RF output signals to the FEM circuitry 2308 for transmission.

[00186] In some embodiments, the receive signal path of the RF circuitry 2306 may include mixer circuitry 2306A, amplifier circuitry 2306B and filter circuitry 2306C. In some embodiments, the transmit signal path of the RF circuitry 2306 may include filter circuitry 2306C and mixer circuitry 2306A. RF circuitry 2306 may also include synthesizer circuitry 2306D for synthesizing a frequency for use by the mixer circuitry 2306A of the receive signal path and the transmit signal path. In some embodiments, the mixer circuitry 2306A of the receive signal path may be configured to down-convert RF signals received from the FEM circuitry 2308 based on the synthesized frequency provided by synthesizer circuitry 2306D. The amplifier circuitry 2306B may be configured to amplify the down-converted signals and the filter circuitry 2306C 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 2304 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 2306A of the receive signal path may comprise passive mixers, although the scope of the embodiments is not limited in this respect.

[00187] In some embodiments, the mixer circuitry 2306A of the transmit signal path may be configured to up-convert input baseband signals based on the synthesized frequency provided by the synthesizer circuitry 2306D to generate RF output signals for the FEM circuitry 2308. The baseband signals may be provided by the baseband circuitry 2304 and may be filtered by filter circuitry 2306C.

[00188] In some embodiments, the mixer circuitry 2306A of the receive signal path and the mixer circuitry 2306A of the transmit signal path may include two or more mixers and may be arranged for quadrature downconversion and upconversion, respectively. In some embodiments, the mixer circuitry 2306A of the receive signal path and the mixer circuitry 2306A 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 2306A of the receive signal path and the mixer circuitry 2306A may be arranged for direct downconversion and direct upconversion, respectively. In some embodiments, the mixer circuitry 2306A of the receive signal path and the mixer circuitry 2306A of the transmit signal path may be configured for super-heterodyne operation.

[00189] 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 2306 may include analog-to-digital converter (ADC) and digital-to-analog converter (DAC) circuitry and the baseband circuitry 2304 may include a digital baseband interface to communicate with the RF circuitry 2306.

[00190] 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.

[00191] In some embodiments, the synthesizer circuitry 2306D 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 2306D may be a delta-sigma synthesizer, a frequency multiplier, or a synthesizer comprising a phase-locked loop with a frequency divider.

[00192] The synthesizer circuitry 2306D may be configured to synthesize an output frequency for use by the mixer circuitry 2306A of the RF circuitry 2306 based on a frequency input and a divider control input. In some embodiments, the synthesizer circuitry 2306D may be a fractional N/N+1 synthesizer.

[00193] 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 2304 or the applications processor 2302 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 2302.

[00194] Synthesizer circuitry 2306D of the RF circuitry 2306 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.

[00195] In some embodiments, synthesizer circuitry 2306D 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 2306 may include an IQ/polar converter.

[00196] FEM circuitry 2308 may include a receive signal path which may include circuitry configured to operate on RF signals received from one or more antennas 2310, amplify the received signals and provide the amplified versions of the received signals to the RF circuitry 2306 for further processing. FEM circuitry 2308 may also include a transmit signal path which may include circuitry configured to amplify signals for transmission provided by the RF circuitry 2306 for transmission by one or more of the one or more antennas 2310. In various embodiments, the amplification through the transmit or receive signal paths may be done solely in the RF circuitry 2306, solely in the FEM 2308, or in both the RF circuitry 2306 and the FEM 2308.

[00197] In some embodiments, the FEM circuitry 2308 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 an LNA to amplify received RF signals and provide the amplified received RF signals as an output (e.g., to the RF circuitry 2306). The transmit signal path of the FEM circuitry 2308 may include a power amplifier (PA) to amplify input RF signals (e.g., provided by RF circuitry 2306), and one or more filters to generate RF signals for subsequent transmission (e.g., by one or more of the one or more antennas 2310).

[00198] In some embodiments, the PMC 2312 may manage power provided to the baseband circuitry 2304. In particular, the PMC 2312 may control power-source selection, voltage scaling, battery charging, or DC-to-DC conversion. The PMC 2312 may often be included when the device 2300 is capable of being powered by a battery, for example, when the device is included in a UE. The PMC 2312 may increase the power conversion efficiency while providing desirable implementation size and heat dissipation characteristics.

[00199] While **Fig. 23** shows the PMC 2312 coupled only with the baseband circuitry 2304. However, in other embodiments, the PMC 2312 may be additionally or alternatively coupled with, and perform similar power management operations for, other components such as, but not limited to, application circuitry 2302, RF circuitry 2306, or FEM 2308.

[00200] In some embodiments, the PMC 2312 may control, or otherwise be part of, various power saving mechanisms of the device 2300. For example, if the device 2300 is in an RRC_Connected state, where it is still connected to the RAN node as it expects to receive traffic shortly, then it may enter a state known as Discontinuous Reception Mode (DRX) after a period of inactivity. During this state, the device 2300 may power down for brief intervals of time and thus save power.

[00201] If there is no data traffic activity for an extended period of time, then the device 2300 may transition off to an RRC_Idle state, where it disconnects from the network and does not perform operations such as channel quality feedback, handover, etc. The device 2300 goes into a very low power state and it performs paging where again it periodically wakes up to listen to the network and then powers down again. The device 2300 may not receive data in this state, in order to receive data, it must transition back to RRC_Connected state.

[00202] An additional power saving mode may allow a device to be unavailable to the network for periods longer than a paging interval (ranging from seconds to a few hours). During this time, the device is totally unreachable to the network and may power down completely. Any data sent during this time incurs a large delay and it is assumed the delay is acceptable.

[00203] Processors of the application circuitry 2302 and processors of the baseband circuitry 2304 may be used to execute elements of one or more instances of a protocol stack. For example, processors of the baseband circuitry 2304, alone or in combination, may be used execute Layer 3, Layer 2, or Layer 1 functionality, while processors of the application circuitry 2304 may utilize data (e.g., packet data) received from these layers and further execute Layer 4 functionality (e.g., transmission communication protocol (TCP) and user datagram protocol (UDP) layers). As referred to herein, Layer 3 may comprise a radio resource control (RRC) layer, described in further detail below. As referred to herein, Layer 2 may comprise a medium access control (MAC) layer, a radio link control (RLC) layer, and a packet data convergence protocol (PDCP) layer, described in further detail below. As referred to herein, Layer 1 may comprise a physical (PHY) layer of a UE/RAN node, described in further detail below.

[00204] **Fig. 24** illustrates example interfaces of baseband circuitry, in accordance with some embodiments of the disclosure. As discussed above, the baseband circuitry 2304 of **Fig. 23** may comprise processors 2304A-2304E and a memory 2304G utilized by said processors. Each of the processors 2304A-2304E may include a memory interface, 2404A-2404E, respectively, to send/receive data to/from the memory 2304G.

[00205] The baseband circuitry 2304 may further include one or more interfaces to communicatively couple to other circuitries/devices, such as a memory interface 2412 (e.g., an interface to send/receive data to/from memory external to the baseband circuitry 2304), an application circuitry interface 2414 (e.g., an interface to send/receive data to/from the application circuitry 2302 of **Fig. 23**), an RF circuitry interface 2416 (e.g., an interface to send/receive data to/from RF circuitry 2306 of **Fig. 23**), a wireless hardware connectivity interface 2418 (e.g., an interface to send/receive data to/from Near Field Communication (NFC) components, Bluetooth® components (e.g., Bluetooth® Low Energy), Wi-Fi® components, and other communication components), and a power management interface 2420 (e.g., an interface to send/receive power or control signals to/from the PMC 2312.

[00206] It is pointed out that elements of any of the Figures herein having the same reference numbers and/or names as elements of any other Figure herein may, in various embodiments, operate or function in a manner similar those elements of the other Figure (without being limited to operating or functioning in such a manner).

[00207] Reference in the specification to "an embodiment," "one embodiment," "some embodiments," or "other embodiments" means that a particular feature, structure, or characteristic described in connection with the embodiments is included in at least some embodiments, but not necessarily all embodiments. The various appearances of "an embodiment," "one embodiment," or "some embodiments" are not necessarily all referring to the same embodiments. If the specification states a component, feature, structure, or characteristic "may," "might," or "could" be included, that particular component, feature, structure, or characteristic is not required to be included. If the specification or claim refers to "a" or "an" element, that does not mean there is only one of the elements. If the specification or claims refer to "an additional" element, that does not preclude there being more than one of the additional element.

[00208] Furthermore, the particular features, structures, functions, or characteristics may be combined in any suitable manner in one or more embodiments. For example, a first embodiment may be combined with a second embodiment anywhere the particular features, structures, functions, or characteristics associated with the two embodiments are not mutually exclusive.

[00209] While the disclosure has been described in conjunction with specific embodiments thereof, many alternatives, modifications and variations of such embodiments will be apparent to those of ordinary skill in the art in light of the foregoing description. For example, other memory architectures e.g., Dynamic RAM (DRAM) may use the embodiments discussed. The embodiments of the disclosure are intended to embrace all such alternatives, modifications, and variations as to fall within the broad scope of the appended claims.

[00210] In addition, well known power/ground connections to integrated circuit (IC) chips and other components may or may not be shown within the presented figures, for simplicity of illustration and discussion, and so as not to obscure the disclosure. Further, arrangements may be shown in block diagram form in order to avoid obscuring the disclosure, and also in view of the fact that specifics with respect to implementation of such block diagram arrangements are highly dependent upon the platform within which the present disclosure is to be implemented (i.e., such specifics should be well within purview of one skilled in the art). Where specific details (e.g., circuits) are set forth in order to describe example embodiments of the disclosure, it should be apparent to one skilled in the art that the disclosure can be practiced without, or with variation of, these specific details. The description is thus to be regarded as illustrative instead of limiting.

[00211] The following examples pertain to further embodiments. Specifics in the examples may be used anywhere in one or more embodiments. All optional features of the apparatus described herein may also be implemented with respect to a method or process.

[00212] Example 1 provides an apparatus of a User Equipment (UE) operable to communicate with an Evolved Node B (eNB) on a wireless network, comprising: one or more processors to: process a Downlink Control Information (DCI) received via a first UE beam, the DCI carrying an indicator for switching to a second UE beam; and generate a confirmation transmission for the second UE beam based on a trigger indicator, and an interface for inputting the DCI to the one or more processors and for outputting the confirmation transmission to a transmission circuitry.

[00213] In example 2, the apparatus of example 1, wherein the confirmation transmission is one of: a Sounding Reference Signal (SRS) transmission, a Channel Quality

Indicator (CQI) report transmission, or a Physical Random Access Channel (PRACH) transmission.

[00214] In example 3, the apparatus of either of examples 1 or 2, wherein the DCI carries the trigger indicator.

[00215] In example 4, the apparatus of either of examples 1 or 2, wherein the DCI is a first DCI, and wherein the one or more processors are to: process a second DCI received via the first UE beam, wherein the second DCI carries the trigger indicator.

[00216] In example 5, the apparatus of either of examples 1 or 2, wherein the confirmation transmission is a Sounding Reference Signal (SRS) transmission; and wherein the confirmation transmission is generated at a subframe that is offset from a subframe in which the DCI was received by a number of subframes N.

[00217] In example 6, the apparatus of either of examples 1 or 2, wherein the DCI is a first DCI, and wherein the one or more processors are to: process a second DCI received via the first UE beam within a number of subframes N of a subframe in which the first DCI was received, wherein the second DCI carries the trigger indicator; and wherein the confirmation transmission is a Sounding Reference Signal (SRS) transmission.

[00218] In example 7, the apparatus of either of examples 1 or 2, wherein the one or more processors are to: process a Channel State Information Reference Signal (CSI-RS) transmission received via the first UE beam, and wherein the confirmation transmission is a Channel Quality Indicator (CQI) report transmission carrying a report corresponding to the CSI-RS transmission; and wherein the CSI-RS transmission is received via the second UE receive beam at a subframe that is offset from a subframe in which the DCI was received by a number of subframes N.

[00219] In example 8, the apparatus of either of examples 1 or 2, wherein the DCI is a first DCI, and wherein the one or more processors are to: process a second DCI received via the first UE beam within a number of subframes N of a subframe in which the first DCI was received; and process a Channel State Information Reference Signal (CSI-RS) transmission received via the first UE beam, and wherein the second DCI carries the trigger indicator; and wherein the confirmation transmission is a Channel Quality Indicator (CQI) report transmission carrying a report of the CSI-RS transmission.

[00220] In example 9, the apparatus of either of examples 1 or 2, wherein the confirmation transmission is a Physical Random Access Channel (PRACH) transmission.

[00221] In example 10, the apparatus of any of examples 1 through 9, wherein the first UE beam encompasses a plurality of eNB beams partially overlapping with each other;

wherein the plurality of eNB beams have a respectively corresponding plurality of Azimuth angles of departure (AODs); and wherein the plurality of eNB beams have a respectively corresponding plurality of Zenith angles of departure (ZODs).

[00222] Example 11 provides a User Equipment (UE) device comprising an application processor, a memory, one or more antennas, a wireless interface for allowing the application processor to communicate with another device, and a touch-screen display, the UE device including the apparatus of any of examples 1 through 10.

[00223] Example 12 provides a method comprising: processing, for a User Equipment, a Downlink Control Information (DCI) received via a first UE beam, the DCI carrying an indicator for switching to a second UE beam; and generating a confirmation transmission for the second UE beam based on a trigger indicator.

[00224] In example 13, the method of example 12, wherein the confirmation transmission is one of: a Sounding Reference Signal (SRS) transmission, a Channel Quality Indicator (CQI) report transmission, or a Physical Random Access Channel (PRACH) transmission.

[00225] In example 14, the method of either of examples 12 or 13, wherein the DCI carries the trigger indicator.

[00226] In example 15, the method of either of examples 12 or 13, wherein the DCI is a first DCI, comprising: processing a second DCI received via the first UE beam, wherein the second DCI carries the trigger indicator.

[00227] In example 16, the method of either of examples 12 or 13, wherein the confirmation transmission is a Sounding Reference Signal (SRS) transmission; and wherein the confirmation transmission is generated at a subframe that is offset from a subframe in which the DCI was received by a number of subframes N.

[00228] In example 17, the method of either of examples 12 or 13, wherein the DCI is a first DCI, comprising: processing a second DCI received via the first UE beam within a number of subframes N of a subframe in which the first DCI was received, wherein the second DCI carries the trigger indicator; and wherein the confirmation transmission is a Sounding Reference Signal (SRS) transmission.

[00229] In example 18, the method of either of examples 12 or 13, comprising: processing a Channel State Information Reference Signal (CSI-RS) transmission received via the first UE beam, and wherein the confirmation transmission is a Channel Quality Indicator (CQI) report transmission carrying a report corresponding to the CSI-RS transmission; and wherein the CSI-RS transmission is received via the second UE receive beam at a subframe that is offset from a subframe in which the DCI was received by a number of subframes N.

[00230] In example 19, the method of either of examples 12 or 13, wherein the DCI is a first DCI, comprising: processing a second DCI received via the first UE beam within a number of subframes N of a subframe in which the first DCI was received; and processing a Channel State Information Reference Signal (CSI-RS) transmission received via the first UE beam, and wherein the second DCI carries the trigger indicator; and wherein the confirmation transmission is a Channel Quality Indicator (CQI) report transmission carrying a report of the CSI-RS transmission.

[00231] In example 20, the method of either of examples 12 or 13, wherein the confirmation transmission is a Physical Random Access Channel (PRACH) transmission.

[00232] In example 21, the method of any of examples 12 through 20, wherein the first UE beam encompasses a plurality of eNB beams partially overlapping with each other; wherein the plurality of eNB beams have a respectively corresponding plurality of Azimuth angles of departure (AODs); and wherein the plurality of eNB beams have a respectively corresponding plurality of Zenith angles of departure (ZODs).

[00233] Example 22 provides a machine readable storage media having machine executable instructions stored thereon that, when executed, cause one or more processors to perform a method according to any of examples 12 through 21.

[00234] Example 23 provides an apparatus of a User Equipment (UE) operable to communicate with an Evolved Node B (eNB) on a wireless network, method comprising: means for processing a Downlink Control Information (DCI) received via a first UE beam, the DCI carrying an indicator for switching to a second UE beam; and means for generating a confirmation transmission for the second UE beam based on a trigger indicator.

[00235] In example 24, the apparatus of example 23, wherein the confirmation transmission is one of: a Sounding Reference Signal (SRS) transmission, a Channel Quality Indicator (CQI) report transmission, or a Physical Random Access Channel (PRACH) transmission.

[00236] In example 25, the apparatus of either of examples 23 or 24, wherein the DCI carries the trigger indicator.

[00237] In example 26, the apparatus of either of examples 23 or 24, wherein the DCI is a first DCI, comprising: processing a second DCI received via the first UE beam, wherein the second DCI carries the trigger indicator.

[00238] In example 27, the apparatus of either of examples 23 or 24, wherein the confirmation transmission is a Sounding Reference Signal (SRS) transmission; and wherein the confirmation transmission is generated at a subframe that is offset from a subframe in which the DCI was received by a number of subframes N.

[00239] In example 28, the apparatus of either of examples 23 or 24, wherein the DCI is a first DCI, comprising: processing a second DCI received via the first UE beam within a number of subframes N of a subframe in which the first DCI was received, wherein the second DCI carries the trigger indicator; and wherein the confirmation transmission is a Sounding Reference Signal (SRS) transmission.

[00240] In example 29, the apparatus of either of examples 23 or 24, comprising: processing a Channel State Information Reference Signal (CSI-RS) transmission received via the first UE beam, and wherein the confirmation transmission is a Channel Quality Indicator (CQI) report transmission carrying a report corresponding to the CSI-RS transmission; and wherein the CSI-RS transmission is received via the second UE receive beam at a subframe that is offset from a subframe in which the DCI was received by a number of subframes N.

[00241] In example 30, the apparatus of either of examples 23 or 24, wherein the DCI is a first DCI, comprising: processing a second DCI received via the first UE beam within a number of subframes N of a subframe in which the first DCI was received; and processing a Channel State Information Reference Signal (CSI-RS) transmission received via the first UE beam, and wherein the second DCI carries the trigger indicator; and wherein the confirmation transmission is a Channel Quality Indicator (CQI) report transmission carrying a report of the CSI-RS transmission.

[00242] In example 31, the apparatus of either of examples 23 or 24, wherein the confirmation transmission is a Physical Random Access Channel (PRACH) transmission.

[00243] In example 32, the apparatus of any of examples 23 through 31, wherein the first UE beam encompasses a plurality of eNB beams partially overlapping with each other; wherein the plurality of eNB beams have a respectively corresponding plurality of Azimuth angles of departure (AODs); and wherein the plurality of eNB beams have a respectively corresponding plurality of Zenith angles of departure (ZODs).

[00244] Example 33 provides machine readable storage media having machine executable instructions that, when executed, cause one or more processors of a User Equipment (UE) operable to communicate with an Evolved Node-B (eNB) on a wireless network to perform an operation comprising: process a Downlink Control Information (DCI) received via a first UE beam, the DCI carrying an indicator for switching to a second UE

beam; and generate a confirmation transmission for the second UE beam based on a trigger indicator.

[00245] In example 34, the machine readable storage media of example 33, wherein the confirmation transmission is one of: a Sounding Reference Signal (SRS) transmission, a Channel Quality Indicator (CQI) report transmission, or a Physical Random Access Channel (PRACH) transmission.

[00246] In example 35, the machine readable storage media of either of examples 33 or 34, wherein the DCI carries the trigger indicator.

[00247] In example 36, the machine readable storage media of either of examples 33 or 34, wherein the DCI is a first DCI, and wherein the one or more processors are to: process a second DCI received via the first UE beam, wherein the second DCI carries the trigger indicator.

[00248] In example 37, the machine readable storage media of either of examples 33 or 34, wherein the confirmation transmission is a Sounding Reference Signal (SRS) transmission; and wherein the confirmation transmission is generated at a subframe that is offset from a subframe in which the DCI was received by a number of subframes N.

[00249] In example 38, the machine readable storage media of either of examples 33 or 34, wherein the DCI is a first DCI, and the operation comprising: process a second DCI received via the first UE beam within a number of subframes N of a subframe in which the first DCI was received, wherein the second DCI carries the trigger indicator; and wherein the confirmation transmission is a Sounding Reference Signal (SRS) transmission.

[00250] In example 39, the machine readable storage media of either of examples 33 or 34, the operation comprising: process a Channel State Information Reference Signal (CSI-RS) transmission received via the first UE beam, and wherein the confirmation transmission is a Channel Quality Indicator (CQI) report transmission carrying a report corresponding to the CSI-RS transmission; and wherein the CSI-RS transmission is received via the second UE receive beam at a subframe that is offset from a subframe in which the DCI was received by a number of subframes N.

[00251] In example 40, the machine readable storage media of either of examples 33 or 34, wherein the DCI is a first DCI, and the operation comprising: process a second DCI received via the first UE beam within a number of subframes N of a subframe in which the first DCI was received; and process a Channel State Information Reference Signal (CSI-RS) transmission received via the first UE beam, and wherein the second DCI carries the trigger indicator; and wherein the confirmation transmission is a Channel Quality Indicator (CQI) report transmission carrying a report of the CSI-RS transmission.

[00252] In example 41, the machine readable storage media of either of examples 33 or 34, wherein the confirmation transmission is a Physical Random Access Channel (PRACH) transmission.

[00253] In example 42, the machine readable storage media of any of examples 33 through 41, wherein the first UE beam encompasses a plurality of eNB beams partially overlapping with each other; wherein the plurality of eNB beams have a respectively corresponding plurality of Azimuth angles of departure (AODs); and wherein the plurality of eNB beams have a respectively corresponding plurality of Zenith angles of departure (ZODs).

[00254] Example 43 provides an apparatus of an Evolved Node B (eNB) operable to communicate with a User Equipment (UE) on a wireless network, comprising: one or more processors to: generate a Downlink Control Information (DCI) for a first UE beam, the DCI carrying an indicator for switching to a second UE beam; and process a confirmation transmission from the second UE beam based on a trigger indicator, and an interface for outputting the DCI from the one or more processors and for inputting the confirmation transmission from a receiving circuitry.

[00255] In example 44, the apparatus of example 43, wherein the confirmation transmission is one of: a Sounding Reference Signal (SRS) transmission, a Channel Quality Indicator (CQI) report transmission, or a Physical Random Access Channel (PRACH) transmission.

[00256] In example 45, the apparatus of either of examples 43 or 44, wherein the DCI carries the trigger indicator.

[00257] In example 46, the apparatus of either of examples 43 or 44, wherein the DCI is a first DCI, and wherein the one or more processors are to: generate a second DCI for the first UE beam, wherein the second DCI carries the trigger indicator.

[00258] In example 47, the apparatus of either of examples 43 or 44, wherein the confirmation transmission is a Sounding Reference Signal (SRS) transmission; and wherein the confirmation transmission is generated at a subframe that is offset from a subframe in which the DCI was received by a number of subframes N.

[00259] In example 48, the apparatus of either of examples 43 or 44, wherein the DCI is a first DCI, and wherein the one or more processors are to: generate a second DCI for the first UE beam within a number of subframes N of a subframe in which the first DCI was received, wherein the second DCI carries the trigger indicator; and wherein the confirmation transmission is a Sounding Reference Signal (SRS) transmission.

[00260] In example 49, the apparatus of either of examples 43 or 44, wherein the one or more processors are to: generate a Channel State Information Reference Signal (CSI-RS) transmission for the first UE beam, and wherein the confirmation transmission is a Channel Quality Indicator (CQI) report transmission carrying a report corresponding to the CSI-RS transmission; and wherein the CSI-RS transmission is received via the second UE receive beam at a subframe that is offset from a subframe in which the DCI was received by a number of subframes N.

[00261] In example 50, the apparatus of either of examples 43 or 44, wherein the DCI is a first DCI, and wherein the one or more processors are to: generate a second DCI for the first UE beam within a number of subframes N of a subframe in which the first DCI was received; and generate a Channel State Information Reference Signal (CSI-RS) transmission for the first UE beam, and wherein the second DCI carries the trigger indicator; and wherein the confirmation transmission is a Channel Quality Indicator (CQI) report transmission carrying a report of the CSI-RS transmission.

[00262] In example 51, the apparatus of either of examples 43 or 44, wherein the confirmation transmission is a Physical Random Access Channel (PRACH) transmission.

[00263] In example 52, the apparatus of any of examples 43 through 51, wherein the first UE beam encompasses a plurality of eNB beams partially overlapping with each other; wherein the plurality of eNB beams have a respectively corresponding plurality of Azimuth angles of departure (AODs); and wherein the plurality of eNB beams have a respectively corresponding plurality of Zenith angles of departure (ZODs).

[00264] Example 53 provides an Evolved Node B (eNB) device comprising an application processor, a memory, one or more antenna ports, and an interface for allowing the application processor to communicate with another device, the eNB device including the apparatus of any of examples 43 through 52.

[00265] Example 54 provides a method comprising: generating, for an Evolved Node-B (eNB), a Downlink Control Information (DCI) for a first UE beam, the DCI carrying an indicator for switching to a second UE beam; and processing a confirmation transmission from the second UE beam based on a trigger indicator.

[00266] In example 55, the method of example 54, wherein the confirmation transmission is one of: a Sounding Reference Signal (SRS) transmission, a Channel Quality

Indicator (CQI) report transmission, or a Physical Random Access Channel (PRACH) transmission.

[00267] In example 56, the method of either of examples 54 or 55, wherein the DCI carries the trigger indicator.

[00268] In example 57, the method of either of examples 54 or 55, wherein the DCI is a first DCI, comprising: generating a second DCI for the first UE beam, wherein the second DCI carries the trigger indicator.

[00269] In example 58, the method of either of examples 54 or 55, wherein the confirmation transmission is a Sounding Reference Signal (SRS) transmission; and wherein the confirmation transmission is generated at a subframe that is offset from a subframe in which the DCI was received by a number of subframes N.

[00270] In example 59, the method of either of examples 54 or 55, wherein the DCI is a first DCI, comprising: generating a second DCI for the first UE beam within a number of subframes N of a subframe in which the first DCI was received, wherein the second DCI carries the trigger indicator; and wherein the confirmation transmission is a Sounding Reference Signal (SRS) transmission.

[00271] In example 60, the method of either of examples 54 or 55, the operation comprising: generating a Channel State Information Reference Signal (CSI-RS) transmission for the first UE beam, and wherein the confirmation transmission is a Channel Quality Indicator (CQI) report transmission carrying a report corresponding to the CSI-RS transmission; and wherein the CSI-RS transmission is received via the second UE receive beam at a subframe that is offset from a subframe in which the DCI was received by a number of subframes N.

[00272] In example 61, the method of either of examples 54 or 55, wherein the DCI is a first DCI, comprising: generating a second DCI for the first UE beam within a number of subframes N of a subframe in which the first DCI was received; and generating a Channel State Information Reference Signal (CSI-RS) transmission for the first UE beam, and wherein the second DCI carries the trigger indicator; and wherein the confirmation transmission is a Channel Quality Indicator (CQI) report transmission carrying a report of the CSI-RS transmission.

[00273] In example 62, the method of either of examples 54 or 55, wherein the confirmation transmission is a Physical Random Access Channel (PRACH) transmission.

[00274] In example 63, the method of any of examples 54 through 62, wherein the first UE beam encompasses a plurality of eNB beams partially overlapping with each other;

wherein the plurality of eNB beams have a respectively corresponding plurality of Azimuth angles of departure (AODs); and wherein the plurality of eNB beams have a respectively corresponding plurality of Zenith angles of departure (ZODs).

[00275] Example 64 provides machine readable storage media having machine executable instructions stored thereon that, when executed, cause one or more processors to perform a method according to any of examples 54 through 63.

[00276] Example 65 provides an apparatus of an Evolved Node B (eNB) operable to communicate with a User Equipment (UE) on a wireless network, comprising: means for generating a Downlink Control Information (DCI) for a first UE beam, the DCI carrying an indicator for switching to a second UE beam; and means for processing a confirmation transmission from the second UE beam based on a trigger indicator.

[00277] In example 66, the apparatus of example 65, wherein the confirmation transmission is one of: a Sounding Reference Signal (SRS) transmission, a Channel Quality Indicator (CQI) report transmission, or a Physical Random Access Channel (PRACH) transmission.

[00278] In example 67, the apparatus of either of examples 65 or 66, wherein the DCI carries the trigger indicator.

[00279] In example 68, the apparatus of either of examples 65 or 66, wherein the DCI is a first DCI, comprising: means for generating a second DCI for the first UE beam, wherein the second DCI carries the trigger indicator.

[00280] In example 69, the apparatus of either of examples 65 or 66, wherein the confirmation transmission is a Sounding Reference Signal (SRS) transmission; and wherein the confirmation transmission is generated at a subframe that is offset from a subframe in which the DCI was received by a number of subframes N.

[00281] In example 70, the apparatus of either of examples 65 or 66, wherein the DCI is a first DCI, comprising: means for generating a second DCI for the first UE beam within a number of subframes N of a subframe in which the first DCI was received, wherein the second DCI carries the trigger indicator; and wherein the confirmation transmission is a Sounding Reference Signal (SRS) transmission.

[00282] In example 71, the apparatus of either of examples 65 or 66, the operation comprising: means for generating a Channel State Information Reference Signal (CSI-RS) transmission for the first UE beam, and wherein the confirmation transmission is a Channel Quality Indicator (CQI) report transmission carrying a report corresponding to the CSI-RS transmission; and wherein the CSI-RS transmission is received via the second UE receive beam at a subframe that is offset from a subframe in which the DCI was received by a number of subframes N.

[00283] In example 72, the apparatus of either of examples 65 or 66, wherein the DCI is a first DCI, comprising: means for generating a second DCI for the first UE beam within a number of subframes N of a subframe in which the first DCI was received; and means for generating a Channel State Information Reference Signal (CSI-RS) transmission for the first UE beam, and wherein the second DCI carries the trigger indicator; and wherein the confirmation transmission is a Channel Quality Indicator (CQI) report transmission carrying a report of the CSI-RS transmission.

[00284] In example 73, the apparatus of either of examples 65 or 66, wherein the confirmation transmission is a Physical Random Access Channel (PRACH) transmission.

[00285] In example 74, the apparatus of any of examples 65 through 73, wherein the first UE beam encompasses a plurality of eNB beams partially overlapping with each other; wherein the plurality of eNB beams have a respectively corresponding plurality of Azimuth angles of departure (AODs); and wherein the plurality of eNB beams have a respectively corresponding plurality of Zenith angles of departure (ZODs).

[00286] Example 75 provides machine readable storage media having machine executable instructions that, when executed, cause one or more processors of an Evolved Node B (eNB) operable to communicate with a User Equipment (UE) on a wireless network to perform an operation comprising: generate a Downlink Control Information (DCI) for a first UE beam, the DCI carrying an indicator for switching to a second UE beam; and process a confirmation transmission from the second UE beam based on a trigger indicator.

[00287] In example 76, the machine readable storage media of example 75, wherein the confirmation transmission is one of: a Sounding Reference Signal (SRS) transmission, a Channel Quality Indicator (CQI) report transmission, or a Physical Random Access Channel (PRACH) transmission.

[00288] In example 77, the machine readable storage media of either of examples 75 or 76, wherein the DCI carries the trigger indicator.

[00289] In example 78, the machine readable storage media of either of examples 75 or 76, wherein the DCI is a first DCI, and wherein the one or more processors are to: generate a second DCI for the first UE beam, wherein the second DCI carries the trigger indicator.

[00290] In example 79, the machine readable storage media of either of examples 75 or 76, wherein the confirmation transmission is a Sounding Reference Signal (SRS)

transmission; and wherein the confirmation transmission is generated at a subframe that is offset from a subframe in which the DCI was received by a number of subframes N.

[00291] In example 80, the machine readable storage media of either of examples 75 or 76, wherein the DCI is a first DCI, and the operation comprising: generate a second DCI for the first UE beam within a number of subframes N of a subframe in which the first DCI was received, wherein the second DCI carries the trigger indicator; and wherein the confirmation transmission is a Sounding Reference Signal (SRS) transmission.

[00292] In example 81, the machine readable storage media of either of examples 75 or 76, the operation comprising: generate a Channel State Information Reference Signal (CSI-RS) transmission for the first UE beam, and wherein the confirmation transmission is a Channel Quality Indicator (CQI) report transmission carrying a report corresponding to the CSI-RS transmission; and wherein the CSI-RS transmission is received via the second UE receive beam at a subframe that is offset from a subframe in which the DCI was received by a number of subframes N.

[00293] In example 82, the machine readable storage media of either of examples 75 or 76, wherein the DCI is a first DCI, the operation comprising: generate a second DCI for the first UE beam within a number of subframes N of a subframe in which the first DCI was received; and generate a Channel State Information Reference Signal (CSI-RS) transmission for the first UE beam, and wherein the second DCI carries the trigger indicator; and wherein the confirmation transmission is a Channel Quality Indicator (CQI) report transmission carrying a report of the CSI-RS transmission.

[00294] In example 83, the machine readable storage media of either of examples 75 or 76, wherein the confirmation transmission is a Physical Random Access Channel (PRACH) transmission.

[00295] In example 84, the machine readable storage media of any of examples 75 through 83, wherein the first UE beam encompasses a plurality of eNB beams partially overlapping with each other; wherein the plurality of eNB beams have a respectively corresponding plurality of Azimuth angles of departure (AODs); and wherein the plurality of eNB beams have a respectively corresponding plurality of Zenith angles of departure (ZODs).

[00296] In example 85, the apparatus of any of examples 1 through 10 and examples 43 through 52, wherein the one or more processors comprise a baseband processor.

[00297] In example 86, the apparatus of any of examples 1 through 10 and examples 43 through 52, comprising a memory for storing instructions, the memory being coupled to the one or more processors.

[00298] In example 87, the apparatus of any of examples 1 through 10 and examples 43 through 52, comprising a transceiver circuitry for at least one of: generating transmissions, encoding transmissions, processing transmissions, or decoding transmissions.

[00299] In example 88, the apparatus of any of examples 1 through 10 and examples 43 through 52, comprising a transceiver circuitry for generating transmissions and processing transmissions.

[00300] An abstract is provided that will allow the reader to ascertain the nature and gist of the technical disclosure. The abstract is submitted with the understanding that it will not be used to limit the scope or meaning of the claims. The following claims are hereby incorporated into the detailed description, with each claim standing on its own as a separate embodiment.

CLAIMS

We claim:

1. An apparatus of a User Equipment (UE) operable to communicate with an Evolved Node-B (eNB) on a wireless network, comprising:
   one or more processors to:
      process a Downlink Control Information (DCI) received via a first UE beam, the DCI carrying an indicator for switching to a second UE beam; and
      generate a confirmation transmission for the second UE beam based on a trigger indicator, and
   an interface for inputting the DCI to the one or more processors and for outputting the confirmation transmission to a transmission circuitry.

2. The apparatus of claim 1,
   wherein the confirmation transmission is one of: a Sounding Reference Signal (SRS) transmission, a Channel Quality Indicator (CQI) report transmission, or a Physical Random Access Channel (PRACH) transmission.

3. The apparatus of either of claims 1 or 2,
   wherein the DCI carries the trigger indicator.

4. The apparatus of either of claims 1 or 2, wherein the DCI is a first DCI, and wherein the one or more processors are to:
      process a second DCI received via the first UE beam,
   wherein the second DCI carries the trigger indicator.

5. The apparatus of either of claims 1 or 2,
   wherein the confirmation transmission is a Sounding Reference Signal (SRS) transmission; and
   wherein the confirmation transmission is generated at a subframe that is offset from a subframe in which the DCI was received by a number of subframes N.

6. The apparatus of either of claims 1 or 2, wherein the DCI is a first DCI, and wherein the one or more processors are to:

process a second DCI received via the first UE beam within a number of subframes N of a subframe in which the first DCI was received,

wherein the second DCI carries the trigger indicator; and

wherein the confirmation transmission is a Sounding Reference Signal (SRS) transmission.

7. Machine readable storage media having machine executable instructions that, when executed, cause one or more processors of a User Equipment (UE) operable to communicate with an Evolved Node-B (eNB) on a wireless network to perform an operation comprising:

process a Downlink Control Information (DCI) received via a first UE beam, the DCI carrying an indicator for switching to a second UE beam; and

generate a confirmation transmission for the second UE beam based on a trigger indicator.

8. The machine readable storage media of claim 7,

wherein the confirmation transmission is one of: a Sounding Reference Signal (SRS) transmission, a Channel Quality Indicator (CQI) report transmission, or a Physical Random Access Channel (PRACH) transmission.

9. The machine readable storage media of either of claims 7 or 8,

wherein the DCI carries the trigger indicator.

10. The machine readable storage media of either of claims 7 or 8, wherein the DCI is a first DCI, and wherein the one or more processors are to:

process a second DCI received via the first UE beam,

wherein the second DCI carries the trigger indicator.

11. The machine readable storage media of either of claims 7 or 8,

wherein the confirmation transmission is a Sounding Reference Signal (SRS) transmission; and

wherein the confirmation transmission is generated at a subframe that is offset from a subframe in which the DCI was received by a number of subframes N.

12. The machine readable storage media of either of claims 7 or 8, wherein the DCI is a first DCI, and the operation comprising:
    process a second DCI received via the first UE beam within a number of subframes N of a subframe in which the first DCI was received,
    wherein the second DCI carries the trigger indicator; and
    wherein the confirmation transmission is a Sounding Reference Signal (SRS) transmission.

13. An apparatus of an Evolved Node-B (eNB) operable to communicate with a User Equipment (UE) on a wireless network, comprising:
    one or more processors to:
        generate a Downlink Control Information (DCI) for a first UE beam, the DCI carrying an indicator for switching to a second UE beam; and
        process a confirmation transmission from the second UE beam based on a trigger indicator, and
    an interface for outputting the DCI from the one or more processors and for inputting the confirmation transmission from a receiving circuitry.

14. The apparatus of claim 13,
    wherein the confirmation transmission is one of: a Sounding Reference Signal (SRS) transmission, a Channel Quality Indicator (CQI) report transmission, or a Physical Random Access Channel (PRACH) transmission.

15. The apparatus of either of claims 13 or 14,
    wherein the DCI carries the trigger indicator.

16. The apparatus of either of claims 13 or 14, wherein the DCI is a first DCI, and wherein the one or more processors are to:
        generate a second DCI for the first UE beam,
    wherein the second DCI carries the trigger indicator.

17. The apparatus of either of claims 13 or 14,
    wherein the confirmation transmission is a Sounding Reference Signal (SRS) transmission; and

wherein the confirmation transmission is generated at a subframe that is offset from a subframe in which the DCI was received by a number of subframes N.

18. The apparatus of either of claims 13 or 14, wherein the DCI is a first DCI, and wherein the one or more processors are to:

generate a second DCI for the first UE beam within a number of subframes N of a subframe in which the first DCI was received,

wherein the second DCI carries the trigger indicator; and

wherein the confirmation transmission is a Sounding Reference Signal (SRS) transmission.

19. Machine readable storage media having machine executable instructions that, when executed, cause one or more processors of an Evolved Node-B (eNB) operable to communicate with a User Equipment (UE) on a wireless network to perform an operation comprising:

generate a Downlink Control Information (DCI) for a first UE beam, the DCI carrying an indicator for switching to a second UE beam; and

process a confirmation transmission from the second UE beam based on a trigger indicator.

20. The machine readable storage media of claim 19,

wherein the confirmation transmission is one of: a Sounding Reference Signal (SRS) transmission, a Channel Quality Indicator (CQI) report transmission, or a Physical Random Access Channel (PRACH) transmission.

21. The machine readable storage media of either of claims 19 or 20,

wherein the DCI carries the trigger indicator.

22. The machine readable storage media of either of claims 19 or 20, wherein the DCI is a first DCI, and wherein the one or more processors are to:

generate a second DCI for the first UE beam,

wherein the second DCI carries the trigger indicator.

23. The machine readable storage media of either of claims 19 or 20,

    wherein the confirmation transmission is a Sounding Reference Signal (SRS) transmission; and

    wherein the confirmation transmission is generated at a subframe that is offset from a subframe in which the DCI was received by a number of subframes N.

24. The machine readable storage media of either of claims 19 or 20, wherein the DCI is a first DCI, and the operation comprising:

    generate a second DCI for the first UE beam within a number of subframes N of a subframe in which the first DCI was received,

    wherein the second DCI carries the trigger indicator; and

    wherein the confirmation transmission is a Sounding Reference Signal (SRS) transmission.

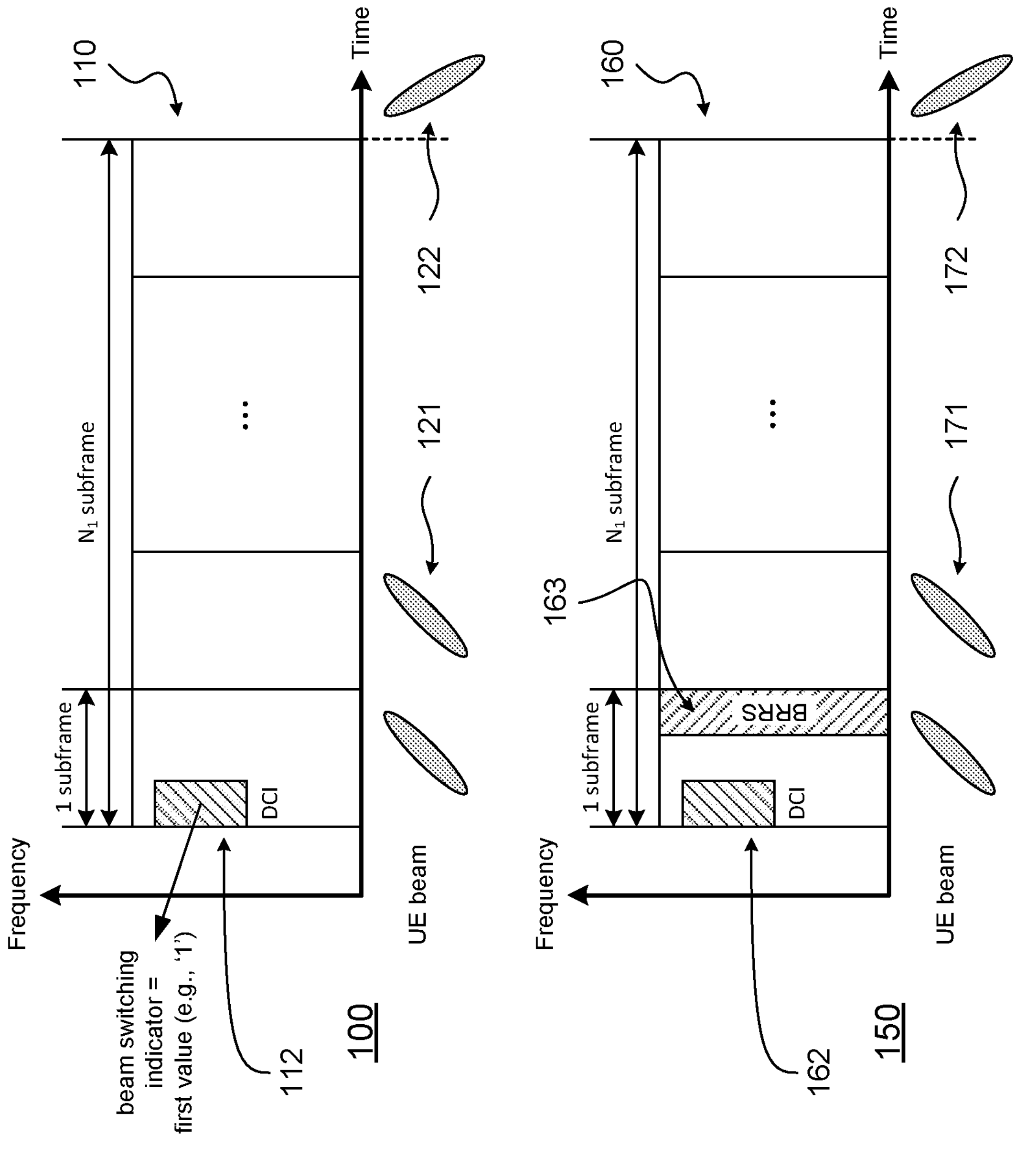
110
Time
Frequency
N_1 subframe
1 subframe
DCI
...
UE beam
121
122
112
beam switching indicator = first value (e.g., '1')
100
160
163
BRS
171
172
162
150

Fig. 1

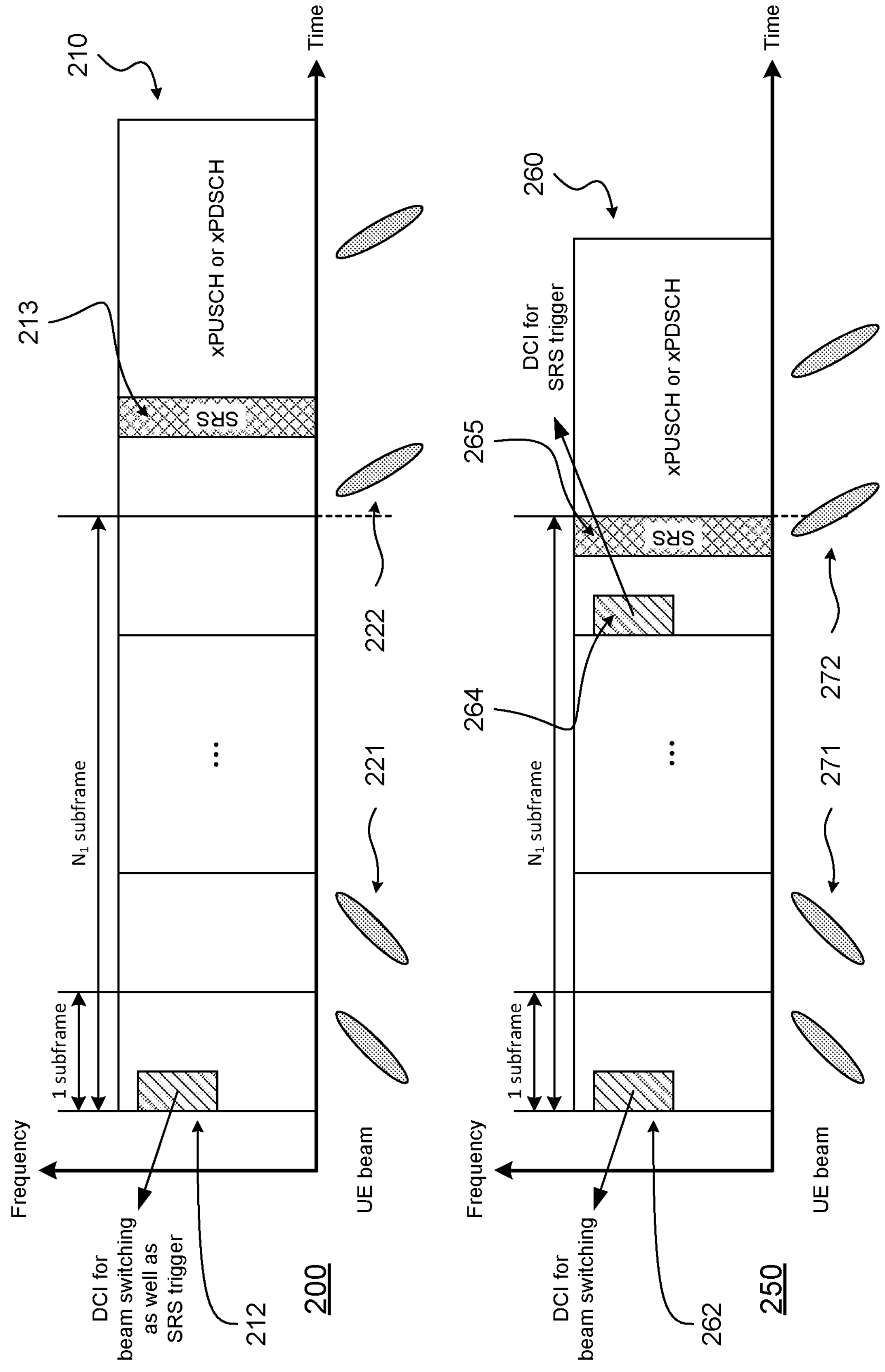
200
DCI for beam switching as well as SRS trigger
212
Frequency
1 subframe
N_1 subframe
...
SRS
213
xPUSCH or xPDSCH
210
Time
UE beam
221
222
250
DCI for beam switching
262
264
265
DCI for SRS trigger
260
271
272

Fig. 2

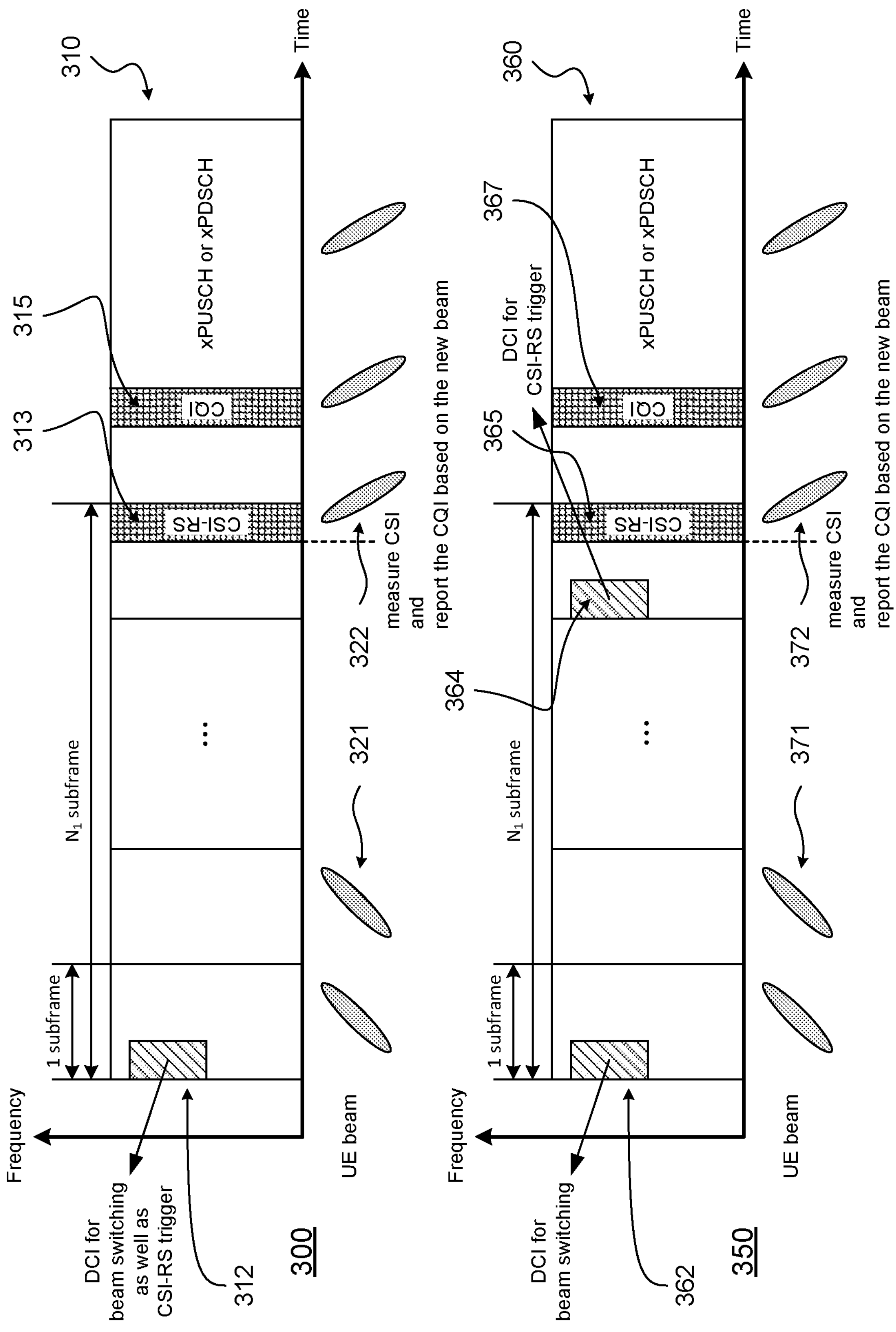
300
310
Time
Frequency
xPUSCH or xPDSCH
CQI
CSI-RS
315
313
1 subframe
N_1 subframe
...
DCI for
beam switching
as well as
CSI-RS trigger
312
UE beam
321
322
measure CSI
and
report the CQI based on the new beam
350
360
Time
Frequency
xPUSCH or xPDSCH
CQI
CSI-RS
367
DCI for
CSI-RS trigger
365
364
1 subframe
N_1 subframe
...
DCI for
beam switching
362
UE beam
371
372
measure CSI
and
report the CQI based on the new beam

Fig. 3

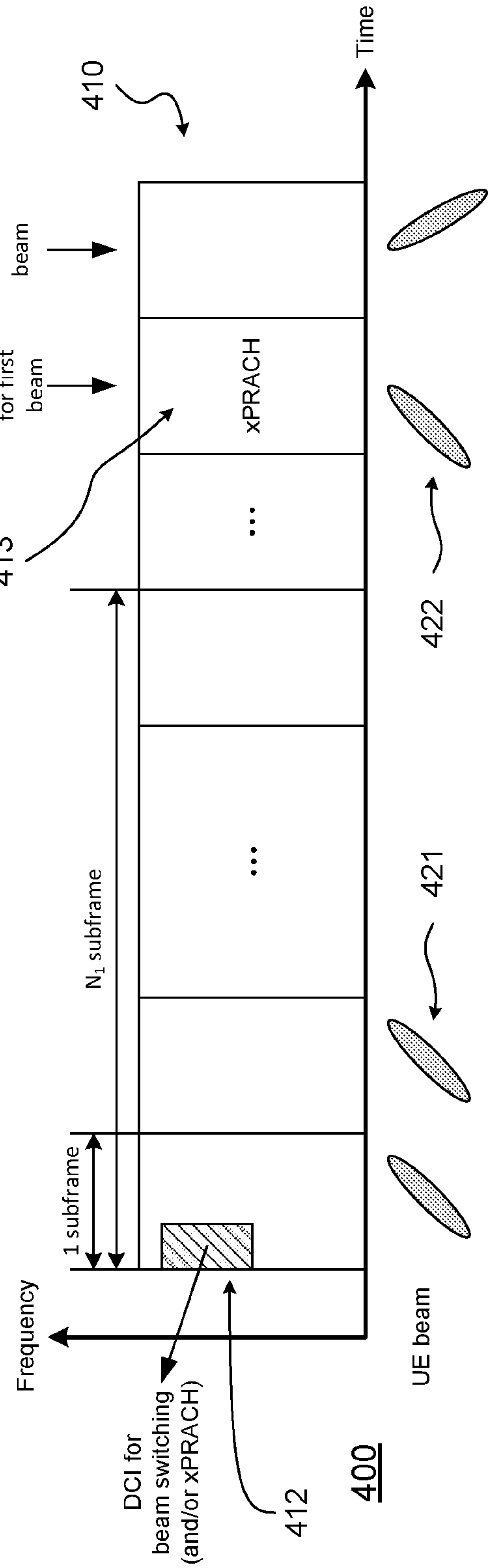
Time
410
switch to second beam
time/ frequency for first beam
xPRACH
413
422
421
N1 subframe
1 subframe
Frequency
UE beam
DCI for beam switching (and/or xPRACH)
412
400

Fig. 4

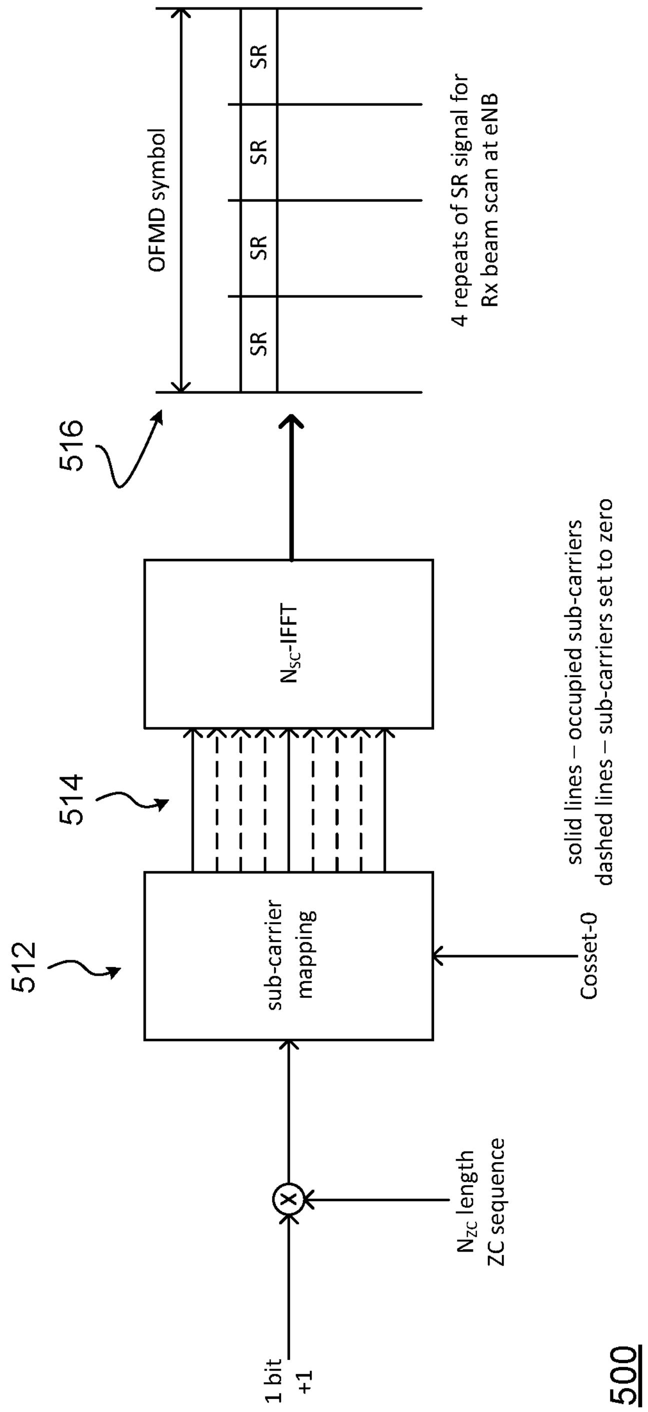
500
1 bit
+1
N_{ZC} length
ZC sequence
512
sub-carrier
mapping
Cosset-0
514
solid lines – occupied sub-carriers
dashed lines – sub-carriers set to zero
N_{SC}-IFFT
516
OFMD symbol
SR
SR
SR
SR
4 repeats of SR signal for
Rx beam scan at eNB

Fig. 5

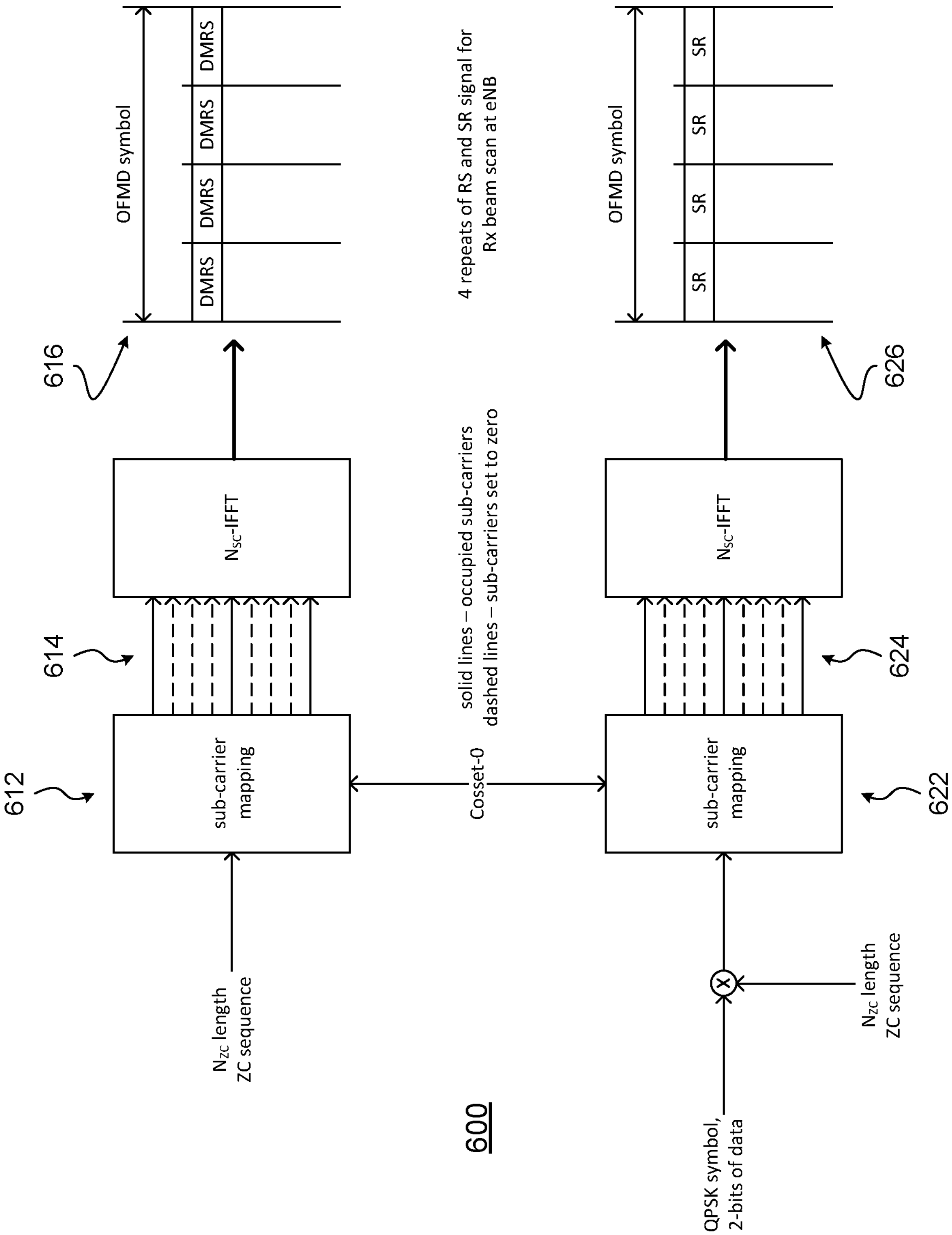
600
612
614
616
622
624
626
NZC length ZC sequence
sub-carrier mapping
NSC-IFFT
OFMD symbol
DMRS
DMRS
DMRS
DMRS
Cosset-0
solid lines – occupied sub-carriers
dashed lines – sub-carriers set to zero
4 repeats of RS and SR signal for Rx beam scan at eNB
QPSK symbol, 2-bits of data
X
NZC length ZC sequence
sub-carrier mapping
NSC-IFFT
OFMD symbol
SR
SR
SR
SR

Fig. 6

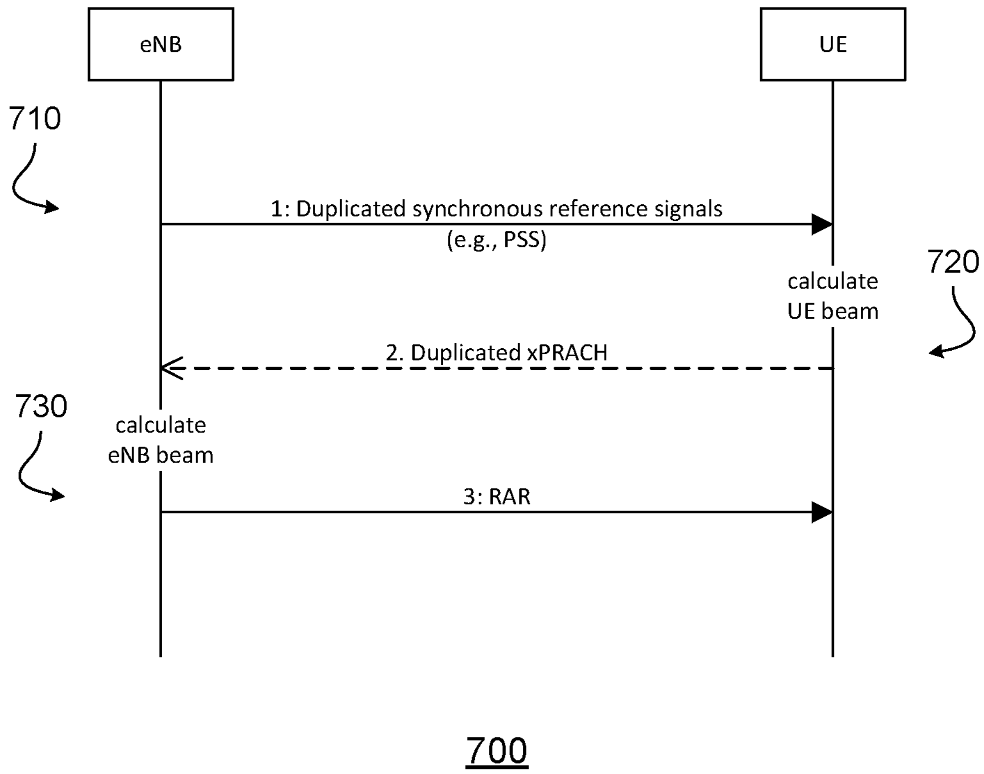
eNB
UE
710
1: Duplicated synchronous reference signals
(e.g., PSS)
720
calculate
UE beam
2. Duplicated xPRACH
730
calculate
eNB beam
3: RAR
700

Fig. 7

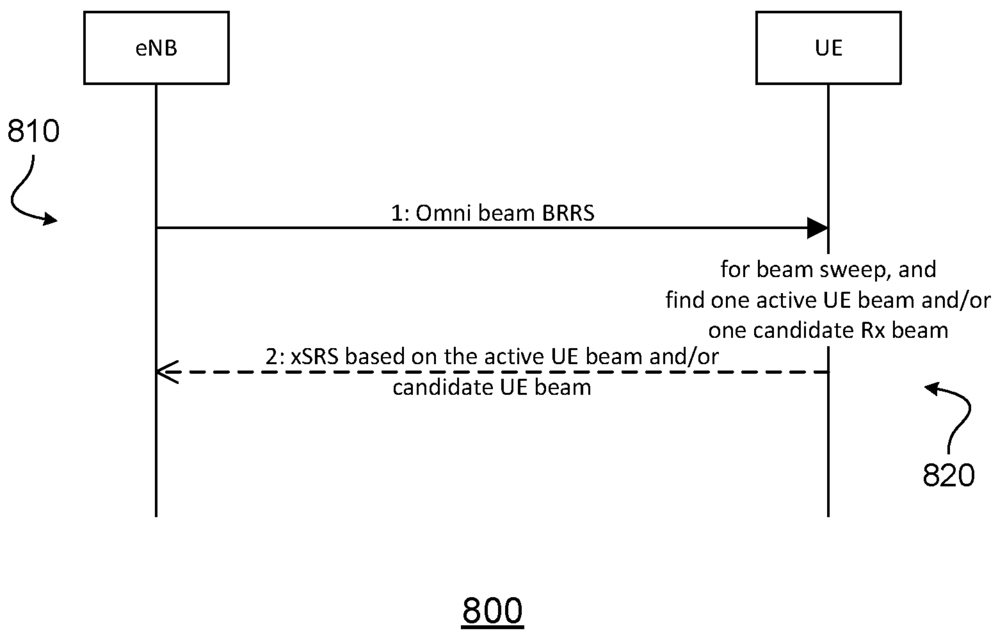
eNB
UE
810
1: Omni beam BRRS
for beam sweep, and
find one active UE beam and/or
one candidate Rx beam
2: xSRS based on the active UE beam and/or
candidate UE beam
820
800

Fig. 8

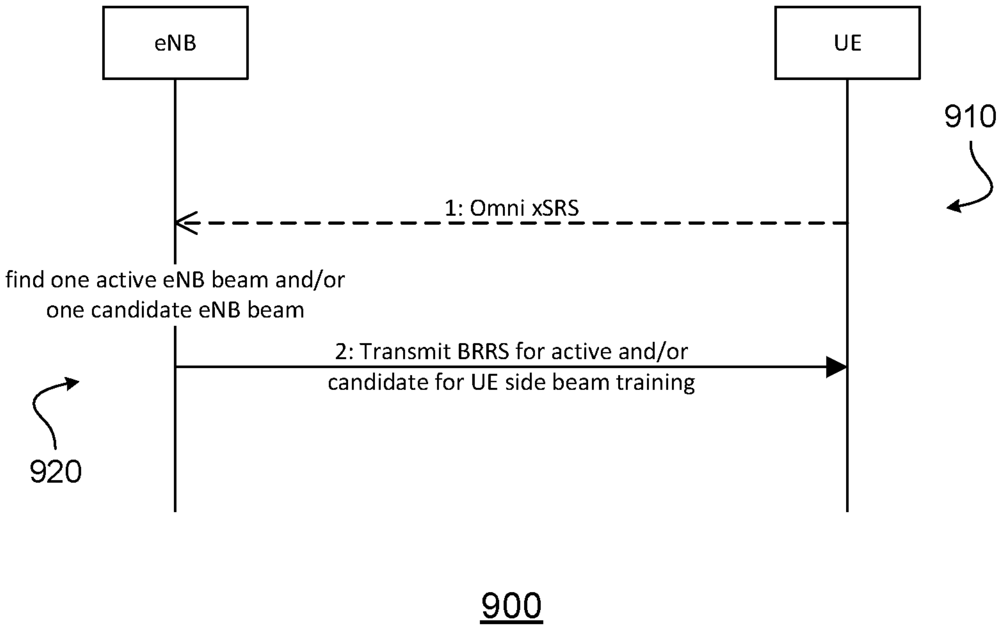
eNB
UE
910
1: Omni xSRS
find one active eNB beam and/or
one candidate eNB beam
2: Transmit BRRS for active and/or
candidate for UE side beam training
920
900

Fig. 9

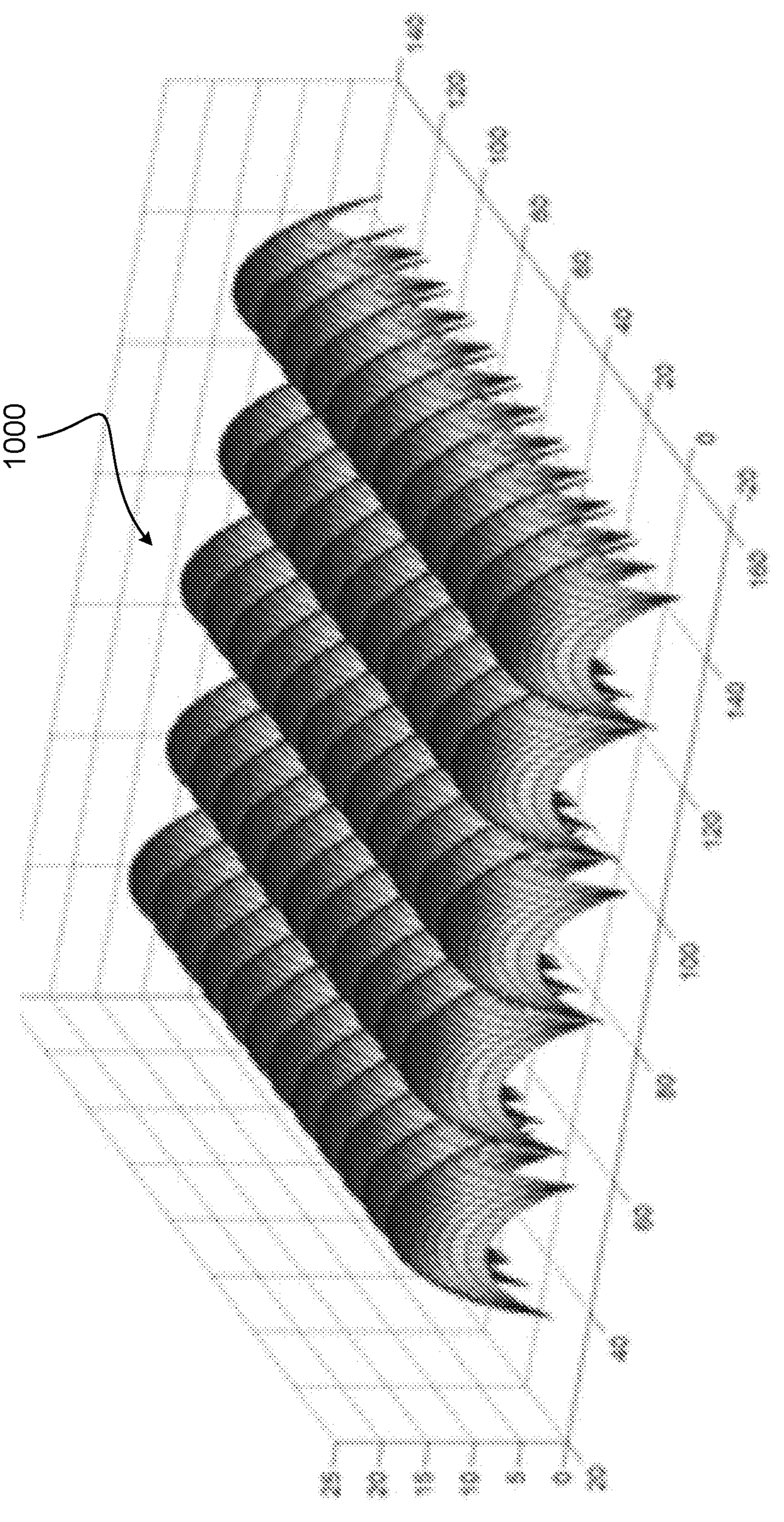

Fig. 10

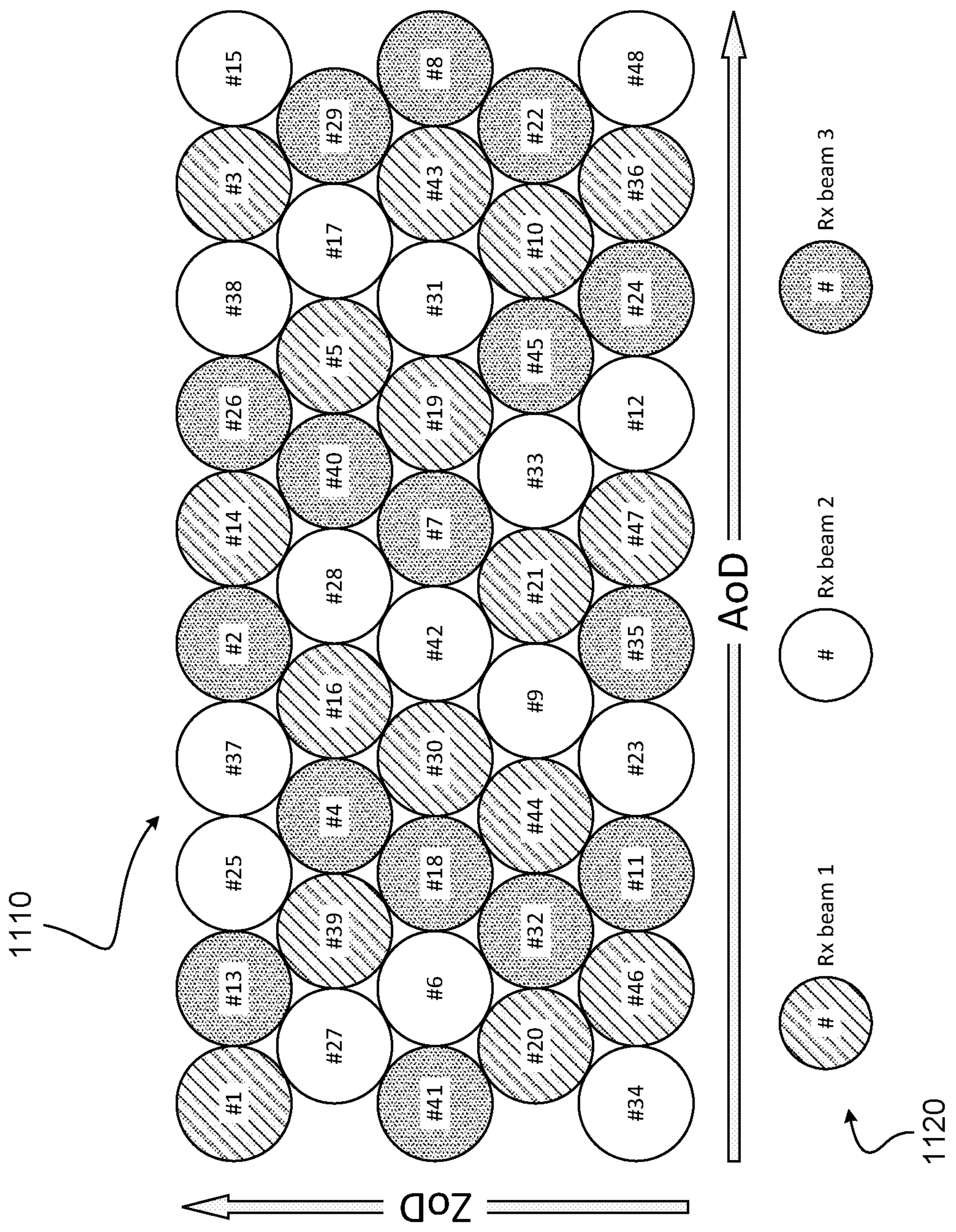
1110
#1
#13
#25
#37
#2
#14
#26
#38
#3
#15
#27
#39
#4
#16
#28
#40
#5
#17
#29
#41
#6
#18
#30
#42
#7
#19
#31
#43
#8
#20
#32
#44
#9
#21
#33
#45
#10
#22
#34
#46
#11
#23
#35
#47
#12
#24
#36
#48
ZoD
AoD
#
Rx beam 1
#
Rx beam 2
#
Rx beam 3
1120

Fig. 11

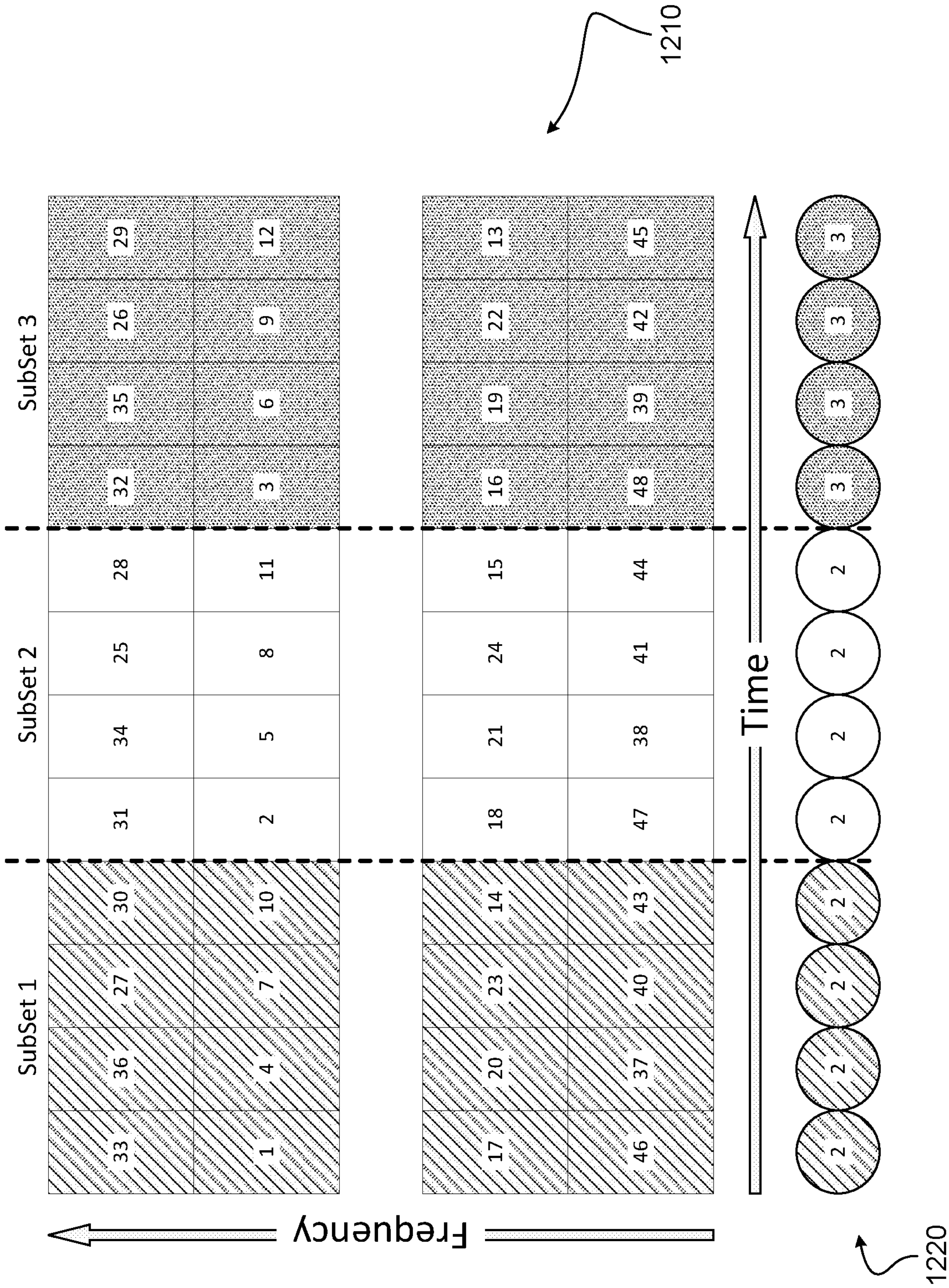
1210
SubSet 1
SubSet 2
SubSet 3
33 36 27 30 31 34 25 28 32 35 26 29
1 4 7 10 2 5 8 11 3 6 9 12
17 20 23 14 18 21 24 15 16 19 22 13
46 37 40 43 47 38 41 44 48 39 42 45
Time
Frequency
2 2 2 2 2 2 2 2 3 3 3 3
1220

Fig. 12

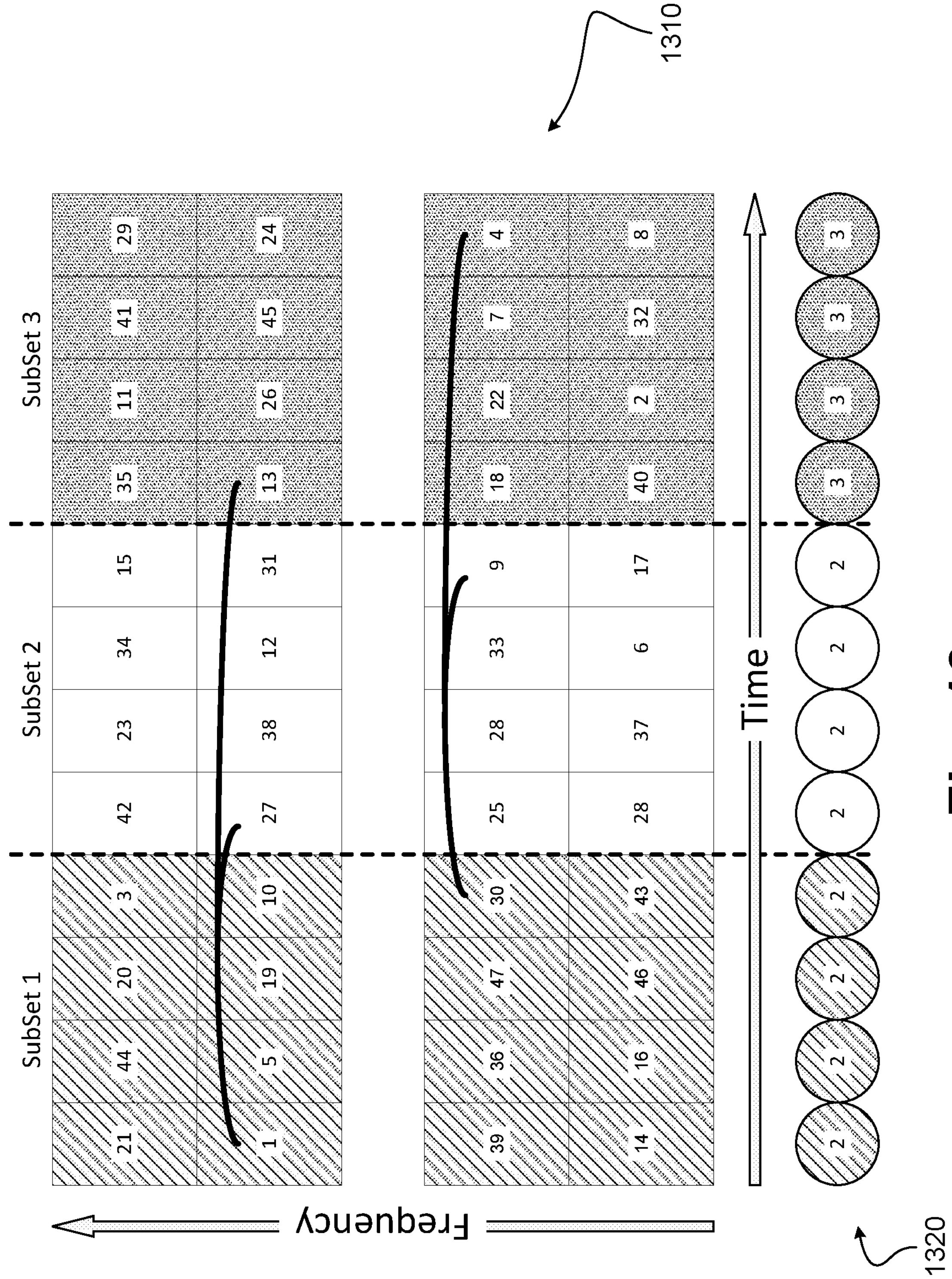
1310
SubSet 1
SubSet 2
SubSet 3
21 44 20 3 42 23 34 15 35 11 41 29
1 5 19 10 27 38 12 31 13 26 45 24
39 36 47 30 25 28 33 9 18 22 7 4
14 16 46 43 28 37 6 17 40 2 32 8
Frequency
Time
2 2 2 2 2 2 2 2 3 3 3 3
1320

Fig. 13

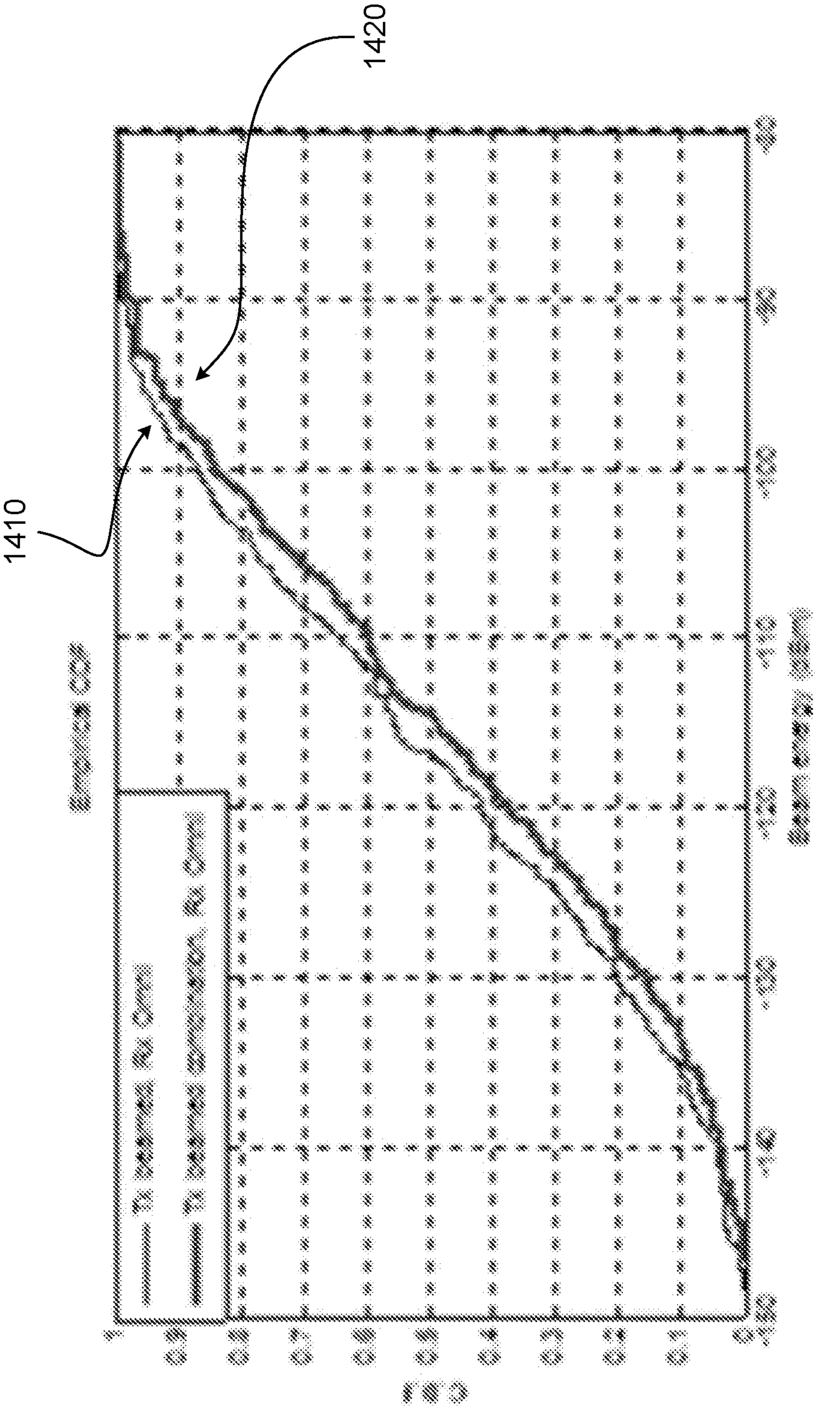

Fig. 14

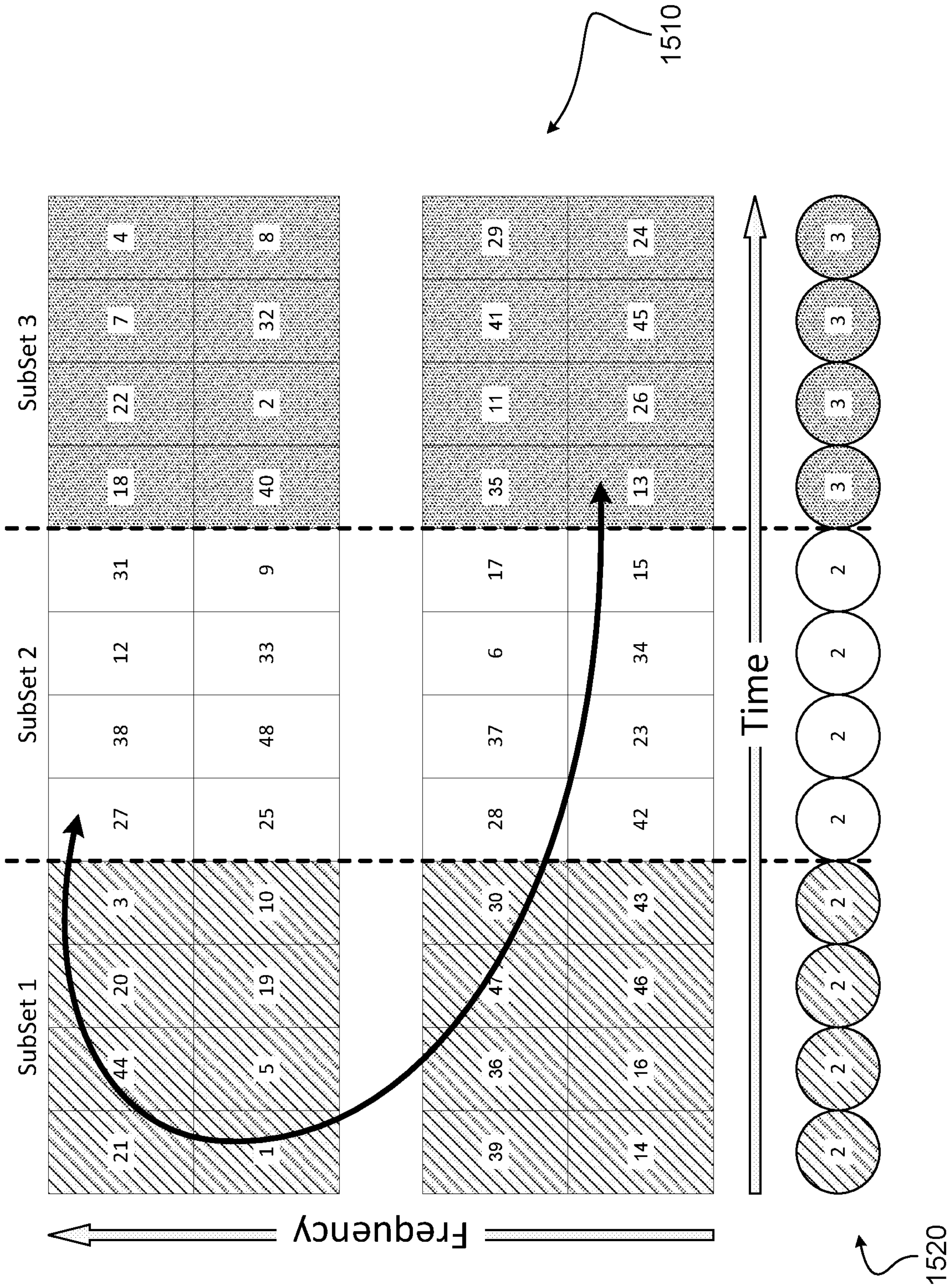
1510
SubSet 1
SubSet 2
SubSet 3
21 44 20 3 27 38 12 31 18 22 7 4
1 5 19 10 25 48 33 9 40 2 32 8
39 36 47 30 28 37 6 17 35 11 41 29
14 16 46 43 42 23 34 15 13 26 45 24
Frequency
Time
2 2 2 2 2 2 2 2 3 3 3 3
1520

Fig. XX

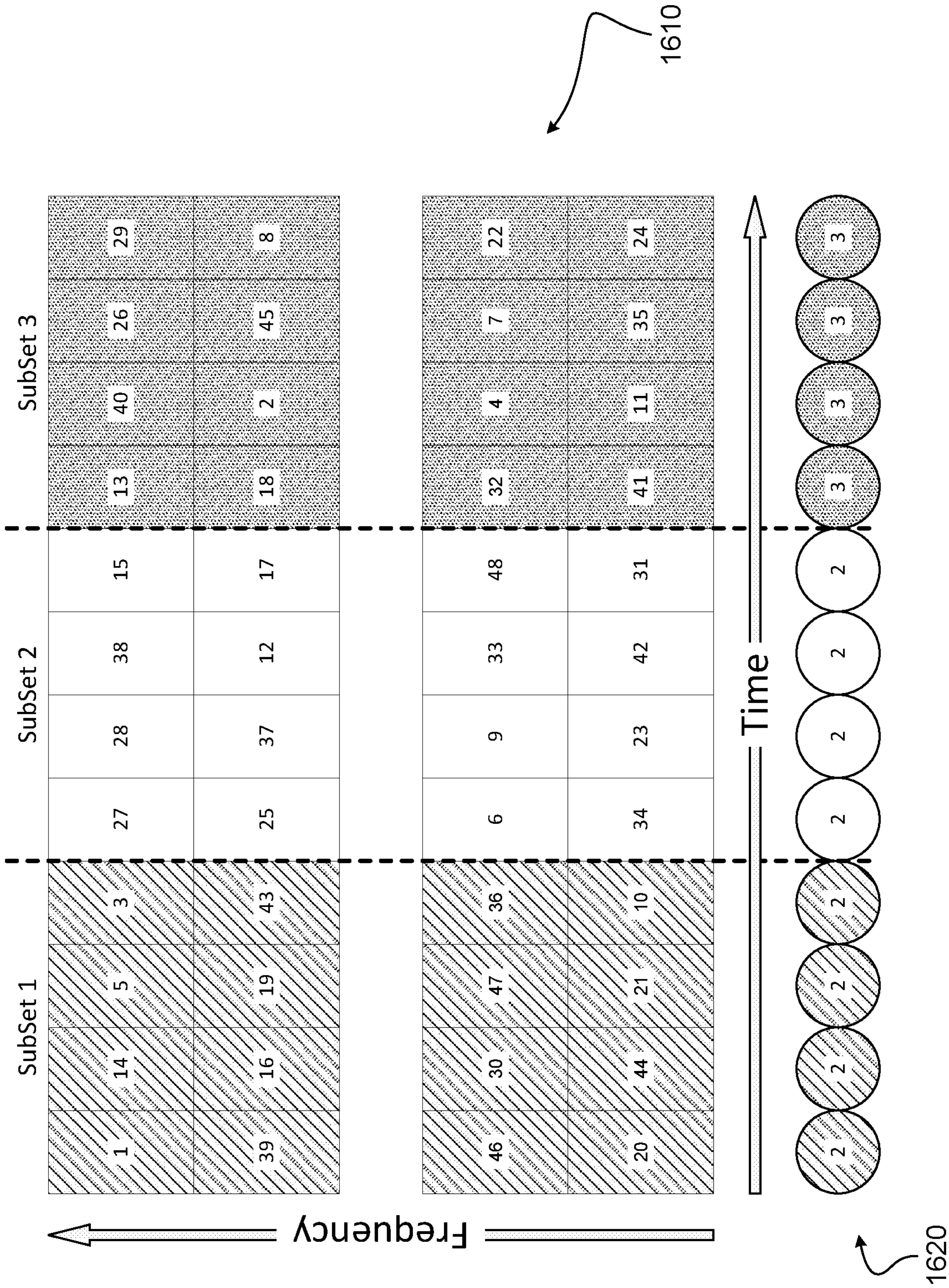
1610
SubSet 1
SubSet 2
SubSet 3
1 14 5 3 27 28 38 15 13 40 26 29
39 16 19 43 25 37 12 17 18 2 45 8
46 30 47 36 6 9 33 48 32 4 7 22
20 44 21 10 34 23 42 31 41 11 35 24
Frequency
Time
2 2 2 2 2 2 2 2 3 3 3 3
1620

Fig. 16

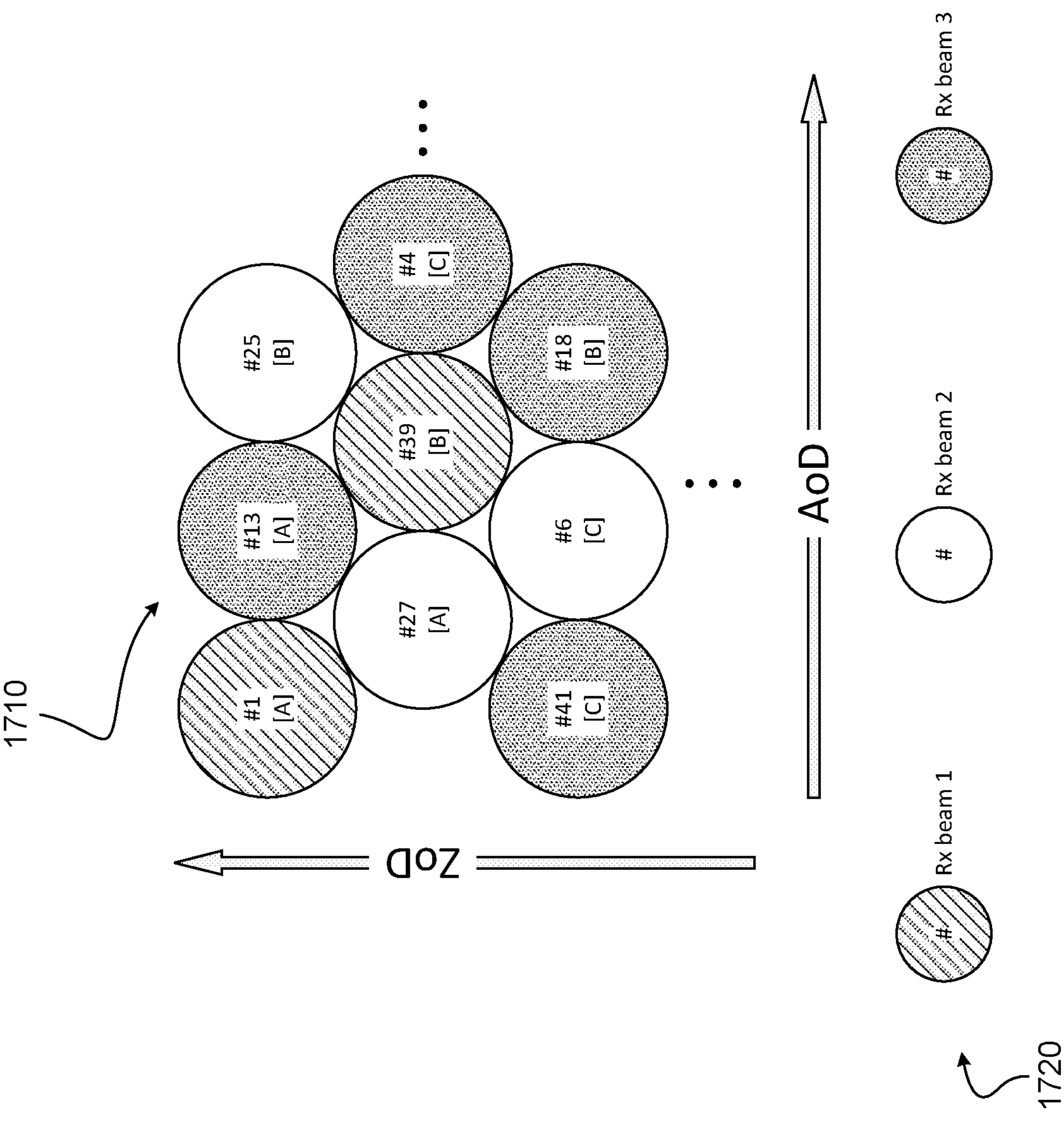
1710
#1
[A]
#27
[A]
#41
[C]
#13
[A]
#6
[C]
#39
[B]
#25
[B]
#18
[B]
#4
[C]
ZoD
AoD
Rx beam 1
Rx beam 2
Rx beam 3
#
#
#
1720

Fig. 17

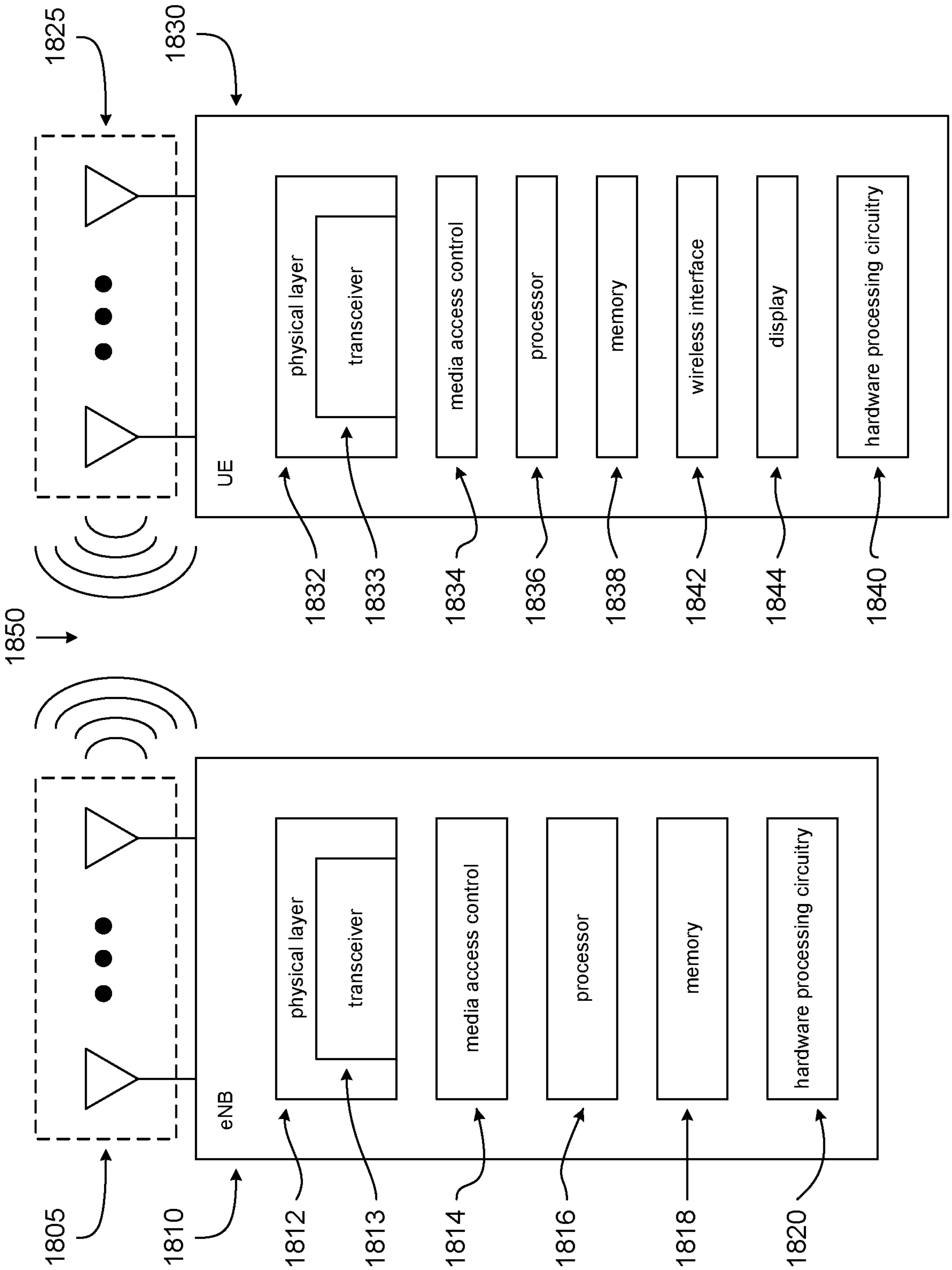
1825
1830
UE
physical layer
transceiver
media access control
processor
memory
wireless interface
display
hardware processing circuitry
1832
1833
1834
1836
1838
1842
1844
1840
1850
1805
1810
eNB
physical layer
transceiver
media access control
processor
memory
hardware processing circuitry
1812
1813
1814
1816
1818
1820

Fig. 18

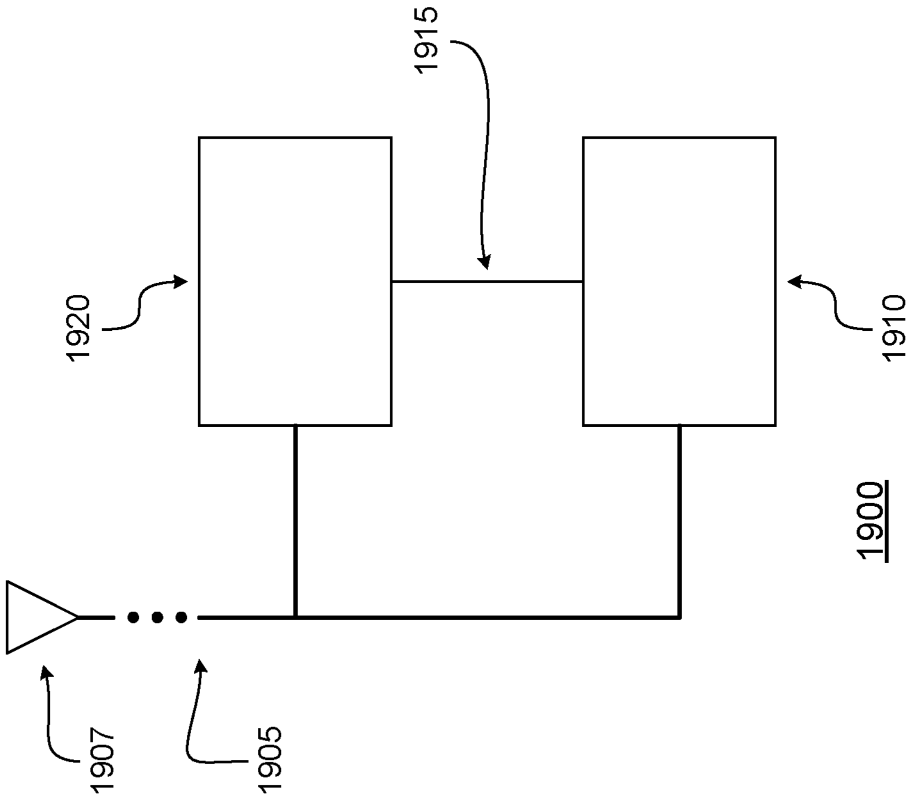

Fig. 19

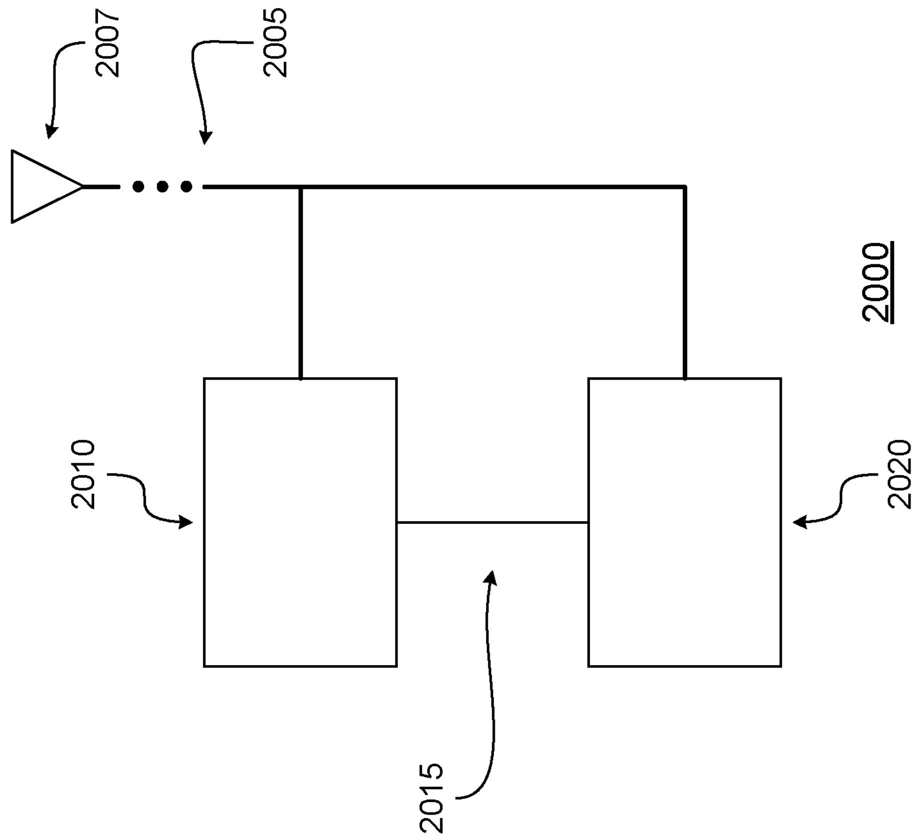

Fig. 20

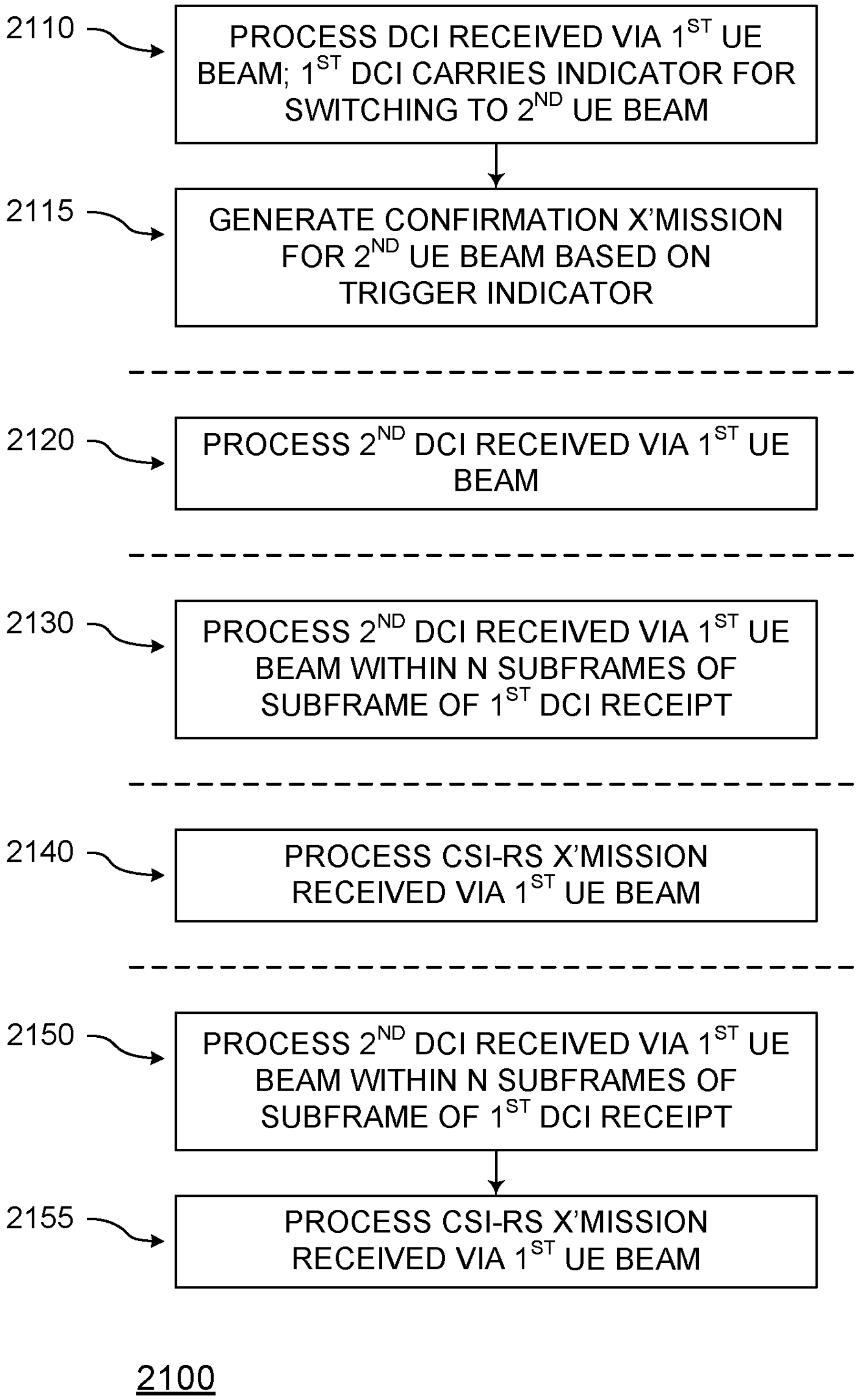
2110
PROCESS DCI RECEIVED VIA 1ST UE BEAM; 1ST DCI CARRIES INDICATOR FOR SWITCHING TO 2ND UE BEAM
2115
GENERATE CONFIRMATION X'MISSION FOR 2ND UE BEAM BASED ON TRIGGER INDICATOR
2120
PROCESS 2ND DCI RECEIVED VIA 1ST UE BEAM
2130
PROCESS 2ND DCI RECEIVED VIA 1ST UE BEAM WITHIN N SUBFRAMES OF SUBFRAME OF 1ST DCI RECEIPT
2140
PROCESS CSI-RS X'MISSION RECEIVED VIA 1ST UE BEAM
2150
PROCESS 2ND DCI RECEIVED VIA 1ST UE BEAM WITHIN N SUBFRAMES OF SUBFRAME OF 1ST DCI RECEIPT
2155
PROCESS CSI-RS X'MISSION RECEIVED VIA 1ST UE BEAM
2100

Fig. 21

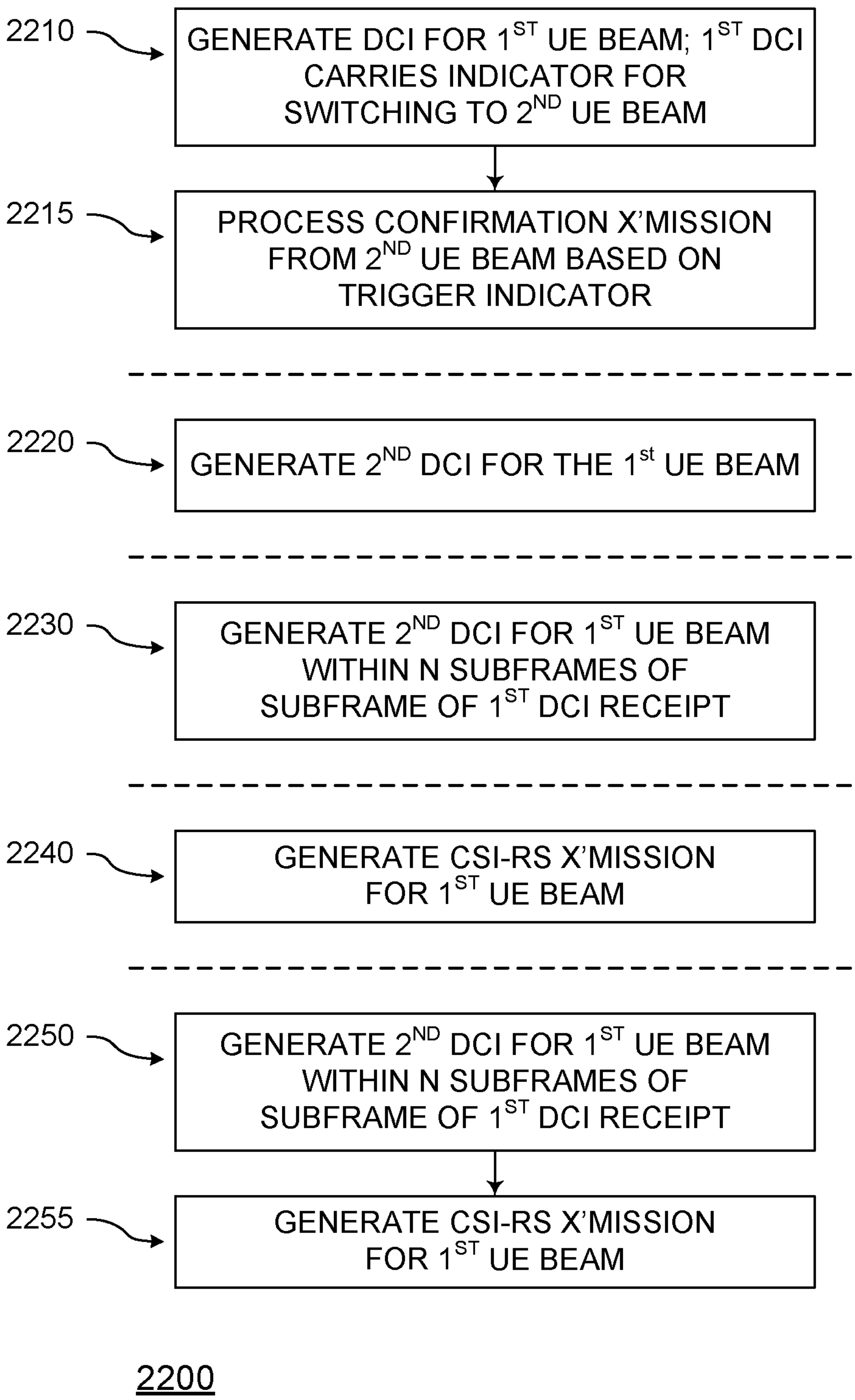
2210
GENERATE DCI FOR 1ST UE BEAM; 1ST DCI CARRIES INDICATOR FOR SWITCHING TO 2ND UE BEAM
2215
PROCESS CONFIRMATION X'MISSION FROM 2ND UE BEAM BASED ON TRIGGER INDICATOR
2220
GENERATE 2ND DCI FOR THE 1st UE BEAM
2230
GENERATE 2ND DCI FOR 1ST UE BEAM WITHIN N SUBFRAMES OF SUBFRAME OF 1ST DCI RECEIPT
2240
GENERATE CSI-RS X'MISSION FOR 1ST UE BEAM
2250
GENERATE 2ND DCI FOR 1ST UE BEAM WITHIN N SUBFRAMES OF SUBFRAME OF 1ST DCI RECEIPT
2255
GENERATE CSI-RS X'MISSION FOR 1ST UE BEAM
2200

Fig. 22

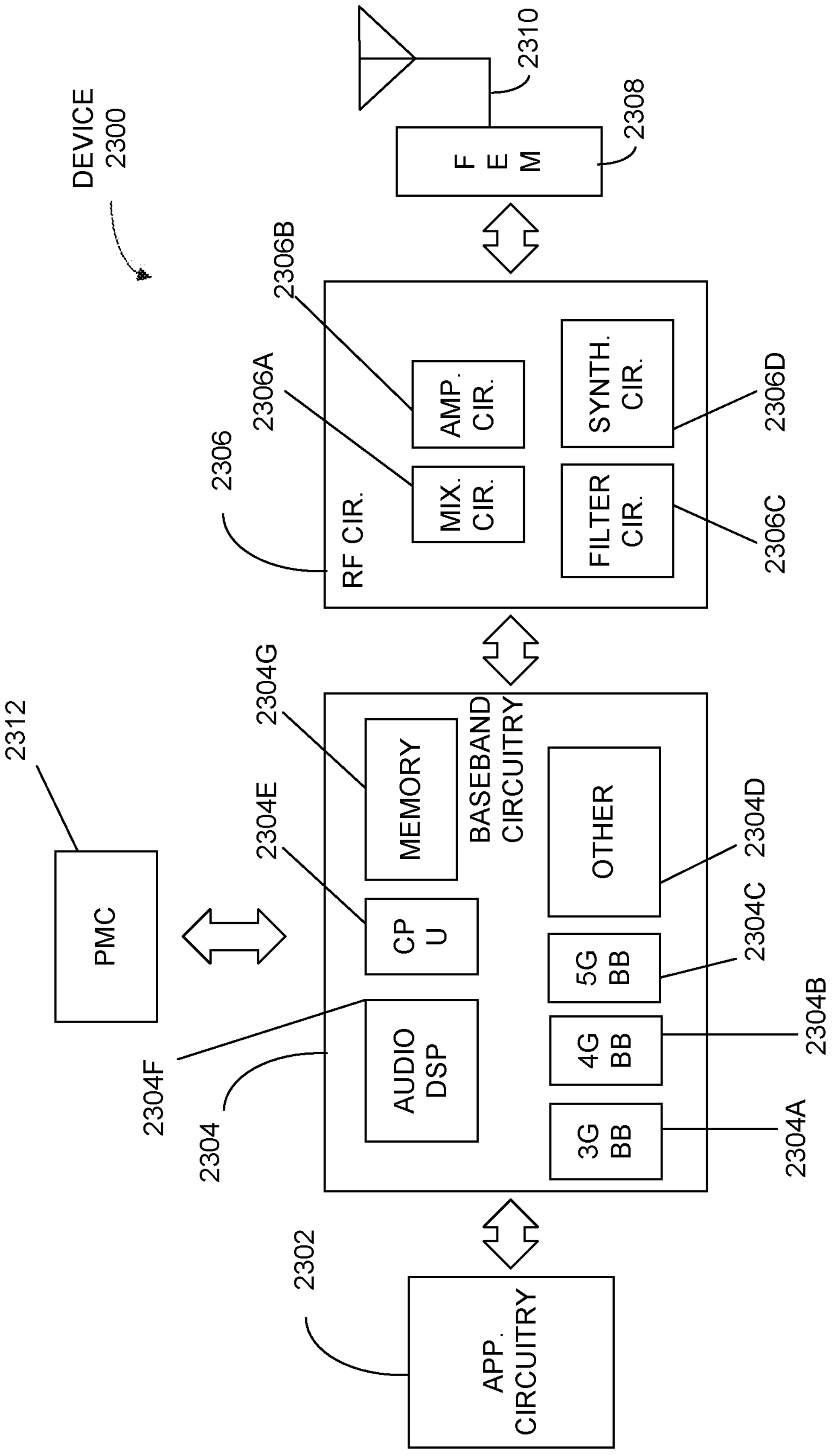
DEVICE
2300
2310
2308
F
E
M
2306B
2306A
2306
RF CIR.
AMP.
CIR.
MIX.
CIR.
SYNTH.
CIR.
FILTER
CIR.
2306D
2306C
2312
PMC
2304G
MEMORY
BASEBAND
CIRCUITRY
2304E
CP
U
OTHER
2304D
5G
BB
2304C
4G
BB
2304B
3G
BB
2304A
AUDIO
DSP
2304F
2304
2302
APP.
CIRCUITRY

Fig. 23

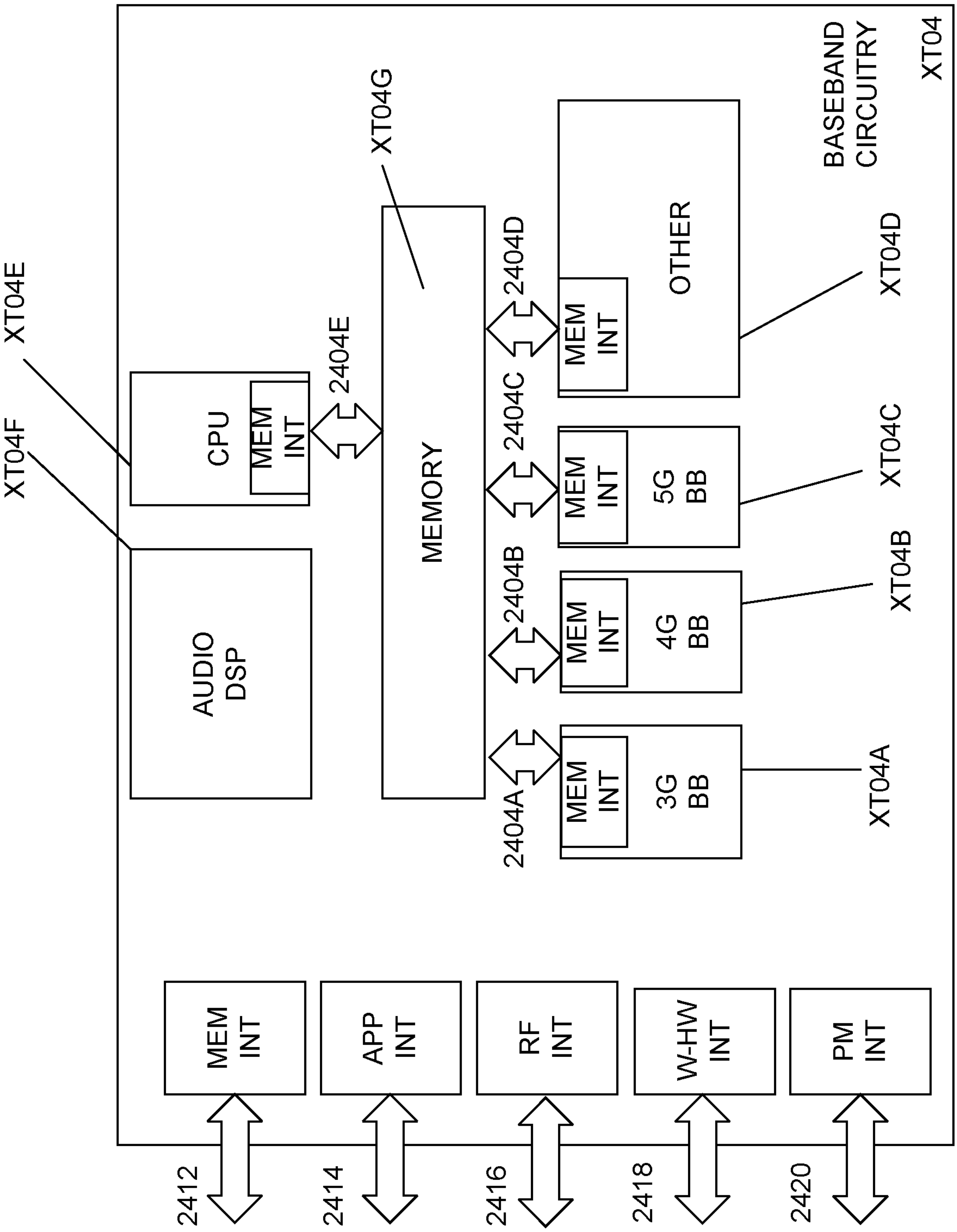
BASEBAND
CIRCUITRY
XT04
XT04G
XT04E
XT04F
XT04D
XT04C
XT04B
XT04A
OTHER
MEM
INT
CPU
MEM
INT
AUDIO
DSP
MEMORY
5G
BB
4G
BB
3G
BB
2404A
2404B
2404C
2404D
2404E
MEM
INT
APP
INT
RF
INT
W-HW
INT
PM
INT
2412
2414
2416
2418
2420

Fig. 24

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2017/041576

A. CLASSIFICATION OF SUBJECT MATTER
INV. H04B7/06 H04B7/08
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)
H04B

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2016/007261 A1 (OH SUNG-MIN [KR] ET AL) 7 January 2016 (2016-01-07)	1-5, 7-11, 13-17, 19-23
A	paragraphs [0046], [0070], [0071]; figures 2,6	6,12,18, 24

X	WO 2016/086144 A1 (INTERDIGITAL PATENT HOLDINGS [US]) 2 June 2016 (2016-06-02)	1-5, 7-11, 13-17, 19-23
A	paragraphs [0184] - [0188]; figures 19A, 19B	6,12,18, 24

E	WO 2017/146766 A1 (INTEL IP CORP [US]) 31 August 2017 (2017-08-31) page 18, lines 23-29	1-3,7-9, 13-15, 19-21

☐ 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
18 September 2017	27/09/2017

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	Franz, Volker

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/US2017/041576

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2016007261 A1	07-01-2016	KR 20160004003 A	12-01-2016
		US 2016007261 A1	07-01-2016
WO 2016086144 A1	02-06-2016	EP 3225070 A1	04-10-2017
		WO 2016086144 A1	02-06-2016
WO 2017146766 A1	31-08-2017	NONE	