



- (51) International Patent Classification:
H04W 24/10 (2009.01) *H04W 88/02* (2009.01)
H04W 88/08 (2009.01)
- (21) International Application Number:
PCT/CN2016/077515
- (22) International Filing Date:
28 March 2016 (28.03.2016)
- (25) Filing Language: English
- (26) Publication Language: English
- (71) Applicant: INTEL IP CORPORATION [US/US]; 2200 Mission College Boulevard, M/S: RNB-4-150, Santa Clara, California 95054 (US).
- (72) Inventors; and
- (71) Applicants (for US only): ZHANG, Yushu [CN/CN]; 8F, Raycom Info Park A, No. 2 Kexueyuan South Road, Haidian District, Beijing 100190 (CN). ZHU, Yuan [CN/CN]; Room 605, Building 16, Mo Li Yuan, Bei Yuan Jia Yuan, Chao Yang District, Beijing 100012 (CN). NIU, Huaning [CN/US]; 1308 Knollview Dr, Milpitas, California 95035 (US). XIONG, Gang Gary [CN/US]; 16682 NW Arizona Dr, Beaverton, Oregon 97006 (US). LI, Qinghua [CN/US]; 5117 Chiltern Lane, San Ramon, California 94582 (US).
- (74) Agent: SHANGHAI PATENT & TRADEMARK LAW OFFICE, LLC; 435 Guiping Road, Shanghai 200233 (CN).
- (81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.
- (84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).
- Published:
— with international search report (Art. 21(3))

(54) Title: APPARATUS AND METHOD FOR CONTROL SIGNALING OF CSI-RS

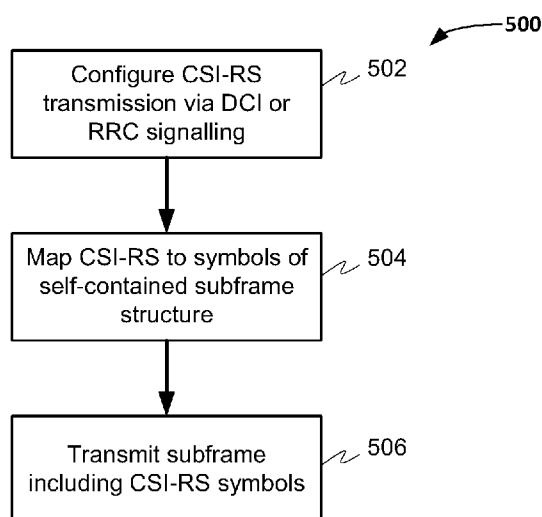


Fig. 5

(57) Abstract: There are provided methods and apparatus for controlling signaling of channel state information reference signals in a wireless communication system, including an apparatus for use in an eNB in a wireless communication network, the apparatus comprising control circuitry to generate first channel state information reference signals (CSI-RS), and map the generated CSI-RS as symbols of a self-contained subframe structure, and transmit circuitry coupled to the control circuitry, the transmit circuitry to transmit the mapped CSI-RS symbols.

APPARATUS AND METHOD FOR CONTROL SIGNALING OF CSI-RS

TECHNICAL FIELD

Embodiments described herein generally relate to the field of wireless communications and, more particularly, to methods and apparatus for signaling of reference signals

5 BACKGROUND

It is becoming more important to be able to provide telecommunication services to fixed and mobile subscribers as efficient and inexpensively as possible. Further, the increased use of mobile applications has resulted in much focus on developing wireless systems capable of delivering large amounts of data at high speed.

10 It has been proposed to use a wide range of frequency bands, including millimeter wave frequencies to achieve wider bandwidths and facilitate increased user throughput. Further, future networks are expected to handle a much broader range of traffic types including device-to-device, relaying, etc. as well as traditional voice and data services. Thus, traffic may be expected to be varied and bursty in nature and current
15 implementations may not efficiently support the proposed frequencies and traffic profiles.

BRIEF DESCRIPTION OF THE DRAWING.

Aspects, features and advantages of embodiments of the present invention will become apparent from the following description of the invention in reference to the appended
20 drawings in which like numerals denote like elements and in which:

Fig. 1 is diagram of an example wireless network according to various embodiments;

Fig. 2a illustrates a Type 1 self-contained subframe structure;

Fig. 2b illustrates a Type 2 self-contained subframe structure;

Fig. 3a and 3b illustrate Type 1 self-contained subframe structures according to
25 embodiments;

Fig. 4a and 4b illustrate Type 2 self-contained subframe structures according to embodiments;

Fig. 5 illustrates a method performed by an eNB according to embodiments;

Fig. 6 illustrates a method performed by a User Equipment (UE) according to some
30 embodiments;

Fig. 7 is a block diagram of an example system operable to implement some embodiments; and

Fig. 8 is a block diagram of an example User Equipment device operable to implement some embodiments.

5 DETAILED DESCRIPTION OF EMBODIMENTS

Various aspects of the illustrative embodiments will be described using terms commonly employed by those skilled in the art to convey the substance of their work to others skilled in the art. However, it will be apparent to those skilled in the art that some alternate embodiments may be practiced using with portions of the described aspects.

10 For purposes of explanation, specific numbers, materials, and configurations are set forth in order to provide a thorough understanding of the illustrative embodiments. However, it will be apparent to one skilled in the art that alternate embodiments may be practiced without the specific details. In other instances, well-known features are omitted or simplified in order to not obscure the illustrative embodiments.

15 Further, various operations will be described as multiple discrete operations, in turn, in a manner that is most helpful in understanding the illustrative embodiments; however, the order of description should not be construed as to imply that these operations are necessarily order dependent. In particular, these operations need not be performed in the order of presentation.

20 The phrase “in one embodiment” is used repeatedly. The phrase generally does not refer to the same embodiment; however, it may. The terms “comprising,” “having,” and “including” are synonymous, unless the context dictates otherwise. The phrase “A/B” means “A or B”. The phrase “A and/or B” means “(A), (B), or (A and B)”. The phrase “at least one of A, B and C” means “(A), (B), (C), (A and B), (A and C), (B and C) or (A, B and C)”. The phrase “(A) B” means “(B) or (A B)”, that is, A is optional.

Although specific embodiments have been illustrated and described herein, it will be appreciated by those of ordinary skill in the art that a wide variety of alternate and/or equivalent implementations may be substituted for the specific embodiments shown and described, without departing from the scope of the embodiments of the present
30 disclosure. This application is intended to cover any adaptations or variations of the embodiments discussed herein. Therefore, it is manifestly intended that the embodiments of the present disclosure be limited only by the claims and the equivalents thereof.

As used herein, the term “module” may refer to, be part of, or include an Application
35 Specific Integrated Circuit (ASIC), an electronic circuit, a processor (shared, dedicated, or group) and/or memory (shared, dedicated, or group) that execute one or more software

or firmware instructions and/or programs, a combinational logic circuit, and/or other suitable components that provide the described functionality.

The following inventive embodiments may be used in a variety of applications including transmitters and receivers of a radio system, although the present invention is not limited in this respect. Radio systems specifically included within the scope of the present invention include, but are not limited to, network interface cards (NICs), network adaptors, fixed or mobile client devices, relays, base stations, femtocells, gateways, bridges, hubs, routers, access points, or other network devices. Further, the radio systems within the scope of the invention may be implemented in cellular radiotelephone systems, satellite systems, two-way radio systems as well as computing devices including such radio systems including personal computers (PCs), tablets and related peripherals, personal digital assistants (PDAs), personal computing accessories, hand-held communication devices and all systems which may be related in nature and to which the principles of the inventive embodiments could be suitably applied.

Figure 1 schematically illustrates the wireless communication network 100 in accordance with various embodiments. Wireless communication network 100 (hereinafter “network 100”) may be an access network of a 3rd Generation Partnership Project (3GPP) long-term evolution (LTE), long-term evolution-advanced (LTE-A) network such as an evolved universal mobile telecommunication system (UMTS) terrestrial radio access network (E-UTRAN) or 5G network.

The network 100 may include a base station, e.g., evolved node base station (eNB) 102, configured to wirelessly communicate with one or more mobile device(s) or terminal(s), e.g., user equipment (UE) 104. In various embodiments, the eNB 102 may be a fixed station (e.g., a fixed node) or a mobile station/node.

The eNB 104 may include receiver circuitry 120 with which to receive signals from UE 104 via one or more antennas 130. eNB 104 may include transmitter circuitry 124 with which to transmit signals to UE 104 via one or more antennas 130. eNB 104 may also include controller circuitry 128 in communication with receiver module 120 and transmitter module 124 and configured to encode and decode information communicated by the signals. Controller module 128 also includes CSI-RS configuration circuitry 126 to facilitate generation and mapping CSI-RS messages in the network 100.

In various embodiments, the control circuitry 128 may be comprised in a separate device from the receiver circuitry 120 and/or the transmitter circuitry 124. For example, the eNB 104 may be implemented as part of a cloud-RAN (C-RAN).

In various embodiments, the UE 104 and/or the eNB 102 may include a plurality of antennas 156, 130 to implement a multiple-input-multiple-output (MIMO) transmission

system, which may operate in a variety of MIMO modes, including single-user MIMO (SU-MIMO), multi-user MIMO (MU-MIMO), close loop MIMO, open loop MIMO or variations of smart antenna processing.

In various embodiments, UE 104 comprises transmitter circuitry 148 for transmitting signals to eNB 102 and receiver circuitry 144 for receiving signals from the eNB 102. UE 104 further comprises controller circuitry 152 coupled between receiver circuitry 144 and transmitter circuitry 148 and including communication circuitry 154 to encode and decode information communicated by the signals. Controller circuitry 152 may also include CSI reporting circuitry 158 to facilitate measurement and reporting of channel state information by the UE 104.

Example embodiments provide systems, apparatuses, and methods for control signaling of CSI-RS in millimeter wave (mmW) systems.

Use of millimeter wave (mmW) frequencies has been proposed for use in 5G networks to achieve wider available bandwidth such that the user data throughput may be increased. To facilitate efficient operation at mmW frequencies and to better match the expected traffic profile of 5G networks, a new subframe structure, such as self-contained subframe structure shown in Figure 1, may be used for such a wideband system. In introducing this new subframe structure backward compatibility with current wireless standards may be broken. However, this provides an opportunity for a new physical layer signal design.

In order to increase spectral efficiency in wireless networks, 5G networks may implement spatial multiplexing using multiple input multiple output (MIMO) techniques. In particular, Full Dimension MIMO (FD-MIMO) or Massive MIMO has been proposed.

In support of the new physical layer signal design, a new Channel State Information Reference Signal (CSI-RS) may need to be designed to support downlink Transmission (Tx) beams measurement and selection in this new frame structure, by which the massive MIMO can be applied.

Figures 2a/2b illustrates a self-contained subframe structure that may be used. In particular, Figure 2a illustrates a Type 1 subframe 210 including a physical downlink control channel (PDCCH) 212 and a physical downlink shared channel (PDSCH) 214 from a eNB 102 to a UE 104 and acknowledgements (ACK) 218 of data transmitted in the PDSCH 214 from the UE to the eNB. A guard gap 216 is provided between the PDSCH 214 and the ACK regions 218 to avoid interference.

Figure 2b illustrates a Type 2 subframe 220 including a physical downlink control channel (PDCCH) 212 from the eNB 102 to the UE 104, a physical uplink shared channel (PUSCH) 224 from the UE to the eNB and acknowledgements (ACK) 218 of data transmitted in the

PUSCH 224 from the eNB 102 to the UE 104. In the Type 2 subframe 220 guard gaps 222, 216 are provided between the PDCCH 212 and the PUSCH 224 and between the PUSCH 224 and the ACK regions 218 to avoid interference.

Further an Omni-directional antenna may be used in both eNodeB 102 and UE 104. Thus, the Tx beamforming and Receiving (Rx) beamforming may be used in the downlink. CSI-RS may be used to measure one or more of the Tx beams and search the best receive (Rx) beams. However, how such control signaling for the CSI-RS to support the Tx and Rx beamforming is to be supported in the new frame structure 210, 220 of Figures 2a/2b remains undefined.

10 CSI-RS Signal Generation

The base sequence used for the CSI-RS may be generated based on a cell ID and a number of subframes in a Quadrature Phase Shift Keying (QPSK) waveform or Zadoff-Chu sequence to achieve symmetric design for CSI-RS and a Sounding Reference Signal (SRS).

To support the analog beamforming, the CSI-RS may be mapped into more than one symbol within different Tx beams. Furthermore, each Tx beam may be applied in more than one Antenna Ports (APs). To facilitate measurement of a greater number of Tx beams in one subframe, more symbols and APs may be used for the CSI-RS.

For both type 1 and type 2 subframe structures 210, 220 shown in Figures 2a and 2b, which may illustrate an example for a self-contained subframe structure, the CSI-RS may be mapped to different symbols.

In embodiments, for the type 1 subframe structure 310, the CSI-RS may be mapped to a first position 312 between the PDCCH 212 and PDSCH 214 area, as illustrated in Figure 3a, so that the CSI-RS may act as a gap for PDCCH decoding processing in the case that the Rx beams for PDSCH rely on the information in downlink assignment transmitted in the PDCCH.

Alternatively, the CSI-RS may be mapped to a second position 322 after the PDSCH, in a Type 1 subframe 320 as illustrated in Figure 3b.

For the type 2 structure, the CSI-RS may be mapped to the symbols after the PDCCH and before the ACK. Figures 4a and 4b illustrate Type 2 subframe structures 410, 420 including the CSI-RS. According to the arrangement shown in Figure 4a, the CSI-RS may be mapped to a first position 412 to symbols between the PDCCH 212 and a gap region 222 before the PUSCH 224 in the subframe 410. Alternatively, the CSI-RS may be mapped to a second position 422 to symbols between a gap region 216 after the PUSCH 224 and the ACK region 218 of the Type 2 subframe 420, as illustrated in Figure 4b.

In embodiments, the CSI-RS may be mapped to either of the illustrated positions in the Type 1 or Type 2 subframes. In some embodiments, both positions may be used simultaneously.

5 In embodiments, the CSI-RS may be mapped to the first position 412 for a Type 2 subframe 410 as illustrated in Figure 4a, between the PDCCH 212 and first GAP region 222, while the SRS may be mapped to symbols in the second position 422 between the gap region 216 after the PUSCH 224 and the ACK region 218 of the Type 2 subframe.

Control Signaling for CSI-RS

10 As there may only be one opportunity for downlink transmission in the self-contained subframe, the CSI-RS may be transmitted periodically. The period and subframe offset for each CSI-RS process may be configured via RRC signaling. Thus, the symbols allocated for CSI-RS transmission may not be required for that purpose in every subframe.

15 In embodiments, for a subframe that does not include a CSI-RS transmission, the symbols reserved for CSI-RS may be considered as a gap and no data will be mapped to these symbols.

In embodiments, the first position for the CSI-RS in Type 1 and Type 2 subframes may be used for periodical CSI reporting by a UE 104. The number of symbols and APs for this CSI-RS allocation may be fixed in the system or configured via master information block (MIB), system information block (SIB) or RRC signaling.

20 In the case that the capacity of the PDCCH (i.e. number of symbols allocated to the PDCCH) is variable in the system, the UE 104 may first need to determine the number of symbols used for the PDCCH to identify a starting symbol index for the CSI-RS allocation to be used for CSI reporting.

25 In embodiments, the CSI reporting may be in an aperiodical mode. For example, the second position for CSI-RS in Type 1 and Type 2 Subframe may be used for aperiodical CSI reporting.

30 In embodiments, the aperiodical CSI reporting may be triggered in response to a downlink control information, e.g. a downlink assignment, which may include CSI-RS trigger information. A 2-bit field may be used in the downlink assignment to trigger CSI measurement and the indication for this trigger may be listed in Table 1 as an example. Alternatively the information in Table 1 may be configured for each CSI process, and the downlink assignment may contain a CSI process indicator, where value 0 may indicate there is no CSI-RS and a value x, where x is not equal to 0, may indicate a configuration associated with a CSI process x-1 is to be used for the aperiodical CSI reporting.

35

2-bit CSI-RS Trigger	Indication
0	Two CSI-RS symbols measured with different Rx beams
1	Two CSI-RS symbols measured with the same Rx beam
2	Three CSI-RS symbols with symbol 0 for one Rx beam, symbol 1 and symbol 2 for a dual-peak Rx beam
3	No CSI-RS symbols

Table 1: CSI-RS Trigger Indication

In embodiments, the aperiodical CSI transmission may be triggered using the semi-persistent scheduling (SPS) mechanism using downlink control signaling. The SPS configuration may be predefined in the RRC signaling and may contain information such as: a number of OFDM symbols per subframe for CSI-RS; CSI-RS OFDM positions (either after the PDCCH, first position, or after PDSCH/PUSCH, second position); a CSI-RS transmission period and offset; whether interference averaging is allowed among IMRs of the same OFDM symbol across all or subsets of subframes scheduled by one SPS scheduling. The scheduled aperiodical CSI transmission may be stopped by a corresponding SPS-release.

In embodiments, for UEs without a PDSCH transmission in a particular subframe, the aperiodical CSI reporting may be triggered by provision of a downlink assignment for CSI measurement only on the PDCCH, which may include the CSI process index only or the information as below:

- Group index for Tx beams in CSI-RS symbol 0
- Group index for Tx beams in CSI-RS symbol 1
- ...
- Group index for Tx beams in CSI-RS symbol N-1

The Tx beams may be divided into several groups according to their correlation, which may be configured by RRC signaling. N indicates the maximum number of aperiodical CSI-RS, which may be configured by RRC signaling or fixed in the system. The Group index 0 may indicate no CSI-RS is applied in this symbol. Then the UE may measure the Tx beam groups with a corresponding Rx beam. One special case may be defined as one group that only contains one Tx beam. The Tx beam index may be used by the UE to derive the corresponding Rx beam which are searched from the Tx beam including the reference signal.

In embodiments, for another type of subframe structure, cross-subframe scheduling can be used for triggering the aperiodical CSI. For example, for a subframe k containing the CSI-RS, the aperiodical CSI may be scheduled in subframe $k+g$, where g may be fixed in the system or configured via RRC signaling or downlink assignment for CSI reporting.

5 Figure 5 illustrates a method 500 performed by an eNB 102 according to some embodiments. According to the illustrated method, the eNB 102 first configures 502 a CSI-RS transmission using downlink control information (DCI) or RRC signaling in accordance with the above described techniques. The eNB 102 then generate 504 CSI-RS and map the generated CSI-RS to symbols of the self-contained subframe structure based
10 on the configuration for the CSI-RS. The eNB 102 then transmits 506 the subframe including the CSI-RS symbols to one or more UEs 104.

Figure 6 illustrates a method 600 performed at UE 104 according to some embodiments. According to the illustrated method, the UE 104 receives 602 CSI-RS configuration information in the form of DCI or RRC signaling. Based on the received CSI-RS
15 configuration, the UE 104 is then able to receive and measure CSI-RS symbols in a subframe received by the UE 104 from an eNB 102. The UE 104 then reports 606 channel state information corresponding to the measured CSI-RS in accordance with the received configuration information in line with the above described techniques.

Embodiments of the technology herein may be described as related to the third
20 generation partnership project (3GPP) long term evolution (LTE) or LTE-advanced (LTE-A) standards. For example, terms or entities such as eNodeB (eNB), mobility management entity (MME), user equipment (UE), etc. may be used that may be viewed as LTE-related terms or entities. However, in other embodiments the technology may be used in or related to other wireless technologies such as the Institute of Electrical and Electronic
25 Engineers (IEEE) 802.16 wireless technology (WiMax), IEEE 802.11 wireless technology (WiFi), various other wireless technologies such as global system for mobile communications (GSM), enhanced data rates for GSM evolution (EDGE), GSM EDGE radio access network (GERAN), universal mobile telecommunications system (UMTS), UMTS terrestrial radio access network (UTRAN), or other 2G, 3G, 4G, 5G, etc. technologies
30 either already developed or to be developed. In those embodiments, where LTE-related terms such as eNB, MME, UE, etc. are used, one or more entities or components may be used that may be considered to be equivalent or approximately equivalent to one or more of the LTE-based terms or entities.

As used herein, the term "circuitry" may refer to, be part of, or include an Application
35 Specific Integrated Circuit (ASIC), an electronic circuit, a processor (shared, dedicated, or group), and/or memory (shared, dedicated, or group) that execute one or more software or firmware programs, a combinational logic circuit, and/or other suitable hardware components that provide the described functionality. In some embodiments, the circuitry

may be implemented in, or functions associated with the circuitry may be implemented by, one or more software or firmware modules. In some embodiments, circuitry may include logic, at least partially operable in hardware.

Embodiments described herein may be implemented into a system using any suitably configured hardware and/or software. Figure 7 illustrates, for one embodiment, example components of an electronic device 700. In embodiments, the electronic device 700 may be, implement, be incorporated into, or otherwise be a part of a user equipment (UE), an evolved NodeB (eNB), or any other suitable electronic device. In some embodiments, the electronic device 700 may include application circuitry 702, baseband circuitry 704, Radio Frequency (RF) circuitry 706, front-end module (FEM) circuitry 708 and one or more antennas 710, coupled together at least as shown.

The application circuitry 702 may include one or more application processors. For example, the application circuitry 702 may include circuitry such as, but not limited to, one or more single-core or multi-core processors. The processor(s) may include any combination of general-purpose processors and dedicated processors (e.g., graphics processors, application processors, etc.). The processors may be coupled with and/or may include memory/storage and may be configured to execute instructions stored in the memory/storage to enable various applications and/or operating systems to run on the system.

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

Viterbi, and/or Low Density Parity Check (LDPC) encoder/decoder functionality. Embodiments of modulation/demodulation and encoder/decoder functionality are not limited to these examples and may include other suitable functionality in other embodiments.

- 5 In some embodiments, the baseband circuitry 704 may include elements of a protocol stack such as, for example, elements of an evolved universal terrestrial radio access network (EUTRAN) protocol including, for example, physical (PHY), media access control (MAC), radio link control (RLC), packet data convergence protocol (PDCP), and/or radio resource control (RRC) elements. A central processing unit (CPU) 704e of the baseband
- 10 circuitry 704 may be configured to run elements of the protocol stack for signaling of the PHY, MAC, RLC, PDCP and/or RRC layers. In some embodiments, the baseband circuitry may include one or more audio digital signal processor(s) (DSP) 704f. The audio DSP(s) 704f may include elements for compression/decompression and echo cancellation and may include other suitable processing elements in other embodiments.
- 15 The baseband circuitry 704 may further include memory/storage 704g. The memory/storage 704g may be used to load and store data and/or instructions for operations performed by the processors of the baseband circuitry 704. Memory/storage for one embodiment may include any combination of suitable volatile memory and/or non-volatile memory. The memory/storage 704g may include any combination of various
- 20 levels of memory/storage including, but not limited to, read-only memory (ROM) having embedded software instructions (e.g., firmware), random access memory (e.g., dynamic random access memory (DRAM)), cache, buffers, etc. The memory/storage 704g may be shared among the various processors or dedicated to particular processors.

- Components of the baseband circuitry may be suitably combined in a single chip, a single
- 25 chipset, or disposed on a same circuit board in some embodiments. In some embodiments, some or all of the constituent components of the baseband circuitry 704 and the application circuitry 702 may be implemented together such as, for example, on a system on a chip (SOC).

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

RF circuitry 706 may enable communication with wireless networks using modulated electromagnetic radiation through a non-solid medium. In various embodiments, the RF circuitry 706 may include switches, filters, amplifiers, etc. to facilitate the communication with the wireless network. RF circuitry 706 may include a receive signal path which may include circuitry to down-convert RF signals received from the FEM circuitry 708 and provide baseband signals to the baseband circuitry 704. RF circuitry 706 may also include a transmit signal path which may include circuitry to up-convert baseband signals provided by the baseband circuitry 704 and provide RF output signals to the FEM circuitry 708 for transmission.

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

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

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

direct downconversion and/or direct upconversion, respectively. In some embodiments, the mixer circuitry 706a of the receive signal path and the mixer circuitry 706a of the transmit signal path may be configured for super-heterodyne operation.

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

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

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

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

25 In some embodiments, frequency input may be provided by a voltage controlled oscillator (VCO), although that is not a requirement. Divider control input may be provided by either the baseband circuitry 704 or the applications processor 702 depending on the desired output frequency. In some embodiments, a divider control input (e.g., N) may be determined from a look-up table based on a channel indicated by the applications processor 702.

30 Synthesizer circuitry 706d of the RF circuitry 706 may include a divider, a delay-locked loop (DLL), a multiplexer and a phase accumulator. In some embodiments, the divider may be a dual modulus divider (DMD) and the phase accumulator may be a digital phase accumulator (DPA). In some embodiments, the DMD may be configured to divide the input signal by either N or N+1 (e.g., based on a carry out) to provide a fractional division ratio. In some example embodiments, the DLL may include a set of cascaded, tunable, delay elements, a phase detector, a charge pump and a D-type flip-flop. In these
35 embodiments, the delay elements may be configured to break a VCO period up into Nd

equal packets of phase, where N_d is the number of delay elements in the delay line. In this way, the DLL provides negative feedback to help ensure that the total delay through the delay line is one VCO cycle.

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

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

In some embodiments, the FEM circuitry 708 may include a TX/RX switch to switch between transmit mode and receive mode operation. The FEM circuitry may include a receive signal path and a transmit signal path. The receive signal path of the FEM circuitry may include a low-noise amplifier (LNA) to amplify received RF signals and provide the amplified received RF signals as an output (e.g., to the RF circuitry 706). The transmit signal path of the FEM circuitry 708 may include a power amplifier (PA) to amplify input RF signals (e.g., provided by RF circuitry 706), and one or more filters to generate RF signals for subsequent transmission (e.g., by one or more of the one or more antennas 610).

In some embodiments, the electronic device 700 may include additional elements such as, for example, memory/storage, display, camera, sensor, and/or input/output (I/O) interface.

In some embodiments, the electronic device 700 of Figure 7 may be configured to perform one or more processes, techniques, and/or methods as described herein, or portions thereof. Such processes may include one or more of the following examples.

Figure 8 shows an embodiment in which the electronic device 700 implements a UE 104 in the specific form of a mobile device 800.

In various embodiments, user interfaces could include, but are not limited to, a display 840 (e.g., a liquid crystal display, a touch screen display, etc.), a speaker 830, a

microphone 890, one or more cameras 880 (e.g., a still camera and/or a video camera), a flashlight (e.g., a light emitting diode flash), and a keyboard 870.

In various embodiments, the peripheral component interfaces may include, but are not limited to, a non-volatile memory port, an audio jack, and a power supply interface.

- 5 In various embodiments, the sensors may include, but are not limited to, a gyro sensor, an accelerometer, a proximity sensor, an ambient light sensor, and a positioning unit. The positioning unit may also be part of, or interact with, a network interface to communicate with components of a positioning network, e.g., a global positioning system (GPS) satellite.
- 10 In various embodiments, the electronic device 700 may be a mobile computing device such as, but not limited to, a laptop computing device, a tablet computing device, a netbook, a mobile phone, etc. In various embodiments, system 800 may have more or less components, and/or different architectures.

- In embodiments, the implemented wireless network may be a 3rd Generation Partnership Project's long term evolution (LTE) advanced wireless communication standard, which may include, but is not limited to releases 8, 9, 10, 11, 12, 13, and 14 or later, of the 3GPP's LTE-A or 5G standards.
- 15

- Although certain embodiments have been illustrated and described herein for purposes of description, a wide variety of alternate and/or equivalent embodiments or implementations calculated to achieve the same purposes may be substituted for the embodiments shown and described without departing from the scope of the present disclosure. This application is intended to cover any adaptations or variations of the embodiments discussed herein. Therefore, it is manifestly intended that embodiments described herein be limited only by the claims and the equivalents thereof.
- 20

25 **EXAMPLES**

Example 1 may include a system configures the Channel State Information Reference Signal (CSI-RS) transmission in the eNodeB side and the self-contained subframe structure, which may contain two types of subframes: type 1 subframe for downlink data transmission and type 2 subframe for uplink data transmission.

- 30 Example 2 may include the method of example 1, the CSI-RS may be mapped to the symbols after Physical Downlink Control Channel (PDCCH) or Physical Downlink Shared Channel (PDSCH) for the type 1 subframe.

Example 3 may include the method of example 1, the CSI-RS may be mapped to the symbols after PDCCH or before the acknowledge (ACK) for the type 2 subframe.

Example 4 may include the method of example 1, the CSI-RS in symbols after PDCCH may be used for periodical CSI reporting and the CSI-RS before the ACK or after the PDSCH may be used for aperiodical CSI reporting.

5 Example 5 may include the method of example 4, the number of symbols for the periodical CSI-RS may be configured by the RRC signaling or fixed in the system.

Example 6 may include the method of example 4, if the UE is not configured to measure the CSI-RS in one subframe, this area may be considered as a gap.

Example 7 may include the method of example 4, the aperiodical CSI reporting may be triggered by the Downlink Control Information (DCI).

10 Example 8 may include the method of example 7, a 2-bit CSI trigger may be added into the DCI, and its value may indicate the beam pattern of the CSI-RS and value 3 may indicate there is no aperiodical CSI-RS in this subframe.

Example 9 may include the method of example 7, the transmission beam group for each CSI-RS symbols may be configured in the DCI for periodical CSI reporting.

15 Example 10 may include the method of example 4, the semi-persistent scheduling (SPS) may be used for the periodical CSI reporting and the interference averaging may be configured by the Intel Confidential DCI.

20 Example 11 may include the method of example 4, the aperiodical CSI reporting may be pre-scheduled in the other type of subframe structures, and the subframe offset between the control signaling and the CSI-RS subframe may be fixed in the system or configured by the RRC signaling or indicated by the DCI.

25 Example 12 may include an apparatus for use in an eNB in a wireless communication network, the apparatus comprising control circuitry to generate first channel state information reference signals (CSI-RS), and map the generated CSI-RS as symbols of a self-contained subframe structure, and transmit circuitry coupled to the control circuitry, the transmit circuitry to transmit the mapped CSI-RS symbols.

30 Example 13 may include the apparatus of example 12, the control circuitry further to map the first CSI-RS to symbols between a physical downlink control channel (PDCCH) and a physical downlink shared channel (PDSCH) in a type 1 self-contained subframe structure.

Example 14 may include the apparatus of example 12, the control circuitry further to map the first CSI-RS to symbols between a physical downlink shared channel (PDSCH) and acknowledgement (ACK) symbols in a type 1 self-contained subframe structure.

Example 15 may include the apparatus of example 12, the control circuitry further to map the first CSI-RS to at least one of: symbols between a physical downlink control channel (PDCCH) and a gap region prior to a physical uplink shared channel (PUSCH) in a type 2 self-contained subframe structure; and a gap region after the PUSCH and acknowledgement (ACK) symbols in a type 2 self-contained subframe structure.

Example 16 may include the apparatus of example 13, the control circuitry further to allocate symbols of a subframe reserved for the CSI-RS for CSI reporting when no CSI-RS is to be transmitted.

Example 17 may include the apparatus of example 13, the control circuitry further to generate second CSI-RS and to map the second CSI-RS to symbols between a physical downlink shared channel (PDSCH) and acknowledgement (ACK) symbols in a type 1 self-contained subframe structure.

Example 18 may include the apparatus of example 16, wherein the symbols reserved for the first CSI-RS are to provide periodical CSI reporting and the symbols reserved for the second CSI-RS are to provide aperiodical CSI reporting in a subframe when no CSI-RS is to be transmitted.

Example 19 may include the apparatus of any of examples 11 to 18, wherein the generated CSI-RS is mapped as a first number of symbols of the self-contained subframe structure, the first number of symbols comprising one of: a predetermined number of symbols; or a number of symbols configured using radio resource control (RRC) signaling.

Example 20 may include the apparatus of example 17, the control circuitry further to generate downlink control information (DCI) including an indication to initiate aperiodical CSI reporting.

Example 21 may include the apparatus of example 20, wherein the DCI comprises a CSI trigger value, the CSI trigger value indicating a beam pattern of the CSI-RS.

Example 22 may include the apparatus of example 21, wherein the CSI trigger value comprises a plurality of bits.

Example 23 may include the apparatus of example 21 or example 22, wherein the CSI trigger value comprises a predetermined value to indicate that no aperiodical CSI-RS is present in the current subframe.

Example 24 may include the apparatus of example 18, the control circuitry to generate downlink control information comprising an indication of a transmission beam group associated with each CSI-RS symbol in the current subframe to be used for periodical CSI reporting.

Example 25 may include the apparatus of example 18, the control circuitry to generate downlink control information comprising an indication of a semi-persistent scheduling grant to be used for periodical CSI reporting.

5 Example 26 may include the apparatus of example 25, wherein the DCI further comprises an indication that interference averaging is to be applied to the CSI-RS symbols.

Example 27 may include the apparatus of example 18, the control circuitry further to generate downlink control information (DCI) including an indication of at least one resource block to be used for aperiodical CSI reporting in a second subframe later than a first subframe in which the DCI is transmitted.

10 Example 28 may include the apparatus of example 27, wherein a subframe offset comprising a number of subframes between the first subframe and the second subframe comprises one of: a predetermined value, a value indicated by radio resource control signaling; and a value indicated in the DCI.

15 Example 29 may include an apparatus for use in a user equipment (UE) in a wireless communication network, the apparatus comprising receive circuitry to receive an indication of a channel state information reference signal (CSI-RS) configuration, and receive a first CSI-RS based on the received indication, wherein the first CSI-RS is mapped as symbols of a self-contained subframe structure, and control circuitry to determine channel state information based on the received CSI-RS symbols.

20 Example 30 may include the apparatus of example 29, wherein the indication of CSI-RS configuration comprises one of: downlink control information (DCI); or radio resource control (RRC) signaling.

25 Example 31 may include the apparatus of example 29 or example 30, wherein the first CSI-RS is mapped to at least one of: symbols between a physical downlink control channel (PDCCH) and a physical downlink shared channel (PDSCH) in a type 1 self-contained subframe structure; and symbols between a physical downlink shared channel (PDSCH) and acknowledgement (ACK) symbols in a type 1 self-contained subframe structure.

30 Example 32 may include the apparatus of example 29 or example 30, wherein the first CSI-RS is mapped to at least one of: symbols between a physical downlink control channel (PDCCH) and a gap region prior to a physical uplink shared channel (PUSCH) in a type 2 self-contained subframe structure; and a gap region after the PUSCH and acknowledgement (ACK) symbols in a type 2 self-contained subframe structure.

35 Example 33 may include the apparatus of example 29 or example 30, wherein the received CSI-RS configuration comprises an indication that no CSI-RS is present in the

allocated symbols of a subframe and the control circuitry to consider the allocated symbols as a gap region in response to the indication that no CSI-RS is present.

5 Example 34 may include the apparatus of example 29 or example 30, wherein the received CSI-RS configuration comprises an indication of symbols of a subframe reserved for the CSI-RS to be allocated for CSI reporting when no CSI-RS is to be transmitted, the apparatus further comprising transmit circuitry to transmit a CSI report in the allocated symbols of the subframe.

10 Example 35 may include the apparatus of example 29, wherein the received CSI-RS configuration comprises an indication of first CSI-RS mapped to symbols between a physical downlink control channel (PDCCH) and a physical downlink shared channel (PDSCH) in a type 1 self-contained subframe structure and second CSI-RS mapped to symbols between a physical downlink shared channel (PDSCH) and acknowledgement (ACK) symbols in a type 1 self-contained subframe structure.

15 Example 36 may include the apparatus of example 35, wherein the received CSI-RS configuration comprises an indication that the symbols reserved for the first CSI-RS are to provide periodical CSI reporting and the symbols reserved for the second CSI-RS are to provide aperiodical CSI reporting in a subframe when no CSI-RS is to be transmitted.

20 Example 37 may include the apparatus of example 29 or example 30 wherein the CSI-RS is mapped as a first number of symbols of the self-contained subframe structure, the first number of symbols comprising one of: a predetermined number of symbols; or a number of symbols configured using radio resource control (RRC) signaling.

Example 38 may include the apparatus of example 36, the receive circuitry to receive downlink control information (DCI) comprising an indication to initiate aperiodical CSI reporting.

25 Example 39 may include the apparatus of example 38, wherein the DCI comprises a CSI trigger value, the CSI trigger value indicating a beam pattern of the CSI-RS.

Example 40 may include the apparatus of example 39, wherein the CSI trigger value comprises a plurality of bits.

30 Example 41 may include the apparatus of example 39 or example 40, wherein the CSI trigger value comprises a predetermined value to indicate that no aperiodical CSI-RS is present in the current subframe.

Example 42 may include the apparatus of example 36, the receive circuitry to receive downlink control information (DCI) comprising an indication of a transmission beam

group associated with each CSI-RS symbol in the current subframe to be used for periodical CSI reporting.

5 Example 43 may include the apparatus of example 36, the receive circuitry to receive downlink control information (DCI) comprising an indication of a semi-persistent scheduling grant to be used for periodical CSI reporting.

Example 44 may include the apparatus of example 43, wherein the DCI further comprises an indication that interference averaging is to be applied to the CSI-RS symbols.

10 Example 45 may include the apparatus of example 36, the receive circuitry to receive downlink control information (DCI) comprising an indication of at least one resource block to be used for aperiodical CSI reporting in a second subframe later than a first subframe in which the DCI is transmitted.

15 Example 46 may include the apparatus of example 45, wherein a subframe offset comprising a number of subframes between the first subframe and the second subframe comprises one of: a predetermined value, a value indicated by radio resource control signaling; and a value indicated in the DCI.

Example 47 may include a computer program product comprising computer program code that when executed implements the steps of generating first channel state information reference signals (CSI-RS), mapping the generated CSI-RS as symbols of a self-contained subframe structure, and transmitting the mapped CSI-RS symbols.

20 Example 48 may include a computer program product comprising computer program code that when executed implements the steps of receiving an indication of a channel state information reference signal (CSI-RS) configuration, receiving a first CSI-RS based on the received indication, wherein the first CSI-RS is mapped as symbols of a self-contained subframe structure, and determining channel state information based on the
25 received CSI-RS symbols.

Example 49 may include a user equipment (UE) comprising the apparatus of any of examples 19 to 46, the UE further comprising at least one of a display; a keyboard; and a touchscreen.

30 Example 50 may include an apparatus for use in an eNB in a wireless communication network, the apparatus comprising control circuitry to generate first channel state information reference signals (CSI-RS), map the generated CSI-RS as symbols of a self-contained subframe structure, and cause the mapped CSI-RS symbols to be transmitted.

Example 51 may include an apparatus for use in a user equipment (UE) in a wireless communication network, the apparatus comprising control circuitry to obtain an

indication of a channel state information reference signal (CSI-RS) configuration, obtain a first CSI-RS based on the obtained indication, wherein the first CSI-RS is mapped as symbols of a self-contained subframe structure, and determine channel state information based on the obtained CSI-RS symbols.

CLAIMS

1. An apparatus for use in an eNB in a wireless communication network, the apparatus comprising:
control circuitry to:
- 5 generate first channel state information reference signals (CSI-RS); and
map the generated CSI-RS as symbols of a self-contained subframe structure; and
transmit circuitry coupled to the control circuitry, the transmit circuitry to transmit the mapped CSI-RS symbols.
- 10 2. The apparatus of claim 1, the control circuitry further to map the first CSI-RS to symbols between a physical downlink control channel (PDCCH) and a physical downlink shared channel (PDSCH) in a type 1 self-contained subframe structure.
3. The apparatus of claim 1, the control circuitry further to map the first CSI-RS to symbols between a physical downlink shared channel (PDSCH) and acknowledgement
15 (ACK) symbols in a type 1 self-contained subframe structure.
- 4 The apparatus of claim 1, the control circuitry further to map the first CSI-RS to at least one of: symbols between a physical downlink control channel (PDCCH) and a gap region prior to a physical uplink shared channel (PUSCH) in a type 2 self-contained subframe structure; and a gap region after the PUSCH and acknowledgement (ACK)
20 symbols in a type 2 self-contained subframe structure.
5. The apparatus of claim 2, the control circuitry further to allocate symbols of a subframe reserved for the CSI-RS for CSI reporting when no CSI-RS is to be transmitted.
6. The apparatus of claim 2, the control circuitry further to generate second CSI-RS and to map the second CSI-RS to symbols between a physical downlink shared channel
25 (PDSCH) and acknowledgement (ACK) symbols in a type 1 self-contained subframe structure.

7. The apparatus of claim 5, wherein the symbols reserved for the first CSI-RS are to provide periodical CSI reporting and the symbols reserved for the second CSI-RS are to provide aperiodical CSI reporting in a subframe when no CSI-RS is to be transmitted.

8. The apparatus of any preceding claim, wherein the generated CSI-RS is mapped as
5 a first number of symbols of the self-contained subframe structure, the first number of symbols comprising one of: a predetermined number of symbols; or a number of symbols configured using radio resource control (RRC) signaling.

9. The apparatus of claim 6, the control circuitry further to generate downlink control information (DCI) including an indication to initiate aperiodical CSI reporting.

10 10. The apparatus of claim 9, wherein the DCI comprises a CSI trigger value, the CSI trigger value indicating a beam pattern of the CSI-RS.

11. The apparatus of claim 7, the control circuitry to generate downlink control information comprising an indication of a transmission beam group associated with each CSI-RS symbol in the current subframe to be used for periodical CSI reporting.

15 12. The apparatus of claim 7, the control circuitry to generate downlink control information comprising an indication of a semi-persistent scheduling grant to be used for periodical CSI reporting.

13. The apparatus of claim 7, the control circuitry further to generate downlink control information (DCI) including an indication of at least one resource block to be used
20 for aperiodical CSI reporting in a second subframe later than a first subframe in which the DCI is transmitted.

14. An apparatus for use in a user equipment (UE) in a wireless communication network, the apparatus comprising:

receive circuitry to:

25 receive an indication of a channel state information reference signal (CSI-RS) configuration; and

receive a first CSI-RS based on the received indication, wherein the first CSI-RS is mapped as symbols of a self-contained subframe structure; and

control circuitry to determine channel state information based on the received CSI-RS symbols.

15. The apparatus of claim 14, wherein the indication of CSI-RS configuration comprises one of: downlink control information (DCI); or radio resource control (RRC) signaling.

16. The apparatus of claim 14 or claim 15, wherein the first CSI-RS is mapped to at least one of: symbols between a physical downlink control channel (PDCCH) and a physical downlink shared channel (PDSCH) in a type 1 self-contained subframe structure; and symbols between a physical downlink shared channel (PDSCH) and acknowledgement (ACK) symbols in a type 1 self-contained subframe structure.

17. The apparatus of claim 14 or claim 15, wherein the first CSI-RS is mapped to at least one of: symbols between a physical downlink control channel (PDCCH) and a gap region prior to a physical uplink shared channel (PUSCH) in a type 2 self-contained subframe structure; and a gap region after the PUSCH and acknowledgement (ACK) symbols in a type 2 self-contained subframe structure.

18. The apparatus of claim 14 or claim 15, wherein the received CSI-RS configuration comprises an indication that no CSI-RS is present in the allocated symbols of a subframe and the control circuitry to consider the allocated symbols as a gap region in response to the indication that no CSI-RS is present.

19. The apparatus of claim 14 or claim 15, wherein the received CSI-RS configuration comprises an indication of symbols of a subframe reserved for the CSI-RS to be allocated for CSI reporting when no CSI-RS is to be transmitted, the apparatus further comprising transmit circuitry to transmit a CSI report in the allocated symbols of the subframe.

20. The apparatus of claim 14, wherein the received CSI-RS configuration comprises an indication of first CSI-RS mapped to symbols between a physical downlink control channel (PDCCH) and a physical downlink shared channel (PDSCH) in a type 1 self-contained subframe structure and second CSI-RS mapped to symbols between a physical

downlink shared channel (PDSCH) and acknowledgement (ACK) symbols in a type 1 self-contained subframe structure.

21. The apparatus of claim 20, wherein the received CSI-RS configuration comprises an indication that the symbols reserved for the first CSI-RS are to provide periodical CSI reporting and the symbols reserved for the second CSI-RS are to provide aperiodical CSI reporting in a subframe when no CSI-RS is to be transmitted.

22. The apparatus of claim 14 or claim 15 wherein the CSI-RS is mapped as a first number of symbols of the self-contained subframe structure, the first number of symbols comprising one of: a predetermined number of symbols; or a number of symbols configured using radio resource control (RRC) signaling.

23. A computer program product comprising computer program code that when executed implements the steps of:

generating first channel state information reference signals (CSI-RS);

mapping the generated CSI-RS as symbols of a self-contained subframe structure;

and

transmitting the mapped CSI-RS symbols.

24. A computer program product comprising computer program code that when executed implements the steps of:

receiving an indication of a channel state information reference signal (CSI-RS)

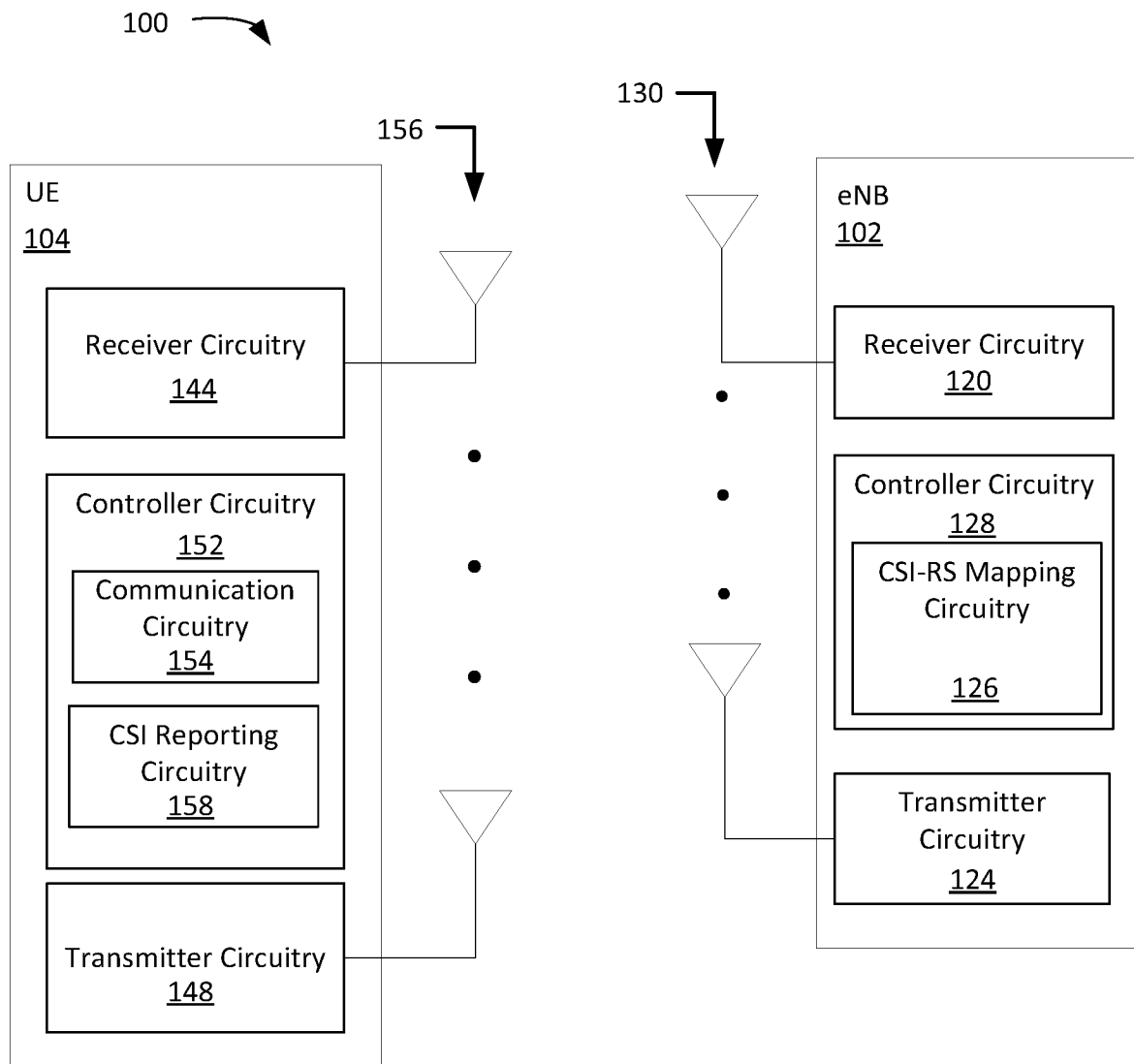
configuration;

receiving a first CSI-RS based on the received indication, wherein the first CSI-RS is mapped as symbols of a self-contained subframe structure; and

determining channel state information based on the received CSI-RS symbols.

25. A user equipment (UE) comprising the apparatus of any of claims 14 to 22, the UE

further comprising at least one of a display; a keyboard; and a touchscreen.

**Fig. 1**

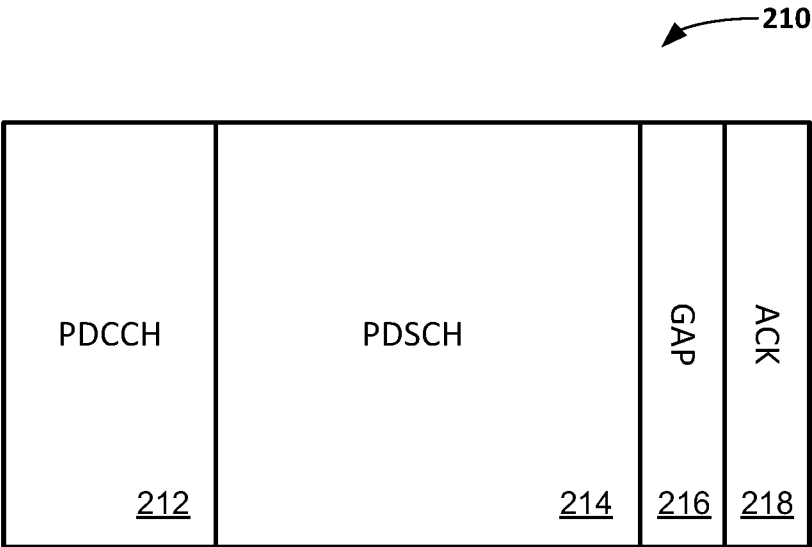


Fig. 2a

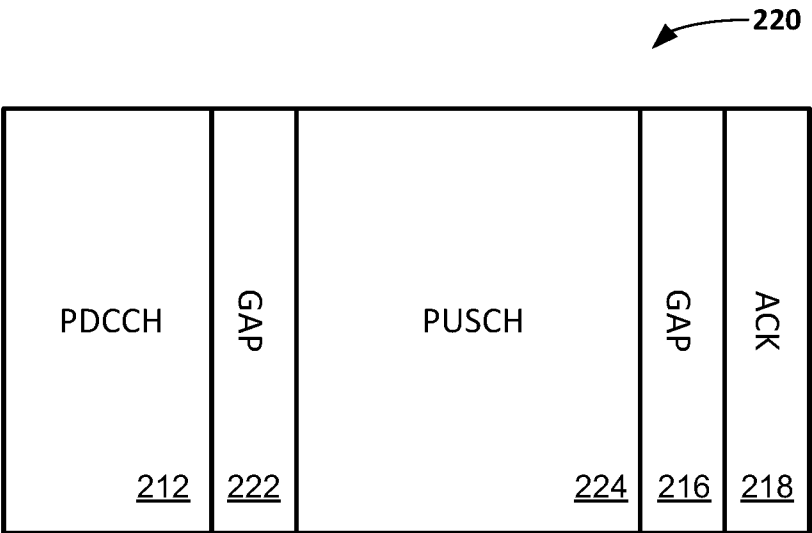


Fig. 2b

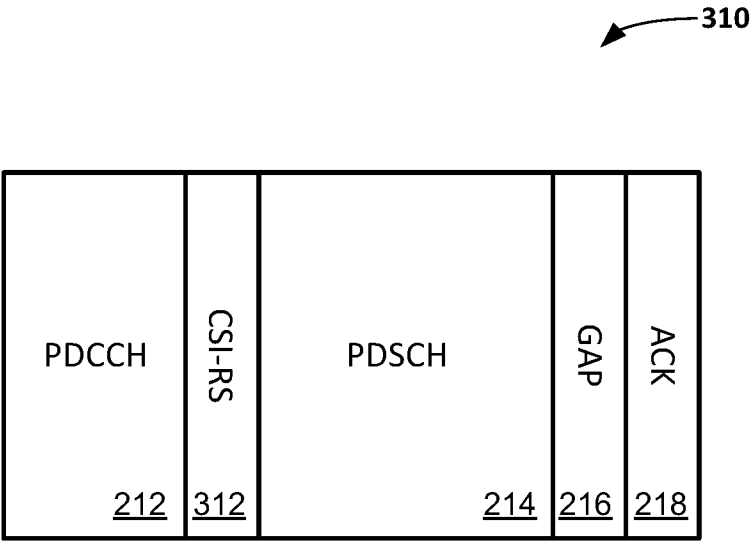


Fig. 3a

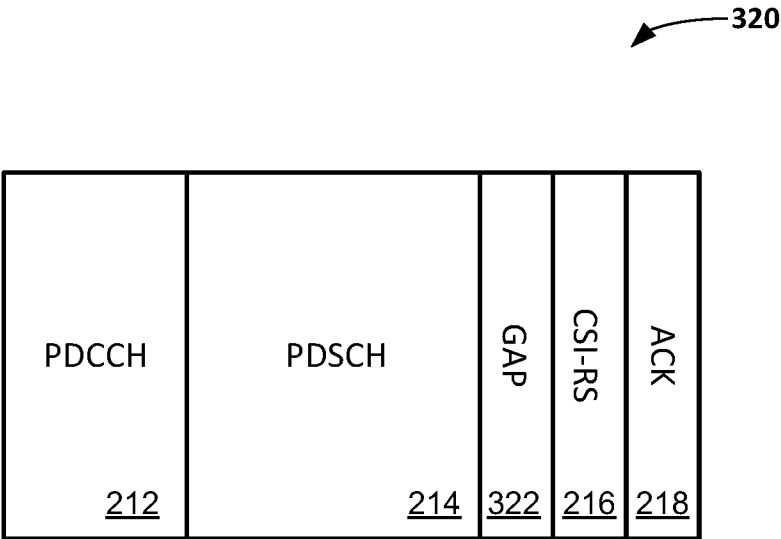


Fig. 3b

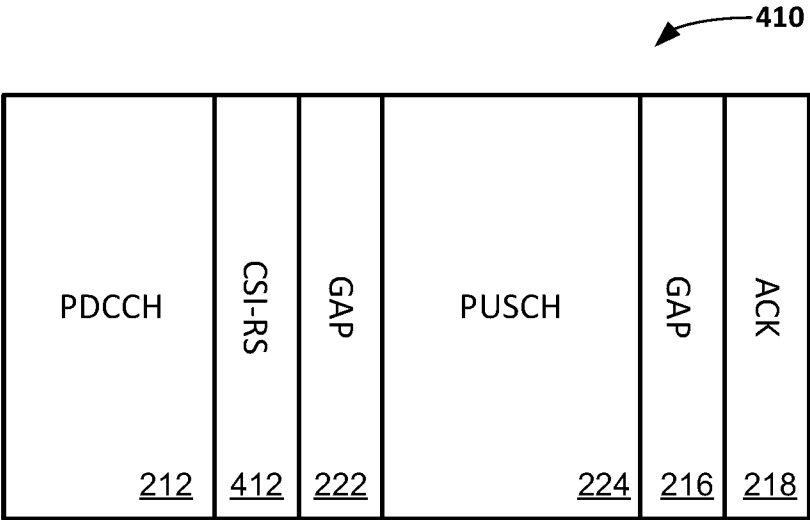


Fig. 4a

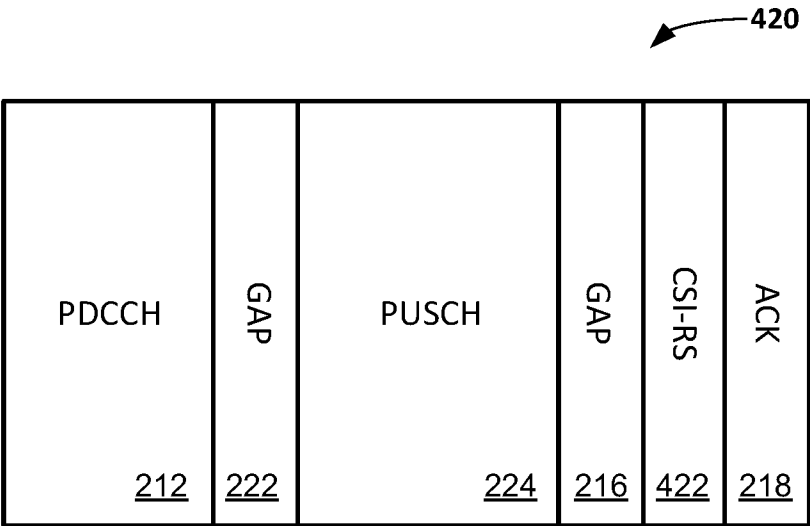
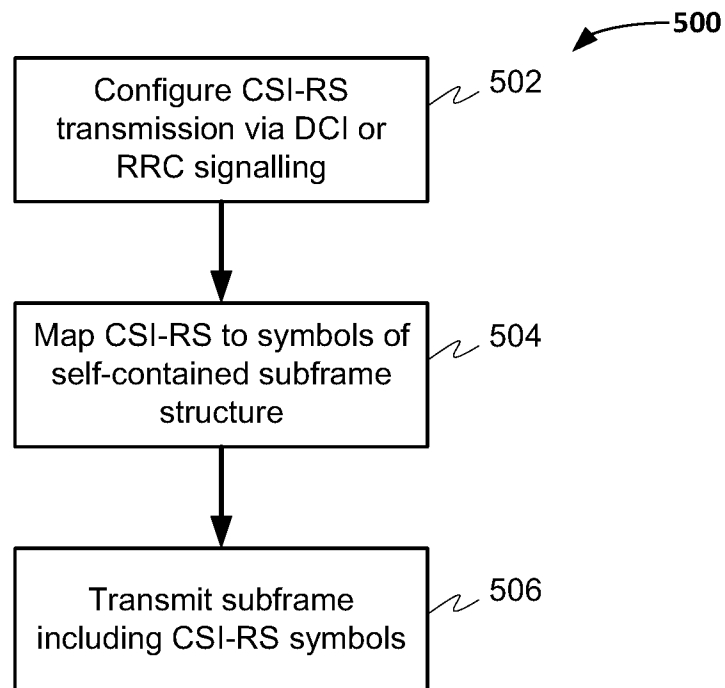
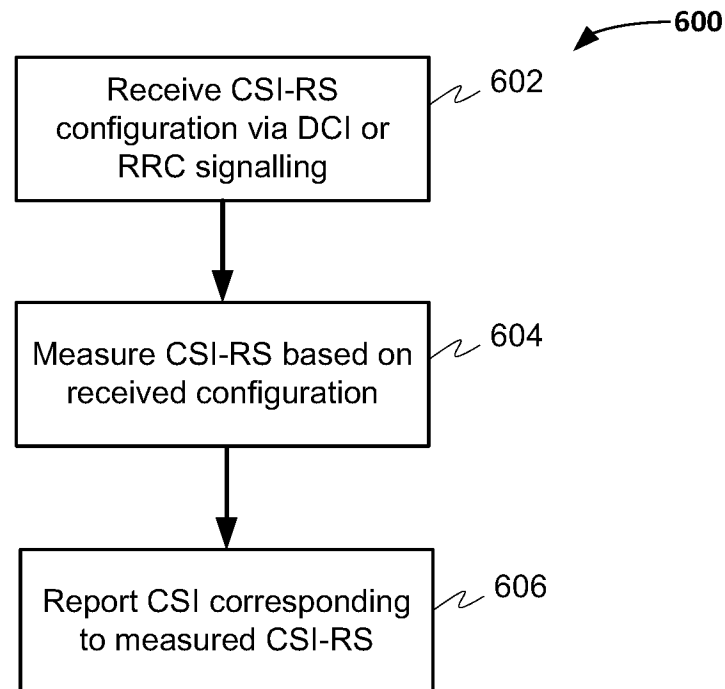


Fig. 4b

5/7

**Fig. 5****Fig. 6**

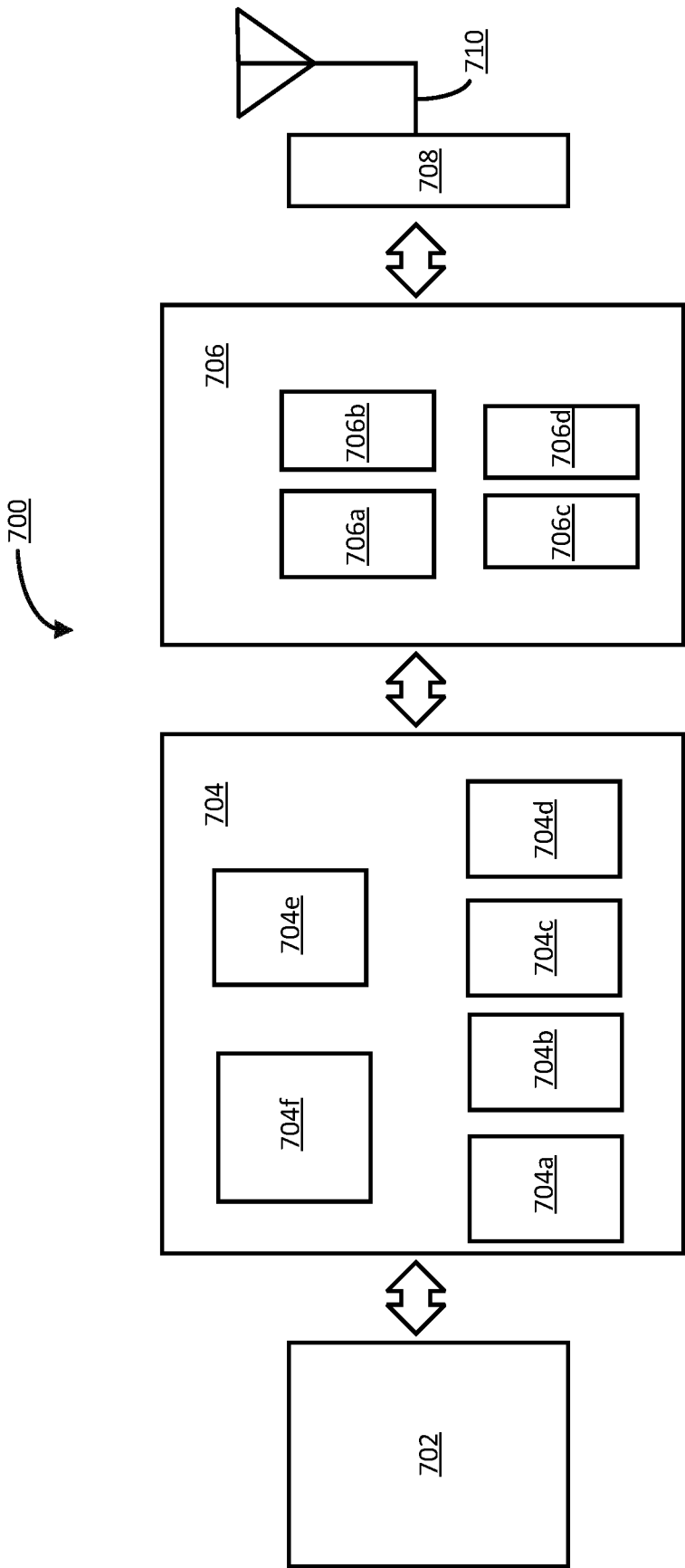
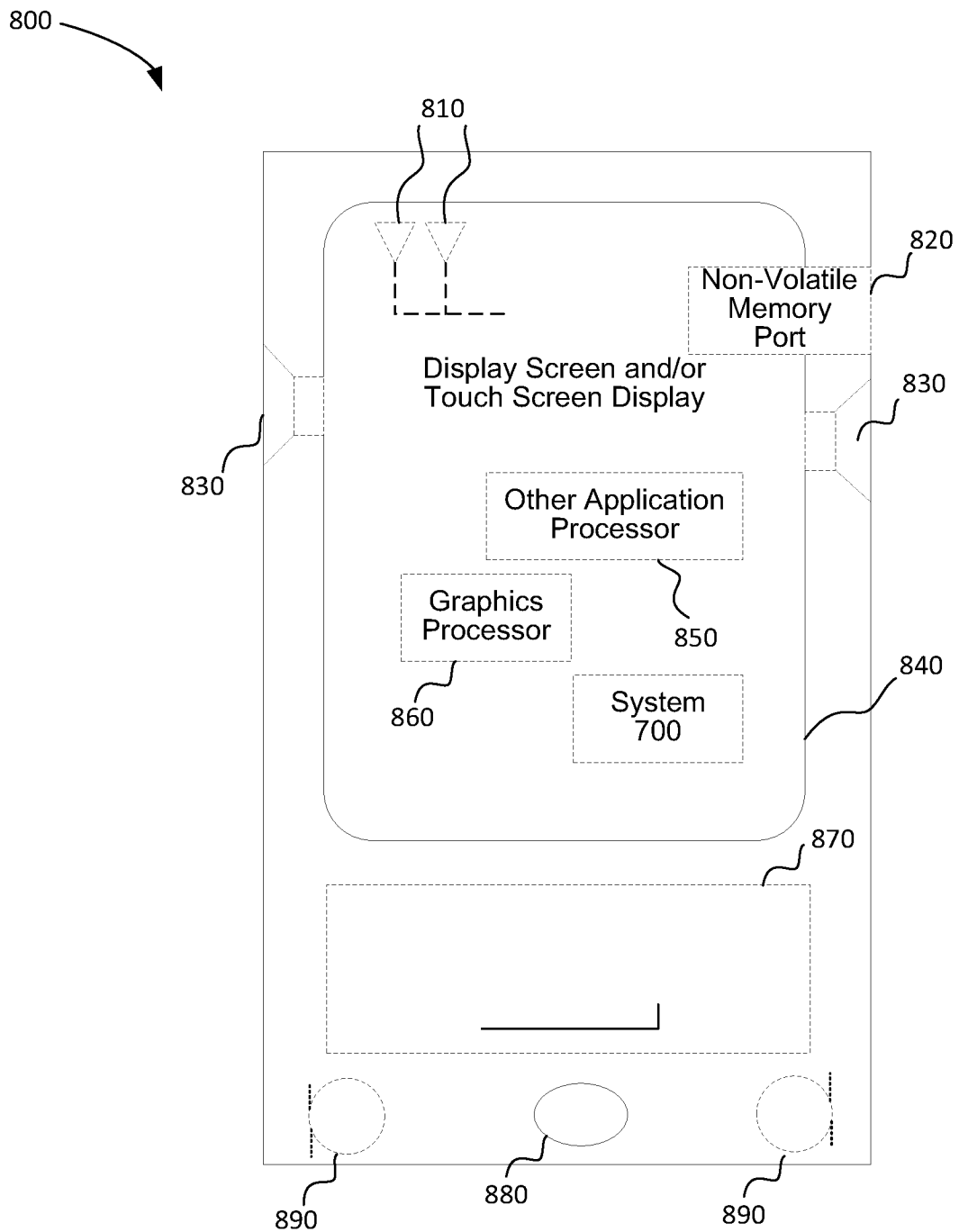


Fig. 7

**Fig. 8**

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2016/077515

A. CLASSIFICATION OF SUBJECT MATTER

H04W 24/10(2009.01)i; H04W 88/08(2009.01)i; H04W 88/02(2009.01)i

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)

H04W; H04L

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)

CNABS, CNTXT, CNKI, VEN: csi-rs, csi, channel state information, reference signal, reference symbol, pilot, self-contained, +frame?, pdcch, pdsch, pusch, ack, gap

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 2015045696 A1 (NTT DOCOMO INC.) 02 April 2015 (2015-04-02) description paragraphs [0051] to [0064], and figures 6 and 7	1-25
A	US 2011200137 A1 (SAMSUNG ELECTRONICS CO., LTD.) 18 August 2011 (2011-08-18) the whole document	1-25
A	WO 2014116061 A1 (SAMSUNG ELECTRONICS CO., LTD.) 31 July 2014 (2014-07-31) the whole document	1-25
A	WO 2015012653 A1 (LG ELECTRONICS INC.) 29 January 2015 (2015-01-29) the whole document	1-25

☐ Further documents are listed in the continuation of Box C.☒ See patent family annex.

* Special categories of cited documents:

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

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

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

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

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

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

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

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

“&” document member of the same patent family

Date of the actual completion of the international search

20 September 2016

Date of mailing of the international search report

03 January 2017

Name and mailing address of the ISA/CN

STATE INTELLECTUAL PROPERTY OFFICE OF THE
P.R.CHINA
6, Xitucheng Rd., Jimen Bridge, Haidian District, Beijing
100088
China

Authorized officer

YU, Yannong

Facsimile No. (86-10)62019451

Telephone No. (86-10)62089153

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

PCT/CN2016/077515

Patent document cited in search report			Publication date (day/month/year)	Patent family member(s)			Publication date (day/month/year)
WO	2015045696	A1	02 April 2015	EP	3051904	A1	03 August 2016
				CN	105580468	A	11 May 2016
				JP	2015070335	A	13 April 2015
US	2011200137	A1	18 August 2011	KR	20110095060	A	24 August 2011
				US	9059826	B2	16 June 2015
				KR	101587458	B1	22 January 2016
WO	2014116061	A1	31 July 2014	CN	103973391	A	06 August 2014
				US	2015365925	A1	17 December 2015
WO	2015012653	A1	29 January 2015	US	2016182208	A1	23 June 2016
				CN	105340316	A	17 February 2016