



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

(21) International Application Number:
PCT/CN2024/085195

(22) International Filing Date:
01 April 2024 (01.04.2024)

(25) Filing Language: English

(26) Publication Language: English

(71) Applicant: **LENOVO (BEIJING) LIMITED** [CN/CN]; 6 Shangdi West Road, Haidian District, Beijing 100085 (CN).

(72) Inventors: **LIU, Bingchao**; Lenovo HQ East, Building No. 1, No. 10 Xibeiwang East Road, Haidian District, Beijing 100094 (CN). **ZHU, Chenxi**; Lenovo HQ East, Building No. 1, No. 10 Xibeiwang East Road, Haidian District, Beijing 100094 (CN). **ZHANG, Yi**; Lenovo HQ East, Building No. 1, No. 10 Xibeiwang East Road, Haidian District, Beijing 100094 (CN). **LING, Wei**; Lenovo HQ East, Building

No. 1, No. 10 Xibeiwang East Road, Haidian District, Beijing 100094 (CN).

(74) Agent: **KING & WOOD MALLESONS**; 20th Floor, East Tower, World Financial Centre, No. 1 Dongsanhuan Zhonglu, Chaoyang District, Beijing 100020 (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, CV, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IQ, IR, IS, IT, JM, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, MG, MK, MN, MU, 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, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, WS, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, CV,

(54) Title: CSI REPORT FOR MULTI-TRP CALIBRATION

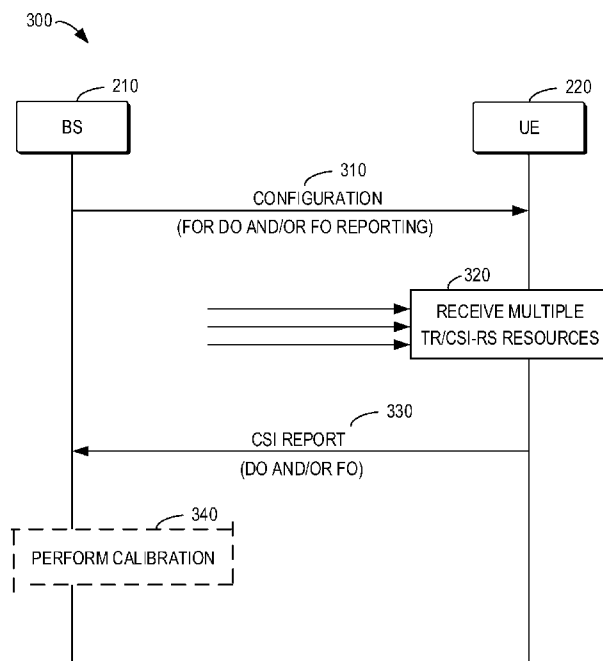


FIG. 3

(57) Abstract: Example embodiments of the present disclosure relate to user equipment, a base station, methods, apparatuses, and computer readable medium for CSI report for multi-TRP calibration. In the solution, a UE may receive a configuration for phase offset report for reciprocity calibration, the configuration may include a CMR and associated SRS resource. The UE transmits a CSI report including a DL phase offset, and transmits SRS resource to TRPs for UL phase offset estimation. As such, a calibration based on the CSI report may be further performed accordingly. In this way, a synchronization among multiple TRPs may be achieved and a CJT may be guaranteed.

GH, GM, KE, LR, LS, MW, MZ, NA, RW, SC, 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, ME, 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))*
- *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))*
- *upon request of the applicant, before the expiration of the time limit referred to in Article 21(2)(a)*

CSI REPORT FOR MULTI-TRP CALIBRATION

TECHNICAL FIELD

[0001] The present disclosure relates to wireless communications, and more specifically to a user equipment (UE), a base station (BS), methods, apparatuses, and computer readable medium for channel state information (CSI) report for multiple transmission and reception points (multi-TRP) calibration.

BACKGROUND

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

[0003] The coherent joint transmission (CJT) offers downlink spectral efficiency and coverage gain. In release 18 (Rel-18) of 3rd Generation Partnership Project (3GPP), Type-II CSI has been enhanced to accommodate CJT assuming ideal synchronization and backhaul. Scenarios such as inter-site CJT and a base station equipped with distributed remote radio heads (RRHs) require additional delay and phase/frequency calibration. Although basic principles for inter-TRP delay offset, timing offset and phase offset estimation has been agreed, some details should be further studied.

SUMMARY

[0004] The present disclosure relates to a UE, a BS, methods, apparatuses, processors, and

computer readable medium for CSI report for multi-TRP calibration. According to the proposed solution, a CSI report may be transmitted from the UE to the BS, where the CSI report may indicate at least one of a phase offset, a delay offset, or a frequency offset, accordingly the multi-TRP calibration can be further made.

5 [0005] In some implementations, there is provided a UE. The UE comprises at least one memory; and at least one processor coupled with the at least one memory and configured to cause the UE to: receive, from a first base station, a configuration of a phase offset report for reciprocity calibration, wherein the configuration indicates a channel measurement resource (CMR) and associated sounding reference signal (SRS) resource, and wherein the CMR
10 comprises a resource set for a plurality of channel state information (CSI) reference signal (RS) resources; determine, based on the configuration, a downlink (DL) phase offset between the first base station and a second base station upon a reception of a first CSI-RS resource from the first base station and a second CSI-RS resource from the second base station; transmit, to each of the first base station and the second base station, a CSI report comprising
15 the DL phase offset; and transmit, to each of the first base station and the second base station, at least one SRS resource based on the configuration.

[0006] In some implementations, there is provided a base station. The base station comprises at least one memory; and at least one processor coupled with the at least one memory and configured to cause the base station to: transmit, to a UE, a configuration of a
20 phase offset report for reciprocity calibration, wherein the configuration indicates a CMR and associated SRS resource, and wherein the CMR comprises a resource set for a plurality of CSI-RS resources; receive, from the UE, a CSI report comprising a DL phase offset between the base station and a second base station; determine an uplink (UL) phase offset based on at least one SRS resource from the UE and an SRS resource from the UE to the second base
25 station; and determine a reciprocity calibration factor based on the DL phase offset and the UL phase offset.

[0007] In some implementations, there is provided a UE. The UE comprises at least one memory; and at least one processor coupled with the at least one memory and configured to cause the UE to: receive, from a base station, a configuration of a joint delay offset and
30 frequency offset report, wherein the configuration indicates a CMR which comprises a resource set for a plurality of tracking reference signal (TRS) or CSI-RS resources; receive, from a plurality of transmission reception points (TRP), the plurality of TRS or CSI-RS resources respectively based on the configuration; and transmit, to the base station, a CSI

report comprising at least one of a delay offset or a frequency offset for the plurality of TRPs.

[0008] In some implementations, there is provided a base station. The base station comprises at least one memory; and at least one processor coupled with the at least one memory and configured to cause the base station to: transmit, to a UE, a configuration of a joint delay offset and frequency offset report, wherein the configuration indicates a CMR which comprises a resource set for a plurality of TRS or CSI-RS resources; and receive, from the UE, a CSI report comprising at least one of a delay offset or a frequency offset for the plurality of TRPs.

[0009] In some implementations, there is provided a method performed by the UE. The method comprises: receiving, from a first base station, a configuration of a phase offset report for reciprocity calibration, wherein the configuration indicates a CMR and associated SRS resource, and wherein the CMR comprises a resource set for a plurality of CSI-RS resources; determining, based on the configuration, a DL phase offset between the first base station and a second base station upon a reception of a first CSI-RS resource from the first base station and a second CSI-RS resource from the second base station; transmitting, to each of the first base station and the second base station, a CSI report comprising the DL phase offset; and transmitting, to each of the first base station and the second base station, at least one SRS resource based on the configuration.

[0010] In some implementations, there is provided a method performed by the base station. The method comprises: transmitting, to a UE, a configuration of a phase offset report for reciprocity calibration, wherein the configuration indicates a CMR and associated SRS resource, and wherein the CMR comprises a resource set for a plurality of CSI-RS resources; receiving, from the UE, a CSI report comprising a DL phase offset between the base station and a second base station; determining a UL phase offset based on at least one SRS resource from the UE and an SRS resource from the UE to the second base station; and determining a reciprocity calibration factor based on the DL phase offset and the UL phase offset.

[0011] In some implementations, there is provided a method performed by the UE. The method comprises: receiving, from a base station, a configuration of a joint delay offset and frequency offset report, wherein the configuration indicates a CMR which comprises a resource set for a plurality of TRS or CSI-RS resources; receiving, from a plurality of TRPs, the plurality of TRS or CSI-RS resources respectively based on the configuration; and transmitting, to the base station, a CSI report comprising at least one of a delay offset or a

frequency offset for the plurality of TRPs.

[0012] In some implementations, there is provided a method performed by the base station. The method comprises: transmitting, to a UE, a configuration of a joint delay offset and frequency offset report, wherein the configuration indicates a CMR which comprises a resource set for a plurality of TRS or CSI-RS resources; and receiving, from the UE, a CSI report comprising at least one of a delay offset or a frequency offset for the plurality of TRPs.

[0013] In some implementations, there is provided a processor for wireless communication. The processor comprises at least one controller coupled with at least one memory and configured to cause the processor to: receive, from a first base station, a configuration of a phase offset report for reciprocity calibration, wherein the configuration indicates a CMR and associated SRS resource, and wherein the CMR comprises a resource set for a plurality of CSI-RS resources; determine, based on the configuration, a DL phase offset between the first base station and a second base station upon a reception of a first CSI-RS resource from the first base station and a second CSI-RS resource from the second base station; transmit, to each of the first base station and the second base station, a CSI report comprising the DL phase offset; and transmit, to each of the first base station and the second base station, at least one SRS resource based on the configuration.

[0014] In some implementations, there is provided a processor for wireless communication. The processor comprises at least one controller coupled with at least one memory and configured to cause the processor to: transmit, to a UE, a configuration of a phase offset report for reciprocity calibration, wherein the configuration indicates a CMR and associated SRS resource, and wherein the CMR comprises a resource set for a plurality of CSI-RS resources; receive, from the UE, a CSI report comprising a DL phase offset between the base station and a second base station; determine a UL phase offset based on at least one SRS resource from the UE and an SRS resource from the UE to the second base station; and determine a reciprocity calibration factor based on the DL phase offset and the UL phase offset.

[0015] In some implementations, there is provided a processor for wireless communication. The processor comprises at least one controller coupled with at least one memory and configured to cause the processor to: receive, from a base station, a configuration of a joint delay offset and frequency offset report, wherein the configuration indicates a CMR which comprises a resource set for a plurality of TRS or CSI-RS resources; receive, from a plurality

of TRPs, the plurality of TRS or CSI-RS resources respectively based on the configuration; and transmit, to the base station, a CSI report comprising at least one of a delay offset or a frequency offset for the plurality of TRPs.

[0016] In some implementations, there is provided a processor for wireless communication.

5 The processor comprises at least one controller coupled with at least one memory and configured to cause the processor to: transmit, to a UE, a configuration of a joint delay offset and frequency offset report, wherein the configuration indicates a CMR which comprises a resource set for a plurality of TRS or CSI-RS resources; and receive, from the UE, a CSI report comprising at least one of a delay offset or a frequency offset for the plurality of TRPs.

10 **[0017]** In some implementations of the methods and the BS described herein, further comprising: receiving, from the UE, at least one SRS resource based on the configuration, wherein an antenna port that is used for transmitting the at least one SRS resource at the UE is same as that used for receiving a first CSI-RS resource at the UE.

15 **[0018]** In some implementations of the methods, the UE, and the BS described herein, an antenna port used for transmitting the at least one SRS resource is same as that used for receiving the first CSI-RS resource and the second CSI-RS resource.

[0019] In some implementations of the methods, the UE, and the BS described herein, a transmission of the at least one SRS resource is in a same slot with a reception of the first CSI-RS resource and the second CSI-RS resource.

20 **[0020]** In some implementations of the methods, the UE, and the BS described herein, the transmission of the at least one SRS resource is after multiple symbols from the reception of a last symbol of the first CSI-RS resource and the second CSI-RS resource in the same slot.

25 **[0021]** In some implementations of the methods, the UE, and the BS described herein, a transmission of the at least one SRS resource is in a same slot with a reception of downlink control information (DCI) or after multiple slots from the reception of the DCI, wherein the DCI is used to trigger a transmission of the first CSI-RS resource or the second CSI-RS resource.

30 **[0022]** In some implementations of the methods, the UE, and the BS described herein, a time gap from a reception of a last symbol of the first CSI-RS resource and the second CSI-RS resource to a transmission of a first symbol of the at least one SRS resource is larger than a threshold.

[0023] In some implementations of the methods, the UE, and the BS described herein, the time gap is predefined or is determined based on a capability of the UE.

[0024] In some implementations of the methods, the UE, and the BS described herein, each of the plurality of CSI-RS resources is quasi co-located (QCLed) with a tracking reference signal (TRS) with a QCL parameter of delay spread and/or Doppler spread.

[0025] In some implementations of the methods, the UE, and the BS described herein, each of the plurality of TRS or CSI-RS resources is transmitted for multiple times in multiple adjacent slots.

[0026] In some implementations of the methods, the UE, and the BS described herein, a first slot in the multiple adjacent slots is determined based on a triggering offset configured for the resource set.

[0027] In some implementations of the methods, the UE, and the BS described herein, the plurality of TRS or CSI-RS resources for a time among the multiple times are transmitted in a same slot.

[0028] In some implementations of the methods, the UE, and the BS described herein, the plurality of TRS or CSI-RS resources are transmitted in a plurality of adjacent slots respectively.

[0029] In some implementations of the methods, the UE, and the BS described herein, one of the plurality of TRS or CSI-RS resources is transmitted for multiple times in multiple symbols of a same slot.

[0030] In some implementations of the methods, the UE, and the BS described herein, each of the plurality of TRS or CSI-RS resources is transmitted for multiple times in multiple symbols of a specific slot.

[0031] In some implementations of the methods, the UE, and the BS described herein, the plurality of TRS or CSI-RS resources comprise multiple groups of TRS or CSI-RS resources, the multiple groups of TRS or CSI-RS resources are transmitted in multiple adjacent slots respectively.

[0032] In some implementations of the methods, the UE, and the BS described herein, the CSI report comprises a frequency offset, and wherein each of the plurality of TRS or CSI-RS resources is QCLed with a synchronization signal block (SSB) or a further TRS with a QCL parameter of Doppler shift and/or Doppler spread.

[0033] In some implementations of the methods, the UE, and the BS described herein, the CSI report comprises a delay offset, and wherein each of the plurality of TRS or CSI-RS resources is QCLed with an SSB or a further TRS with a QCL parameter of average delay and/or delay spread.

5 [0034] In some implementations of the methods, the UE, and the BS described herein, the CSI report comprises both delay and frequency offsets, and wherein each of the plurality of TRS or CSI-RS resources is QCLed with an SSB or a further TRS with a QCL parameter of at least one of: Doppler shift, Doppler spread, average delay, or delay spread.

[0035] In some implementations of the methods, the UE, and the BS described herein, a
10 number of CSI processing units (CPU) used for the CSI report is determined based on a number of the plurality of TRPs and a parameter associated with a capability of the UE.

BRIEF DESCRIPTION OF THE DRAWINGS

[0036] FIG. 1 illustrates an example of a wireless communications system in which some embodiments of the present disclosure can be implemented;

15 [0037] FIG. 2 illustrates a schematic diagram of an example communication network in which some embodiments of the present disclosure can be implemented;

[0038] FIG. 3 illustrates a signalling chart illustrating communication process in accordance with some example embodiments of the present disclosure;

[0039] FIG. 4 illustrates a signalling chart illustrating communication process in accordance
20 with some example embodiments of the present disclosure;

[0040] FIG. 5 illustrates an example of a device that is suitable for implementing embodiments of the present disclosure;

[0041] FIG. 6 illustrates an example of a processor that is suitable for implementing some embodiments of the present disclosure;

25 [0042] FIG. 7 illustrates a flowchart of an example method implemented at a UE in accordance with aspects of the present disclosure;

[0043] FIG. 8 illustrates a flowchart of an example method implemented at a BS in accordance with aspects of the present disclosure;

[0044] FIG. 9 illustrates a flowchart of an example method implemented at a UE in
30 accordance with aspects of the present disclosure; and

[0045] FIG. 10 illustrates a flowchart of an example method implemented at a BS in accordance with aspects of the present disclosure.

[0046] Throughout the drawings, the same or similar reference numerals represent the same or similar element.

5

DETAILED DESCRIPTION

[0047] Principles of the present disclosure will now be described with reference to some embodiments. It is to be understood that these embodiments are described only for the purpose of illustration and help those skilled in the art to understand and implement the present disclosure, without suggesting any limitation as to the scope of the disclosure. The disclosure described herein can be implemented in various manners other than the ones described below. In the following description and claims, unless defined otherwise, all technical and scientific terms used herein have the same meaning as commonly understood by one of ordinary skills in the art to which this disclosure belongs.

[0048] References in the present disclosure to “one embodiment,” “an example embodiment,” “an embodiment,” “some embodiments,” and the like indicate that the embodiment(s) described may include a particular feature, structure, or characteristic, but it is not necessary that every embodiment includes the particular feature, structure, or characteristic. Moreover, such phrases do not necessarily refer to the same embodiment(s). Further, when a particular feature, structure, or characteristic is described in connection with an embodiment, it is submitted that it is within the knowledge of one skilled in the art to affect such feature, structure, or characteristic in connection with other embodiments whether or not explicitly described.

[0049] It shall be understood that although the terms “first” and “second” or the like may be used herein to describe various elements, these elements should not be limited by these terms. These terms are only used to distinguish one element from another element. For example, a first element could also be termed as a second element, and similarly, a second element could also be termed as a first element, without departing from the scope of embodiments. As used herein, the term “and/or” includes any and all combinations of one or more of the listed terms. In some examples, values, procedures, or apparatuses are referred to as “best,” “lowest,” “highest,” “minimum,” “maximum,” or the like. It will be appreciated that such descriptions are intended to indicate that a selection among many used functional alternatives can be made, and such selections need not be better, smaller, higher,

or otherwise preferable to other selections.

[0050] The terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting of embodiments. As used herein, the singular forms “a,” “an” and “the” are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will be further understood that the terms “comprises,” “comprising,” “has,” “having,” “includes” and/or “including,” when used herein, specify the presence of stated features, elements, components and/or the like, but do not preclude the presence or addition of one or more other features, elements, components and/or combinations thereof. For example, the term “includes” and its variants are to be read as open terms that mean “includes, but is not limited to.” The term “based on” is to be read as “based at least in part on.” The term “one embodiment” and “an embodiment” are to be read as “at least one embodiment.” The term “another embodiment” is to be read as “at least one other embodiment.” The use of an expression such as “A and/or B” can mean either “only A” or “only B” or “both A and B.” Other definitions, explicit and implicit, may be included below.

[0051] FIG. 1 illustrates an example of a wireless communications system 100 in which some embodiments of the present disclosure can be implemented. The wireless communications system 100 may include one or more network entities 102 (also referred to as network equipment (NE)), one or more UEs 104, a core network (CN) 106, and a packet data network 108. The wireless communications system 100 may support various radio access technologies. In some implementations, the wireless communications system 100 may be a 4G network, such as a long term evolution (LTE) network or an LTE-Advanced (LTE-A) network. In some other implementations, the wireless communications system 100 may be a 5G network, such as a new radio (NR) network. In other implementations, the wireless communications system 100 may be a combination of a 4G network and a 5G network, or other suitable radio access technology including Institute of Electrical and Electronics Engineers (IEEE) 802.11 (Wi-Fi), IEEE 802.16 (WiMAX), IEEE 802.20. The wireless communications system 100 may support radio access technologies beyond 5G. Additionally, the wireless communications system 100 may support technologies, such as time division multiple access (TDMA), frequency division multiple access (FDMA), or code division multiple access (CDMA), etc.

[0052] The one or more network entities 102 may be dispersed throughout a geographic region to form the wireless communications system 100. One or more of the network entities 102 described herein may be or include or may be referred to as a network node, a

base station, a network element, a radio access network (RAN), a base transceiver station, an access point, a NodeB, an eNodeB (eNB), a next-generation NodeB (gNB), or other suitable terminology. A network entity 102 and a UE 104 may communicate via a communication link 110, which may be a wireless or wired connection. For example, a network entity 102 and a UE 104 may perform wireless communication (e.g., receive signaling, transmit signaling) over a Uu interface.

[0053] A network entity 102 may provide a geographic coverage area 112 for which the network entity 102 may support services (e.g., voice, video, packet data, message, broadcast, etc.) for one or more UEs 104 within the geographic coverage area 112. For example, a network entity 102 and a UE 104 may support wireless communication of signals related to services (e.g., voice, video, packet data, messaging, broadcast, etc.) according to one or multiple radio access technologies. In some implementations, a network entity 102 may be moveable, for example, a satellite associated with a non-terrestrial network. In some implementations, different geographic coverage areas 112 associated with the same or different radio access technologies may overlap, but the different geographic coverage areas 112 may be associated with different network entities 102. Information and signals described herein may be represented using any of a variety of different technologies and techniques. For example, data, instructions, commands, information, signals, bits, symbols, and chips that may be referenced throughout the description may be represented by voltages, currents, electromagnetic waves, magnetic fields or particles, optical fields or particles, or any combination thereof.

[0054] The one or more UEs 104 may be dispersed throughout a geographic region of the wireless communications system 100. A UE 104 may include or may be referred to as a mobile device, a wireless device, a remote device, a remote unit, a handheld device, or a subscriber device, or some other suitable terminology. In some implementations, the UE 104 may be referred to as a unit, a station, a terminal, or a client, among other examples. Additionally, or alternatively, the UE 104 may be referred to as an Internet-of-Things (IoT) device, an Internet-of-Everything (IoE) device, or machine-type communication (MTC) device, among other examples. In some implementations, a UE 104 may be stationary in the wireless communications system 100. In some other implementations, a UE 104 may be mobile in the wireless communications system 100.

[0055] The one or more UEs 104 may be devices in different forms or having different capabilities. Some examples of UEs 104 are illustrated in FIG. 1. A UE 104 may be

capable of communicating with various types of devices, such as the network entities 102, other UEs 104, or network equipment (e.g., the CN 106, the packet data network 108, a relay device, an integrated access and backhaul (IAB) node, or another network equipment), as shown in FIG. 1. Additionally, or alternatively, a UE 104 may support communication with
5 other network entities 102 or UEs 104, which may act as relays in the wireless communications system 100.

[0056] A UE 104 may also be able to support wireless communication directly with other UEs 104 over a communication link 114. For example, a UE 104 may support wireless communication directly with another UE 104 over a device-to-device (D2D) communication
10 link. In some implementations, such as vehicle-to-vehicle (V2V) deployments, vehicle-to-everything (V2X) deployments, or cellular-V2X deployments, the communication link 114 may be referred to as a sidelink (SL). For example, a UE 104 may support wireless communication directly with another UE 104 over a PC5 interface.

[0057] A network entity 102 may support communications with the CN 106, or with another
15 network entity 102, or both. For example, a network entity 102 may interface with the CN 106 through one or more backhaul links 116 (e.g., via an S1, N2, N3, or another network interface). The network entities 102 may communicate with each other over the backhaul links 116 (e.g., via an X2, Xn, or another network interface). In some implementations, the network entities 102 may communicate with each other directly (e.g., between the network
20 entities 102). In some other implementations, the network entities 102 may communicate with each other or indirectly (e.g., via the CN 106). In some implementations, one or more network entities 102 may include subcomponents, such as an access network entity, which may be an example of an access node controller (ANC). An ANC may communicate with the one or more UEs 104 through one or more other access network transmission entities,
25 which may be referred to as a radio heads, smart radio heads, or transmission-reception points (TRPs).

[0058] In some implementations, a network entity 102 may be configured in a disaggregated architecture, which may be configured to utilize a protocol stack physically or logically distributed among two or more network entities 102, such as an integrated access
30 backhaul (IAB) network, an open RAN (O-RAN) (e.g., a network configuration sponsored by the O-RAN Alliance), or a virtualized RAN (vRAN) (e.g., a cloud RAN (C-RAN)). For example, a network entity 102 may include one or more of a central unit (CU), a distributed unit (DU), a radio unit (RU), a RAN Intelligent Controller (RIC) (e.g., a Near-Real Time RIC

(Near-RT RIC), a Non-Real Time RIC (Non-RT RIC)), a Service Management and Orchestration (SMO) system, or any combination thereof.

[0059] An RU may also be referred to as a radio head, a smart radio head, a remote radio head (RRH), a remote radio unit (RRU), or a transmission reception point (TRP). One or more components of the network entities 102 in a disaggregated RAN architecture may be co-located, or one or more components of the network entities 102 may be located in distributed locations (e.g., separate physical locations). In some implementations, one or more network entities 102 of a disaggregated RAN architecture may be implemented as virtual units (e.g., a virtual CU (VCU), a virtual DU (VDU), a virtual RU (VRU)).

[0060] Split of functionality between a CU, a DU, and an RU may be flexible and may support different functionalities depending upon which functions (e.g., network layer functions, protocol layer functions, baseband functions, radio frequency functions, and any combinations thereof) are performed at a CU, a DU, or an RU. For example, a functional split of a protocol stack may be employed between a CU and a DU such that the CU may support one or more layers of the protocol stack and the DU may support one or more different layers of the protocol stack. In some implementations, the CU may host upper protocol layer (e.g., a layer 3 (L3), a layer 2 (L2)) functionality and signaling (e.g., Radio Resource Control (RRC), service data adaptation protocol (SDAP), Packet Data Convergence Protocol (PDCP)). The CU may be connected to one or more DUs or RUs, and the one or more DUs or RUs may host lower protocol layers, such as a layer 1 (L1) (e.g., physical (PHY) layer) or an L2 (e.g., radio link control (RLC) layer, medium access control (MAC) layer) functionality and signaling, and may each be at least partially controlled by the CU.

[0061] Additionally, or alternatively, a functional split of the protocol stack may be employed between a DU and an RU such that the DU may support one or more layers of the protocol stack and the RU may support one or more different layers of the protocol stack. The DU may support one or multiple different cells (e.g., via one or more RUs). In some implementations, a functional split between a CU and a DU, or between a DU and an RU may be within a protocol layer (e.g., some functions for a protocol layer may be performed by one of a CU, a DU, or an RU, while other functions of the protocol layer are performed by a different one of the CU, the DU, or the RU).

[0062] A CU may be functionally split further into CU control plane (CU-CP) and CU user plane (CU-UP) functions. A CU may be connected to one or more DUs via a midhaul

communication link (e.g., F1, F1-C, F1-U), and a DU may be connected to one or more RUs via a fronthaul communication link (e.g., open fronthaul (FH) interface). In some implementations, a midhaul communication link or a fronthaul communication link may be implemented in accordance with an interface (e.g., a channel) between layers of a protocol stack supported by respective network entities 102 that are in communication via such communication links.

[0063] The CN 106 may support user authentication, access authorization, tracking, connectivity, and other access, routing, or mobility functions. The CN 106 may be an evolved packet core (EPC), or a 5G core (5GC), which may include a control plane entity that manages access and mobility (e.g., a mobility management entity (MME), an access and mobility management functions (AMF)) and a user plane entity that routes packets or interconnects to external networks (e.g., a serving gateway (S-GW), a Packet Data Network (PDN) gateway (P-GW), or a user plane function (UPF)). In some implementations, the control plane entity may manage non-access stratum (NAS) functions, such as mobility, authentication, and bearer management (e.g., data bearers, signal bearers, etc.) for the one or more UEs 104 served by the one or more network entities 102 associated with the CN 106.

[0064] The CN 106 may communicate with the packet data network 108 over one or more backhaul links 116 (e.g., via an S1, N2, N3, or another network interface). The packet data network 108 may include an application server 118. In some implementations, one or more UEs 104 may communicate with the application server 118. A UE 104 may establish a session (e.g., a protocol data unit (PDU) session, or the like) with the CN 106 via a network entity 102. The CN 106 may route traffic (e.g., control information, data, and the like) between the UE 104 and the application server 118 using the established session (e.g., the established PDU session). The PDU session may be an example of a logical connection between the UE 104 and the CN 106 (e.g., one or more network functions of the CN 106).

[0065] In the wireless communications system 100, the network entities 102 and the UEs 104 may use resources of the wireless communications system 100 (e.g., time resources (e.g., symbols, slots, subframes, frames, or the like) or frequency resources (e.g., subcarriers, carriers)) to perform various operations (e.g., wireless communications). In some implementations, the network entities 102 and the UEs 104 may support different resource structures. For example, the network entities 102 and the UEs 104 may support different frame structures. In some implementations, such as in 4G, the network entities 102 and the UEs 104 may support a single frame structure. In some other implementations, such as in

5G and among other suitable radio access technologies, the network entities 102 and the UEs 104 may support various frame structures (i.e., multiple frame structures). The network entities 102 and the UEs 104 may support various frame structures based on one or more numerologies.

- 5 **[0066]** One or more numerologies may be supported in the wireless communications system 100, and a numerology may include a subcarrier spacing and a cyclic prefix. A first numerology (e.g., $\mu=0$) may be associated with a first subcarrier spacing (e.g., 15 kHz) and a normal cyclic prefix. In some implementations, the first numerology (e.g., $\mu=0$) associated with the first subcarrier spacing (e.g., 15 kHz) may utilize one slot per subframe.
- 10 A second numerology (e.g., $\mu=1$) may be associated with a second subcarrier spacing (e.g., 30 kHz) and a normal cyclic prefix. A third numerology (e.g., $\mu=2$) may be associated with a third subcarrier spacing (e.g., 60 kHz) and a normal cyclic prefix or an extended cyclic prefix. A fourth numerology (e.g., $\mu=3$) may be associated with a fourth subcarrier spacing (e.g., 120 kHz) and a normal cyclic prefix. A fifth numerology (e.g., $\mu=4$) may be
- 15 associated with a fifth subcarrier spacing (e.g., 240 kHz) and a normal cyclic prefix.

[0067] A time interval of a resource (e.g., a communication resource) may be organized according to frames (also referred to as radio frames). Each frame may have a duration, for example, a 10 millisecond (*ms*) duration. In some implementations, each frame may include multiple subframes. For example, each frame may include 10 subframes, and each

20 subframe may have a duration, for example, a 1 *ms* duration. In some implementations, each frame may have the same duration. In some implementations, each subframe of a frame may have the same duration.

[0068] Additionally or alternatively, a time interval of a resource (e.g., a communication resource) may be organized according to slots. For example, a subframe may include a

25 number (e.g., quantity) of slots. The number of slots in each subframe may also depend on the one or more numerologies supported in the wireless communications system 100. For instance, the first, second, third, fourth, and fifth numerologies (i.e., $\mu=0$, $\mu=1$, $\mu=2$, $\mu=3$, $\mu=4$) associated with respective subcarrier spacings of 15 kHz, 30 kHz, 60 kHz, 120 kHz, and 240 kHz may utilize a single slot per subframe, two slots per subframe, four slots per subframe,

30 eight slots per subframe, and 16 slots per subframe, respectively. Each slot may include a number (e.g., quantity) of symbols (e.g., orthogonal frequency-division multiplexing (OFDM) symbols). In some implementations, the number (e.g., quantity) of slots for a subframe may depend on a numerology. For a normal cyclic prefix, a slot may include 14 symbols. For

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

[0069] In the wireless communications system 100, an electromagnetic (EM) spectrum may be split, based on frequency or wavelength, into various classes, frequency bands, frequency channels, etc. By way of example, the wireless communications system 100 may support one or multiple operating frequency bands, such as frequency range designations FR1 (410 MHz – 7.125 GHz), FR2 (24.25 GHz – 52.6 GHz), FR3 (7.125 GHz – 24.25 GHz), FR4 (52.6 GHz – 114.25 GHz), FR4a or FR4-1 (52.6 GHz – 71 GHz), and FR5 (114.25 GHz – 300 GHz). In some implementations, the network entities 102 and the UEs 104 may perform wireless communications over one or more of the operating frequency bands. In some implementations, FR1 may be used by the network entities 102 and the UEs 104, among other equipment or devices for cellular communications traffic (e.g., control information, data). In some implementations, FR2 may be used by the network entities 102 and the UEs 104, among other equipment or devices for short-range, high data rate capabilities.

[0070] FR1 may be associated with one or multiple numerologies (e.g., at least three numerologies). For example, FR1 may be associated with a first numerology (e.g., $\mu=0$), which includes 15 kHz subcarrier spacing; a second numerology (e.g., $\mu=1$), which includes 30 kHz subcarrier spacing; and a third numerology (e.g., $\mu=2$), which includes 60 kHz subcarrier spacing. FR2 may be associated with one or multiple numerologies (e.g., at least 2 numerologies). For example, FR2 may be associated with a third numerology (e.g., $\mu=2$), which includes 60 kHz subcarrier spacing; and a fourth numerology (e.g., $\mu=3$), which includes 120 kHz subcarrier spacing.

[0071] Coherent joint transmission (CJT) with multiple TRPs in frequency range 1 (FR1) has been specified in 3GPP NR Release 18 (Rel-18) by assuming ideal synchronization among cooperative TRPs. Scenarios such as inter-site CJT and a base station equipped with distributed RRHs require additional delay and phase/frequency calibration. For TDD, additional inter-TRP DL/UL calibration across TRPs is also beneficial to ensure proper DL/UL reciprocity holds. As the UE possesses more knowledge on DL channel condition in both FDD and TDD, the need for inter-TRP calibration reporting measured from CSI-RS

is evident not only to expand the deployment scenarios, but also to offer additional robustness to CJT operation. With this justification, one of the Rel-19 MIMO objectives is to specify the UE reporting to promote the CJT deployments as follows:

- Specify UE reporting enhancement for CJT deployments under non-ideal synchronization and backhaul, targeting FR1, both FDD and TDD.
- inter-TRP time misalignment and frequency/phase offset measurement and reporting, assuming legacy CSI-RS design, with stand-alone aperiodic reporting on PUSCH.

[0072] Currently, basic principles for inter-TRP delay offset, timing offset and phase offset estimation has been agreed by 3GPP RAN1#116 meeting. However, some detailed issues have not been decided.

[0073] Embodiments of the present disclosure provide a solution for delay, frequency offset reporting for time and/or frequency calibration. In the solution, a UE may be configured with a CSI report configuration for a phase offset report for reciprocity calibration, the configuration indicates a CMR and associated SRS resource. The UE may determine DL phase offset between different TRPs based on the measurement on the CMR and report the DL phase offset, in addition the UE may further transmit SRS based on the configuration. As such, a UL phase offset may be determined by the base station accordingly and the reciprocity calibration may be further performed. Principles and implementations of the present disclosure will be described in detail below with reference to the figures.

[0074] FIG. 2 illustrates a schematic diagram of an example communication network 200 in which some embodiments of the present disclosure can be implemented. As shown in FIG. 2, the communication network 200 may include a BS 210 and a UE 220, which may communicate with each other. With reference to FIG. 1, the BS 210 may be one network entity 102, and the UE 220 may be one UE 104.

[0075] The BS 210 may be a serving gNB of multiple TRPs, for example, FIG. 2 also shows N_{TRP} TPRs, where N_{TRP} is a positive integer. For example, $N_{\text{TRP}} \in \{1, 2, 3, 4\}$. In some implementations, the BS 210 may be one of the multiple TPRs, such as TRP0 among N_{TRP} TPRs. In some other implementations, the BS 210 may be an independent base station from the multiple TPRs, for example, the BS 210 may be a gNB different from any of the N_{TRP} TPRs.

[0076] It is to be understood that the numbers of TRPs or UEs shown in FIG. 2 are only for

the purpose of illustration only. The communication network 200 may include any suitable numbers of devices.

[0077] In the present disclosure, a CSI report may also be referred to as a CSI feedback, a delay, frequency and/or phase offset report, a report for calibration, or a report, the present disclosure does not limit for this aspect. In the present disclosure, a plurality of CSI-RSs may be interchangeably with CSI-RS resources, non-zero power (NZP) CSI-RS resources, a set of NZP CSI-RS resources, NZP CSI-RS resource set(s), or the like, the present disclosure does not limit for this aspect. In some cases, the plurality of CSI-RSs may be configured as CMR for the UE in the present disclosure.

[0078] FIG. 3 illustrates a signalling chart illustrating communication process 300 in accordance with some example embodiments of the present disclosure. The process 300 may involve a BS 210 and a UE 220 as discussed with reference to FIG. 2. It would be appreciated that the process 300 may be applied to other communication scenarios, which will not be described in detail.

[0079] For ease of description, it is assumed that there are N_{TRP} TRPs, e.g. controlled or manipulated by the BS 210. For example, $N_{\text{TRP}} \in \{1, 2, 3, 4\}$. In some examples, the BS 210 may be a serving gNB for the N_{TRP} TRPs. For example, the BS 210 may be one of N_{TRP} TRPs, or may be different from any of N_{TRP} TRPs.

[0080] In the process 300, the BS 210 transmits a configuration to the UE 220 at 310. In some implementations, the configuration at 310 may be a configuration of a joint delay offset and frequency offset report. In some implementations, the configuration may be a CSI report configuration, e.g., being included in an information element (IE) “*CSI-ReportConfig*” which is configured by RRC signaling. In some implementations, the configuration may indicate a plurality of TRSs or CSI-RSs configured as channel measurement resource (CMR).

[0081] In some implementations, the configuration at 310 may indicate a CMR, which may be configured as a CSI-RS resource set. In some examples, the CSI-RS resource set (which is configured as the CMR for a CSI report configuration for FO and/or DO report) may include multiple TRS or NZP CSI-RS resources, e.g., N_{TRP} TRS or NZP CSI-RS resources configured with a single antenna port.

[0082] In some example embodiments, the configuration is associated with a CSI report for FO only reporting, in this case, each of the plurality of TRS/CSI-RS resources is QCLed with an SSB or another TRS with a QCL parameter of Doppler shift and/or Doppler spread.

Alternatively, each of the plurality of TRS/CSI-RS resources is QCLed with an SSB or another TRS with a QCL parameter of average delay and/or delay spread.

[0083] In some example embodiments, the configuration is associated with a CSI report for DO only reporting, in this case, each of the plurality of TRS/CSI-RS resources is QCLed with an SSB or another TRS with a QCL parameter of average delay and/or delay spread. Alternatively, each of the plurality of TRS/CSI-RS resources is QCLed with an SSB or another TRS with a QCL parameter of Doppler shift and/or Doppler spread.

[0084] In some example embodiments, the configuration is associated with a CSI report for joint DO and FO reporting, in this case, each of the plurality of TRSs or CSI-RSs is QCLed with an SSB or a TRS with a QCL parameter of Doppler shift, Doppler spread, average delay, and/or delay spread. For example, each TRS or CSI-RS is QCLed with an SSB with Doppler shift and average delay. For another example, each TRS or CSI-RS is QCLed with another periodic TRS with Doppler shift, Doppler spread, average delay, and delay spread.

[0085] In some embodiments, the configuration may indicate a NZP CSI-RS resource set, which may include one or more CSI-RS resources. In some examples, the configuration may indicate N_{TRP} CSI-RS resources, for example, the i -th CSI-RS resource may be transmitted by the i -th TRP.

[0086] In some embodiments, for aperiodic standalone CJT calibration reporting, the UE 220 may be configured with N_{TRP} NZP CSI-RS resources/resource sets via higher-layer (RRC) signalling where $N_{\text{TRP}} \in \{1, 2, 3, 4\}$ as the CMR for FO, DO and/or PO reporting, and some further restriction(s), such as QCL assumptions, on applicable NZP CSI-RS resources/resource sets may be indicated.

[0087] The ratio of received baseband signals, e.g., TRS or CSI-RS, between two TRPs on the subcarrier k may be represented as

$$C_k(t) = Ae^{j\theta} \cdot e^{j2\pi(kf\Delta\tau + \Delta f \cdot t)} \quad (1)$$

where

- $Ae^{j\theta}$ is the initial amplitude offset and initial phase offset between signals of two TRPs which are constant and do not need to be reported.
- f is the subcarrier space.
- $\Delta\tau$ is the delay offset (DO) between different TRPs.
- Δf is the frequency offset (FO) between different TRPs.

[0088] It is understandable that the FO and the DO will lead relative phase rotation of the signals from different TRPs. In the present disclosure, the UE 220 can determine the DO and FO based on a same set of CSI-RS resources or CSI-RS resource set and can report them in a same CSI report, in some embodiments. For the FO calculation, at least two samples of the CSI-RS resources are required for the UE 220 to obtain a time duration and then to derive the corresponding FO. It means that if aperiodic CSI-RS resource is associated with a CSI report configuration containing FO report, each of the associated CSI-RS resources should be transmitted by X (e.g., X=2) times.

[0089] In some example embodiments, each of the plurality of TRSs or CSI-RSs is transmitted for multiple times in multiple adjacent slots. In some instances, a first slot in the multiple adjacent slots is determined based on a triggering offset configured for the resource set. In some instances, each of resources (e.g., N_{TRP} aperiodic TRS resources or N_{TRP} NZP CSI-RS resources) is transmitted for X times in X adjacent available slots.

[0090] In some examples, the multiple adjacent slots may include X available DL slots, and each of the X available DL slots contains DL symbols for TRS/CSI-RS transmission. It is to be noted that slot which does not include valid symbols for TRS/CSI-RS transmission should not be included in the multiple adjacent slots, that is, if a slot does not include valid symbols for TRS/CSI-RS transmission, then it should be skipped.

[0091] In some examples, the multiple adjacent slots for X times of transmission may include a first slot, a second slot, a third slot, ..., a X-th slot. For example, the first transmission of N_{TRP} resources may be in a first slot, the second transmission of the N_{TRP} resources may be in a second slot, ..., and the X-th transmission of the N_{TRP} resources may be in the X-th slot. In some instances, the first slot may be determined by the aperiodic CSI-RS triggering offset configured for the CSI-RS resource set.

[0092] In some examples, for a transmission of N_{TRP} resources, such as the x-th transmission in the x-th slot, they can be in same symbol(s) or in different symbols.

[0093] In some examples, for X times of transmission of a specific resource, they can be in same symbol(s). For example, a triggered TRS or NZP CSI-RS resource for a TRP (such as TRP1) may be transmitted in symbol y in the first slot for the first time, in symbol y in the second slot for the second time, ..., in symbol y in the X-th slot for the X-th time.

[0094] In some example embodiments, the plurality of TRSs or CSI-RSs are transmitted in a plurality of adjacent slots respectively. In some instances, each of resources (e.g., N_{TRP}

aperiodic TRS resources or N_{TRP} NZP CSI-RS resources) is transmitted for X times in a same slot.

[0095] In some examples, N_{TRP} adjacent available slots may be used for the transmission, and each of resources (e.g., N_{TRP} aperiodic TRS resources or N_{TRP} NZP CSI-RS resources) may be configured with X symbols within a same slot. For example, X symbols in a first slot is used for transmitting a first resource for X times, X symbols in a second slot is used for transmitting a second resource for X times, ..., and X symbols in a N_{TRP} -th slot is used for transmitting a N_{TRP} -th resource for X times.

[0096] In some examples, X symbols for each resource may be configured. For example, X symbols for each of resources (e.g., N_{TRP} aperiodic TRS resources or N_{TRP} NZP CSI-RS resources) may be configured by:

firstOFDMSymbolInTimeDomain(l_0),
firstOFDMSymbolInTimeDomain2(l_1), ..., and
firstOFDMSymbolInTimeDomainX(l_{X-1}).

[0097] In some examples, X symbols for each resource may be X adjacent available DL symbols. For example, the first symbol among the X symbols may be configured, e.g. by firstOFDMSymbolInTimeDomain. For example, an index of the first symbol may be the same for all resources, e.g., all the N_{TRP} TRS or NZP CSI-RS resources are configured with a same symbol, and they are transmitted in X adjacent available DL symbols.

[0098] In some example embodiments, each of the plurality of TRSs or CSI-RSs is transmitted for multiple times in multiple symbols of a specific slot. In some instances, each of the N_{TRP} TRS or NZP CSI-RS resources is uniformly transmitted within a same slot by X times.

[0099] For example, each of the N_{TRP} TRS or NZP CSI-RS resources is transmitted in the first available DL slot on the symbols $\left\{l_0, \text{mod}\left(l_0 + \left\lfloor \frac{14}{X} \right\rfloor, 14\right), \dots, \text{mod}\left(l_0 + (X-1) \times \left\lfloor \frac{14}{X} \right\rfloor, 14\right)\right\}$. l_0 is configured for each NZP CSI-RS resource by an RRC parameter *firstOFDMSymbolInTimeDomain*. For example, the available DL slot should be a DL slot containing DL symbols for all the N_{TRP} TRS or CSI-RS transmission.

[00100] In some example embodiments, the plurality of TRSs or CSI-RSs comprise multiple groups of TRSs or CSI-RSs, the multiple groups of TRSs or CSI-RSs are transmitted in multiple adjacent slots respectively.

[00101] For a specific example, assuming $N_{TRP}=2$, the UE 220 is configured with $N_{TRP}=2$ NZP CSI-RS resources in one slot, and the 2 NZP CSI-RS resources are transmitted for X times in adjacent available slots. In each of the slots, the symbols for the 2 NZP CSI-RS resources transmitted in a slot which can be {4, 8}, {5, 9}, or {6, 10}. In addition, each of N_{TRP} NZP CSI-RS resources will be transmitted for X times in X consecutive available DL slots.

[00102] For a specific example, assuming $N_{TRP}=3$ or $N_{TRP}=4$, the UE 220 is configured with $N_{TRP}=\{3,4\}$ NZP CSI-RS resources in two consecutive slots. The first two NZP CSI-RS resources are transmitted in the first slot, and the other NZP CSI-RS resources (i.e. the last one NZP CSI-RS resource if $N_{TRP}=3$, or the last two NZP CSI-RS resources if $N_{TRP}=4$) are transmitted in the second slot. The symbols for the first two NZP CSI-RS resources in the first slot can be {4, 8}, {5, 9}, or {6, 10}. The third NZP CSI-RS is in the second slot with the same symbol of the first NZP CSI-RS, and the fourth NZP CSI-RS is in the second slot with the same symbol of the second NZP CSI-RS. In addition, each of N_{TRP} NZP CSI-RS resources will be transmitted for X times in 2X consecutive available DL slots.

[00103] In some other example embodiments, the configuration at 310 may indicate N_{TRP} resource sets configured as CMR for the CSI report (e.g. for FO reporting, or for joint DO and FO reporting). In some examples, each of the N_{TRP} resource sets may include X resources which are transmitted in different slots or in different symbols of a same slot.

[00104] Alternatively, only periodic TRS or periodic CSI-RS resources can be configured as the CMR for CSI report configuration for FO and/or DO reporting.

[00105] In the process 300, the UE 220 receives a plurality of TRS or CSI-RS resources from a plurality of TRPs respectively at 320. Specifically, the transmission resources are determined based on the configuration, and the UE 220 receives TRS/CSI-RS resources based on the configuration.

[00106] In addition or alternatively, the UE 220 may generate a CSI report, and then in the process 300, the UE 220 transmits the CSI report to the BS 210 at 330. In some implementations, if the configuration is configured for CSI report for FO reporting, the CSI report at 330 includes FO. In some implementations, if the configuration is configured for

CSI report for DO reporting, the CSI report at 330 includes DO. In some implementations, if the configuration is configured for CSI report for joint DO and FO reporting, the CSI report at 330 includes DO and FO.

[00107] In some implementations, the number of CPUs used for the CSI report is determined based on a number of the plurality of TRPs and a parameter associated with a capability of the UE. In some example embodiments, the number of occupied CPUs corresponding to a CSI report can be represented as O_{CPU} , which may be determined by $O_{CPU} = YN_{TRP}$ or $O_{CPU} = Y(N_{TRP} - 1)$ or $O_{CPU} = Y(N_{TRP} + 1)$ at least for DO and/or FO reporting, where Y is a specific value or configured by NW according to UE capability. For example, $Y \in \{1, 3/2, 2\}$. However, it is to be understood that the value of Y may be another value, and the present disclosure does not limit for this aspect. In some example embodiments, if the configuration is configured for CSI report for joint DO and FO reporting, more CPUs can be occupied. For example, the number of occupied CPUs can be represented as O_{CPU} , which may be determined by $O_{CPU} = Y'YN_{TRP}$ or $O_{CPU} = Y'Y(N_{TRP} - 1)$ or $O_{CPU} = Y'Y(N_{TRP} + 1)$ where $Y' \geq 1$, e.g., $Y'=1$, $Y'=2$, or $Y'=3/2$ which may be configured according to UE capability or be a specific value.

[00108] In some implementations, for the purpose of CJT calibration reporting, the UE 220 can report for all the configured N_{TRP} NZP CSI-RS resources/resource sets, or the UE 220 can report for N out of N_{TRP} NZP CSI-RS resources/resource sets where the selection of N resources/resource sets is dynamically signalled by the BS 210 to the UE 220, or the UE 220 can report for N out of N_{TRP} NZP CSI-RS resources/resource sets where the selection of N resources/resource sets is performed by the UE 220 and included in the CSI report.

[00109] In some implementations, for aperiodic standalone CJT calibration reporting, given the N_{TRP} configured NZP CSI-RS resources/resource sets and the selected N resources/resource sets, it is supported reporting, in one CSI reporting instance, $\{(D_{n,offset}, d_n), n=0, 1, \dots, N-1\}$ where

- $D_{n,offset}$ is a B-bit indicator representing the delay offset associated with the n -th CSI-RS resource/resource set. In some examples, for the reference CSI-RS resource/resource set n_{ref} , the value of $D_{n_{ref},offset}$ is assumed 0 and not reported. It is to be noted that the value n_{ref} may be fixed, or may be configured by the BS 210, or may be determined by the UE 220 and included in the CSI report.

- The value of $D_{n,\text{offset}}$ indicates the interval $[\delta_i, \delta_{i+1})$ which the delay offset falls into down-select from the following: Alt1: $\{\delta_0, \delta_1, \dots, \delta_{M-2}\}$ is uniformly spaced between 0 and A_D , i.e. $\delta_i = i \times \frac{A_D}{M-2}, i = 0, 1, \dots, M-2$, with $M = 2^B$; or Alt2: $\{\delta_0, \delta_1, \dots, \delta_{M-2}\}$ is uniformly spaced between $-A_D$ and A_D , i.e. $\delta_i = -A_D + i \times \frac{2A_D}{M-2}, i = 0, 1, \dots, M-2$, with $M = 2^B$. For example, each interval $[\delta_i, \delta_{i+1})$ corresponds to a codepoint, and $(-\infty, \delta_0)$ and/or $[\delta_{M-2}, \infty)$ represent ‘out-of-range’.
- d_n is a 1-bit indicator associated with the n -th CSI-RS resource/resource set, indicating whether the measured delay offset, plus delay spread, is inside or outside a pre-defined range/interval. For example, the pre-defined range may be a cyclic prefix (CP) length.

[00110] In some implementations, for aperiodic standalone CJT calibration reporting, given the N_{TRP} configured NZP CSI-RS resources/resource sets and the selected N resources/resource sets, it is supported reporting, in one CSI reporting instance, $\{\text{FO}_n, n=0, 1, \dots, N-1, n \neq n_{\text{ref}}\}$, where FO_n denotes the measured frequency offset associated with the n -th CSI-RS resource/resource set relative to the reference CSI-RS resource/resource set n_{ref} .

In some examples, for the reference CSI-RS resource/resource set n_{ref} , the value of $\text{FO}_{n_{\text{ref}}}$ is assumed 0 and not reported. It is to be noted that the value n_{ref} may be fixed, or may be configured by the BS 210, or may be determined by the UE 220 and included in the CSI report.

[00111] In some examples, the value of FO_n indicates a uniformly quantized FO between $-A_{\text{FO}}$ and A_{FO} , or 0 and A_{FO} . In some other examples, the value of FO_n indicates the interval $[\varphi_i, \varphi_{i+1})$ which the FO falls into: Alt2A: $\{\varphi_0, \varphi_1, \dots, \varphi_{M-1}\}$ is uniformly spaced between $-A_{\text{FO}}$ and A_{FO} , i.e. $\varphi_i = -A_{\text{FO}} + i \times \frac{2A_{\text{FO}}}{M-1}, i = 0, 1, \dots, M-1$; or Alt2B: $\{\varphi_0, \varphi_1, \dots, \varphi_{M-1}\}$ is uniformly spaced between 0 and A_{FO} , i.e. $\varphi_i = i \times \frac{A_{\text{FO}}}{M-1}, i = 0, 1, \dots, M-1$. In some examples, if $N < N_{\text{TRP}}$, the rest $(N_{\text{TRP}} - N)$ resources/resource sets are indicated with a state “out of range”.

[00112] In some implementations, the UE 220 may select a reference CSI-RS resource (or a reference TRP) for both DO reporting and FO reporting (e.g., at least for joint DO and FO report), for example, a same reference n may be used for the DO and FO reporting.

[00113] Regarding the uplink control information (UCI) format for joint FO and DO reporting, an example is provided in Table 1. In this case, the UE 220 may select a same set of resources or TRPs for the FO and DO reporting and a same reference resource/TRP is

used for the FO and DO calculation. Alternatively, an independent reference CSI-RS resource can be reported for FO and DO calculation.

[00114] In some examples, the UE 220 may select the reference CSI-RS resource for the delay/frequency offset calculation, e.g., to ensure the delay/frequency offsets are positive, e.g., $D_{n\text{-offset}} \in [0, A_D]$ and $FO_{n\text{-offset}} \in [0, A_{FO}]$. In some examples, the UE 220 may report the selected reference CSI-RS resource in the CSI report, e.g., by a CSI-RS resource indicator (CRI) field. For a specific example, if up to $N_{TRP}=4$ CSI-RS resources being configured for CJT calibration, up to 1 UCI bit can be saved compared with the fixed reference CSI-RS resource or NW configured reference CSI-RS resource scheme.

[00115] Alternatively, the reference CSI-RS resource can be specified (e.g. indicated by the BS 210 or predefined) as the first CSI-RS resource among the N CSI-RS resources selected and reported by the UE 220. In this case, the delay/frequency offsets can be positive or negative, e.g., $D_{n\text{-offset}} \in [-A_D, A_D]$ and $FO_{n\text{-offset}} \in [-A_{FO}, A_{FO}]$.

Table 1. UCI format for joint FO and DO reporting

CSI report number	CSI fields	Bit width
CSI report#i	Bitmap indicate the N out of N_{TRP} resources selected by the UE	N_{TRP}
	CRI to indicate the reference CSI-RS resource for FO calculation	$\lceil \log_2(N) \rceil$
	Frequency offset of the first indicated resource	B_{FO}
	Frequency offset of the second indicated resource	
	Frequency offset of the third indicated resource	
	CRI to indicate the reference CSI-RS resource for DO calculation	$\lceil \log_2(N) \rceil$
	Whether the measured delay offset, plus delay spread corresponding to the first indicated resource is inside or outside a pre-defined range/interval	1
	Delay offset of the first indicated resource or Zero padding bit $O_{B_{DO}}$ when the measured delay offset is indicated outside the pre-defined range/interval	B_{DO}
	Whether the measured delay offset, plus delay spread corresponding to the second indicated resource is inside or outside a pre-defined range/interval	1
	Delay offset of the second indicated resource or Zero padding bit $O_{B_{DO}}$ when the measured delay offset is	B_{DO}

	indicated outside the pre-defined range/interval	
	Whether the measured delay offset, plus delay spread corresponding to the third indicated resource is inside or outside a pre-defined range/interval	1
	Delay offset of the third indicated resource or Zero padding bit $O_{B_{DO}}$ when the measured delay offset is indicated outside the pre-defined range/interval	B_{DO}

[00116] On the other side of communication, the BS 210 receives the CSI report from the UE 210. In addition, the BS 210 performs a calibration for the multiple TRPs based on the CSI report at 340.

5 [00117] Reference is further made to FIG. 4, which illustrates a signalling chart illustrating communication process 400 in accordance with some example embodiments of the present disclosure. The process 400 may involve a BS 210 and a UE 220 as discussed with reference to FIG. 2. The BS 210 in FIG. 4 may be regarded as a first TRP, and the process 400 further involves a second TRP 212. It would be appreciated that the process 400 may be applied to
10 other communication scenarios, which will not be described in detail.

[00118] For ease of description, it is assumed that there are N_{TRP} TRPs, e.g., $N_{TRP} \in \{1, 2, 3, 4\}$. In some examples, the BS 210 may be a serving gNB for the N_{TRP} TRPs. It is to be noted that although the serving gNB is assumed as the first TRP in the process 400, in some other cases, the serving gNB may be different from any of N_{TRP} TRPs, for example, the
15 configuration at 410 may be from the serving gNB rather than the first TRP.

[00119] In the process 400, the BS 210 transmits a configuration to the UE 220 at 410. In some implementations, the configuration at 410 may be a configuration of phase offset report for reciprocity calibration. In some implementations, the configuration may be a CSI report configuration, e.g., being included in an IE “*CSI-ReportConfig*”. In some implementations,
20 the configuration may indicate a plurality of CSI-RS resources configured as CMR. In some implementations, the configuration may further indicate an SRS resource associated with the CMR.

[00120] In the process 400, the UE 220 determines a DL phase offset based on the configuration at 420. Specifically, the phase offset is generated (or calculated) based on
25 received CSI-RSs from different TRPs, where the CSI-RSs are transmitted based on the configuration.

[00121] In some implementations, a single port CSI-RS resources can be configured to the UE 220. As such, the UE 220 can receive multiple CSI-RSs by a single port from different TRPs, and the received CSI-RSs by the single port can be used for DL phase offset estimation.

[00122] In some examples, the UE 220 may receive a first CSI-RS (i.e. CSI-RS#1) from the first TRP 210 at 415 and receive a second CSI-RS (i.e. CSI-RS#2) from the second TRP 212 at 416, by a same antenna port. In addition, the UE 220 can calculate the DL phase offset between the first CSI-RS and the second CSI-RS. For example, the DL phase offset may be represented as:

$$\begin{aligned}\Delta\varphi^{DL} &= \text{ang}(y_1^{DL} \times y_2^{DL,*}) = \text{ang}(H_1^{DL} e^{j\theta_1^{DL}} \times H_2^{DL,*} e^{-j\theta_2^{DL}}) \\ &= \text{ang}(H_1^{DL}) - \text{ang}(H_2^{DL}) + \theta_1^{DL} - \theta_2^{DL}\end{aligned}\quad (2)$$

where, y_1^{DL} is the DL reference signal from TRP1, i.e., CSI-RS#1, y_2^{DL} is the DL reference signal from TRP2, i.e., CSI-RS#2, H_i^{DL} is the channel coefficient from TRPi to the UE which includes the amplitude and the phase.

[00123] In the process 400, the UE 220 transmits a CSI report to each of the first TRP 210 and the second TRP 212 at 430. In some implementations, the CSI report includes a phase offset, e.g., that determined at 420.

[00124] In some implementations, the number of CPUs used for the CSI report is determined based on a number of the plurality of TRPs and a parameter associated with a capability of the UE 220. In some example embodiments, the number of occupied CPUs can be represented as O_{CPU} . In some examples, for a CSI report corresponding to a CSI report configuration associated with N_{TRP} NZP CSI-RS resources/resource sets for phase offset reporting, the number of occupied CPUs may be determined by $O_{CPU} = YN_{TRP}$ or $O_{CPU} = Y(N_{TRP} - 1)$ or $O_{CPU} = Y(N_{TRP} + 1)$, where Y is configured according to UE capability or a specific value. For example, $Y \in \{1, 1.5, 2\}$. However, it is to be understood that the value of Y may be another value, and the present disclosure does not limit for this aspect.

[00125] In some implementations, for aperiodic standalone CJT calibration reporting, given the N_{TRP} configured NZP CSI-RS resources/resource sets and the selected N resources/resource sets, it may be supported reporting, in one CSI reporting instance, $\{\Phi_{n,m} | n=0, 1, \dots, N-1, n \neq n_{ref}, m=0, 1, \dots, M-1\}$, where $\Phi_{n,m}$ denotes the measured phase offset between the n -th CSI-RS resource/resource set and the reference CSI-RS resource/resource set n_{ref} , for the m -th frequency unit. For example, for the reference CSI-RS

resource/resource set n_{ref} , the value of $\Phi_{n,ref}$ is assumed 0 and not reported. It is to be noted that the value n_{ref} may be fixed, or may be configured by the BS 210, or may be determined by the UE 220 and included in the CSI report. In some examples, the value $\Phi_{n,m}$ indicates a uniformly quantized phase between $-A_\Phi$ and A_Φ , or 0 and A_Φ .

- 5 [00126] The reference CSI-RS resource can be report by the UE 220, e.g., by a CRI field contained in the CSI report for phase offset report. In this case, the phase offsets are positive, $\Phi_{n,m} \in [0, A_\Phi]$. Alternatively, the reference CSI-RS resource can be specified (e.g. indicated by the BS 210 or predefined) as the first CSI-RS resource among the N CSI-RS resources selected and reported by the UE 220. In this case, the phase offsets can be positive or negative, e.g., $\Phi_{n,m} \in [-A_\Phi, A_\Phi]$.
- 10

[00127] An example of the UCI format for the subband phase offset report is provided in Table 2 below.

Table 2. UCI format for phase offset reporting

CSI report number	CSI fields	Bit width
CSI report#i	Bitmap indicate the N out of N_{TRP} resources selected by the UE	N_{TRP}
	CRI to indicate the reference CSI-RS resource for PO calculation	$\lceil \log_2(N) \rceil$
	Phase offset of the first indicated resource for the first subband	B_{PO}
	Phase offset of the second indicated resource for the first subband	
	Phase offset of the third indicated resource for the first subband	
	...	
	Phase offset of the first indicated resource for the M-th subband	
	Phase offset of the second indicated resource for the M-th subband	
	Phase offset of the third indicated resource for the M-th subband	

- 15 [00128] On the other side of communication, the BS 210 and the second TRP receives the CSI report from the UE 210. Accordingly, the DL phase offset may be obtained.

[00129] In the process 400, at 440, the UE 220 transmits an SRS resource with a single antenna port to each of the first TRP and the second TRP based on the configuration. In some implementations, a single port SRS resource is configured, e.g. associated with the CSI-RS resource sets configured as CMR or be associated with the CSI report configuration for phase offset reporting. In some implementations, the UE 220 may use an antenna port to transmit the SRS, where the antenna port is the same as that used for the CSI-RS reception, e.g. at 415 and 416. The UE 220 shall use a same antenna port to receive all the CSI-RS resources.

[00130] As a specific example, if an antenna port #1 is used for receiving CSI-RS#1 and CSI-RS#2, then the UE 220 may transmit the SRS to each of the first TRP and the second TRP through the antenna port #1.

[00131] In some implementations, the transmission of the SRS and the reception of the CSI-RSs can be in a same slot. In some examples, for the case that aperiodic CSI-RSs and aperiodic SRS are associated with a same CSI-ReportConfig for PO reporting, the aperiodic SRS is transmitted in a same slot as that for aperiodic CSI-RS reception. In some examples, the aperiodic CSI-RS reception may be earlier or later than the SRS transmission.

[00132] In some examples, there may be a time gap between the reception of CSI-RSs and the transmission of the SRS. In some examples, the time gap may be defined as a duration between a reception of the last symbol of the CSI-RSs and a transmission of the first symbol of the SRS. For example, the time gap may be larger than or equal to a threshold. For example, the threshold may be predefined, or may be determined or configured based on a capability of UE 220. As such, a threshold can be considered, e.g. for the UE to determine the same Rx/Tx antenna port, to ensure the calculation accuracy.

[00133] As a specific example, the threshold may equal to or is larger than P symbols. For example, the SRS may be transmitted after P symbols of the reception of the last symbol of the CSI-RSs, where P may be a predefined value.

[00134] In some implementations, the transmission of the SRS may be in a same slot with a reception of a DCI, or may be after multiple slots of the reception of the DCI, where the DCI is used to trigger the CSI report and the aperiodic CSI-RS transmission. In some examples, for the case that periodic CSI-RSs are configured as CMR, the associated SRS resource may be transmitted in the same slot for the reception of the triggering DCI. Alternatively, the

slot for the SRS transmission can be determined as slot $n+K$, where the triggering DCI is received in slot n and K is the triggering offset configured for the SRS resource.

[00135] In some examples, the SRS transmitted by the UE 220 should be compensated by a

phase offset $(y_1^{DL} \times y_2^{DL,*})^* / \sqrt{|y_1^{DL} \times y_2^{DL,*}|}$, so as to help the BS 210 to cancel the phase

5 offset part of $\text{ang}(H_1^{DL}) - \text{ang}(H_2^{DL})$, as that in Equation (2) above. $(\cdot)^*$ is the complex conjugate of $(\cdot)$. In some examples, if $N_{TRP} > 2$ CSI-RS resources are configured for phase offset estimation for multi-TRP TDD calibration, the phase offset can be determined by

$$\frac{1}{N_{TRP}-1} \sum_{n=1, n \neq n_{ref}}^{N_{TRP}} \frac{y_n^{DL} \times y_{n_{ref}}^{DL,*}}{\sqrt{|y_n^{DL} \times y_{n_{ref}}^{DL,*}|}} \quad (3)$$

10 where $y_{n_{ref}}^{DL}$ is the reference CSI-RS received from the reference TRP.

[00136] In some embodiments, the reported DL phase offset may be used for the reciprocity calibration, and the reported phase offset may reflect the phase offset caused by the Tx phase of different TRPs, e.g., by the hardware impairment. The phase offset caused by frequency offset, delay offset, and the wireless channel should be stripped. This can be done by NW-side pre-compensation. In this case, the UE 220 may only apply the Doppler spread and delay spread of the TRS which is configured as the QCL information RS for the NZP CSI-RS resources configured as the CMR. For example, each of the N_{TRP} NZP CSI-RS resources (configured as the CMR) may be QCLed with a TRS with Doppler spread and delay spread.

20 **[00137]** In addition or alternatively, the SRS exchange may be performed at 445. For example, the BS 210 may obtain the SRS received by the second TRP.

[00138] In the process 400, the BS 210 determine a UL phase offset at 450. In some implementations, the SRS received from the UE 220 at 440, and the SRS obtained from the second TRP at 445, may be used for the UL phase offset calculation. That is, the single port

25 SRS resource may be used for UL phase offset estimation.

[00139] In some examples, the BS 210 may use the received SRS (at 440) and the SRS received by the second TRP (at 445) to obtain the UL phase offset between two TRPs, the UL phase offset can be represented as

$$\Delta\phi^{UL} = \text{ang}(y_1^{UL} \times y_2^{UL,*}) = \text{ang}(H_1^{UL} e^{j\theta_1^{UL}} \times H_2^{UL,*} e^{-j\theta_2^{UL}})$$

$$= \text{ang}(H_1^{UL}) - \text{ang}(H_2^{UL}) + \theta_1^{UL} - \theta_2^{UL} \quad (4)$$

[00140] In addition, the BS 210 may determine a reciprocity calibration factor at 460. In some implementations, the reciprocity calibration factor may be determined based on the DL phase offset and the UL phase offset. For example, the reciprocity calibration factor, which is also called as a phase offset calibration factor, may be determined as:

$$\alpha = \Delta\varphi^{DL} - \Delta\varphi^{UL} = \theta_1^{DL} - \theta_1^{UL} - (\theta_2^{DL} - \theta_2^{UL}) \quad (5)$$

[00141] In addition or alternatively, the BS 210 may apply the reciprocity calibration factor to synchronize with the second TRP, so as to make sure that

$$\text{ang}(H_1^{DL}) - \text{ang}(H_2^{DL}) - (\text{ang}(H_1^{UL}) - \text{ang}(H_2^{UL})) \approx 0 \quad (6)$$

[00142] According to embodiments with reference to FIG. 4, SRS resource may be jointly used with CSI-RS for phase offset estimation and reporting. As such, the phase offset estimation and reporting may be supported for CJT scenario, so as to support the channel reciprocity based DL channel estimation.

[00143] According to some embodiments with reference to FIGS. 3-4, the UE 220 may receive a configuration indicating a NZP CSI-RS resource set configured as CMR. The UE 220 may further transmit a CSI report which is associated with the multiple NZP CSI-RS resources, and the CSI report may indicate at least one of: delay offset, frequency offset, or phase offset. And thus the BS 210 may perform a calibration based on the CSI report. In this way, a synchronization among multiple TRPs may be achieved and a CJT may be guaranteed.

[00144] FIG. 5 illustrates an example of a device 500 that is suitable for implementing embodiments of the present disclosure. The device 500 may be an example of a UE or a BS as described herein. The device 500 may support wireless communication with a BS 210, a UE 220, or any combination thereof. The device 500 may include components for bi-directional communications including components for transmitting and receiving communications, such as a processor 502, a memory 504, a transceiver 506, and, optionally, an I/O controller 508. These components may be in electronic communication or otherwise coupled (e.g., operatively, communicatively, functionally, electronically, electrically) via one or more interfaces (e.g., buses).

[00145] The processor 502, the memory 504, the transceiver 506, or various combinations thereof or various components thereof may be examples of means for performing various

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

[00146] In some implementations, the processor 502, the memory 504, the transceiver 506, or various combinations or components thereof may be implemented in hardware (e.g., in communications management circuitry). The hardware may include a processor, a digital signal processor (DSP), an application-specific integrated circuit (ASIC), a field-programmable gate array (FPGA) or other programmable logic device, a discrete gate or transistor logic, discrete hardware components, or any combination thereof configured as or otherwise supporting a means for performing the functions described in the present disclosure. In some implementations, the processor 502 and the memory 504 coupled with the processor 502 may be configured to perform one or more of the functions described herein (e.g., executing, by the processor 502, instructions stored in the memory 504).

[00147] For example, the processor 502 may support wireless communication at the device 500 in accordance with examples as disclosed herein. The processor 502 may be configured to operable to support a means for operations discussed above.

[00148] The processor 502 may include an intelligent hardware device (e.g., a general-purpose processor, a DSP, a CPU, a microcontroller, an ASIC, an FPGA, a programmable logic device, a discrete gate or transistor logic component, a discrete hardware component, or any combination thereof). In some implementations, the processor 502 may be configured to operate a memory array using a memory controller. In some other implementations, a memory controller may be integrated into the processor 502. The processor 502 may be configured to execute computer-readable instructions stored in a memory (e.g., the memory 504) to cause the device 500 to perform various functions of the present disclosure.

[00149] The memory 504 may include random access memory (RAM) and read-only memory (ROM). The memory 504 may store computer-readable, computer-executable code including instructions that, when executed by the processor 502 cause the device 500 to perform various functions described herein. The code may be stored in a non-transitory computer-readable medium such as system memory or another type of memory. In some implementations, the code may not be directly executable by the processor 502 but may cause a computer (e.g., when compiled and executed) to perform functions described herein. In

some implementations, the memory 504 may include, among other things, a basic I/O system (BIOS) which may control basic hardware or software operation such as the interaction with peripheral components or devices.

[00150] The I/O controller 508 may manage input and output signals for the device 500.

5 The I/O controller 508 may also manage peripherals not integrated into the device 500. In some implementations, the I/O controller 508 may represent a physical connection or port to an external peripheral. In some implementations, the I/O controller 508 may utilize an operating system such as iOS®, ANDROID®, MS-WINDOWS®, OS/2®, UNIX®, LINUX®, or another known operating system. In some implementations, the I/O controller
10 508 may be implemented as part of a processor, such as the processor 502. In some implementations, a user may interact with the device 500 via the I/O controller 508 or via hardware components controlled by the I/O controller 508.

[00151] In some implementations, the device 500 may include a single antenna 510.

However, in some other implementations, the device 500 may have more than one antenna
15 510 (i.e., multiple antennas), including multiple antenna panels or antenna arrays, which may be capable of concurrently transmitting or receiving multiple wireless transmissions. The transceiver 506 may communicate bi-directionally, via the one or more antennas 510, wired, or wireless links as described herein. For example, the transceiver 506 may represent a wireless transceiver and may communicate bi-directionally with another wireless transceiver.
20 The transceiver 506 may also include a modem to modulate the packets, to provide the modulated packets to one or more antennas 510 for transmission, and to demodulate packets received from the one or more antennas 510. The transceiver 506 may include one or more transmit chains, one or more receive chains, or a combination thereof.

[00152] A transmit chain may be configured to generate and transmit signals (e.g., control

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

[00153] A receive chain may be configured to receive signals (e.g., control information, data, packets) over a wireless medium. For example, the receive chain may include one or more antennas 510 for receive the signal over the air or wireless medium. The receive chain may include at least one amplifier (e.g., a low-noise amplifier (LNA)) configured to amplify the received signal. The receive chain may include at least one demodulator configured to demodulate the receive signal and obtain the transmitted data by reversing the modulation technique applied during transmission of the signal. The receive chain may include at least one decoder for decoding the processing the demodulated signal to receive the transmitted data.

[00154] FIG. 6 illustrates an example of a processor 600 that is suitable for implementing some embodiments of the present disclosure. The processor 600 may be an example of a processor configured to perform various operations in accordance with examples as described herein. The processor 600 may include a controller 602 configured to perform various operations in accordance with examples as described herein. The processor 600 may optionally include at least one memory 604, such as L1/L2/L3 cache. Additionally, or alternatively, the processor 600 may optionally include one or more arithmetic-logic units (ALUs) 606. One or more of these components may be in electronic communication or otherwise coupled (e.g., operatively, communicatively, functionally, electronically, electrically) via one or more interfaces (e.g., buses).

[00155] The processor 600 may be a processor chipset and include a protocol stack (e.g., a software stack) executed by the processor chipset to perform various operations (e.g., receiving, obtaining, retrieving, transmitting, outputting, forwarding, storing, determining, identifying, accessing, writing, reading) in accordance with examples as described herein. The processor chipset may include one or more cores, one or more caches (e.g., memory local to or included in the processor chipset (e.g., the processor 600) or other memory (e.g., random access memory (RAM), read-only memory (ROM), dynamic RAM (DRAM), synchronous dynamic RAM (SDRAM), static RAM (SRAM), ferroelectric RAM (FeRAM), magnetic RAM (MRAM), resistive RAM (RRAM), flash memory, phase change memory (PCM), and others).

[00156] The controller 602 may be configured to manage and coordinate various operations (e.g., signaling, receiving, obtaining, retrieving, transmitting, outputting, forwarding, storing, determining, identifying, accessing, writing, reading) of the processor 600 to cause the processor 600 to support various operations in accordance with examples as described herein.

For example, the controller 602 may operate as a control unit of the processor 600, generating control signals that manage the operation of various components of the processor 600. These control signals include enabling or disabling functional units, selecting data paths, initiating memory access, and coordinating timing of operations.

5 **[00157]** The controller 602 may be configured to fetch (e.g., obtain, retrieve, receive) instructions from the memory 604 and determine subsequent instruction(s) to be executed to cause the processor 600 to support various operations in accordance with examples as described herein. The controller 602 may be configured to track memory address of instructions associated with the memory 604. The controller 602 may be configured to
10 decode instructions to determine the operation to be performed and the operands involved. For example, the controller 602 may be configured to interpret the instruction and determine control signals to be output to other components of the processor 600 to cause the processor 600 to support various operations in accordance with examples as described herein. Additionally, or alternatively, the controller 602 may be configured to manage flow of data
15 within the processor 600. The controller 602 may be configured to control transfer of data between registers, arithmetic logic units (ALUs), and other functional units of the processor 600.

[00158] The memory 604 may include one or more caches (e.g., memory local to or included in the processor 600 or other memory, such RAM, ROM, DRAM, SDRAM, SRAM, MRAM,
20 flash memory, etc. In some implementations, the memory 604 may reside within or on a processor chipset (e.g., local to the processor 600). In some other implementations, the memory 604 may reside external to the processor chipset (e.g., remote to the processor 600).

[00159] The memory 604 may store computer-readable, computer-executable code including instructions that, when executed by the processor 600, cause the processor 600 to perform
25 various functions described herein. The code may be stored in a non-transitory computer-readable medium such as system memory or another type of memory. The controller 602 and/or the processor 600 may be configured to execute computer-readable instructions stored in the memory 604 to cause the processor 600 to perform various functions. For example,
the processor 600 and/or the controller 602 may be coupled with or to the memory 604, the
30 processor 600, the controller 602, and the memory 604 may be configured to perform various functions described herein. In some examples, the processor 600 may include multiple processors and the memory 604 may include multiple memories. One or more of the multiple processors may be coupled with one or more of the multiple memories, which may,

individually or collectively, be configured to perform various functions herein.

[00160] The one or more ALUs 606 may be configured to support various operations in accordance with examples as described herein. In some implementations, the one or more ALUs 606 may reside within or on a processor chipset (e.g., the processor 600). In some other implementations, the one or more ALUs 606 may reside external to the processor chipset (e.g., the processor 600). One or more ALUs 606 may perform one or more computations such as addition, subtraction, multiplication, and division on data. For example, one or more ALUs 606 may receive input operands and an operation code, which determines an operation to be executed. One or more ALUs 606 be configured with a variety of logical and arithmetic circuits, including adders, subtractors, shifters, and logic gates, to process and manipulate the data according to the operation. Additionally, or alternatively, the one or more ALUs 606 may support logical operations such as AND, OR, exclusive-OR (XOR), not-OR (NOR), and not-AND (NAND), enabling the one or more ALUs 606 to handle conditional operations, comparisons, and bitwise operations.

[00161] The processor 600 may support wireless communication in accordance with examples as disclosed herein. The processor 600 may be configured to or operable to support a means for operations described in some embodiments of the present disclosure.

[00162] FIG. 7 illustrates a flowchart of a method 700 performed by a UE in accordance with aspects of the present disclosure. The operations of the method 700 may be implemented by a device or its components as described herein. For example, the operations of the method 700 may be performed by the UE 220 in FIG. 2. In some implementations, the device may execute a set of instructions to control the function elements of the device to perform the described functions. Additionally, or alternatively, the device may perform aspects of the described functions using special-purpose hardware.

[00163] At 710, the method may include receiving, from a first base station, a configuration of a phase offset report for reciprocity calibration, wherein the configuration indicates a CMR and associated SRS resource, and wherein the CMR comprises a resource set for a plurality of CSI-RS resources. The operations of 710 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of 710 may be performed by the UE 220 as described with reference to FIG. 2.

[00164] At 720, the method may include determining, based on the configuration, a DL phase offset between the first base station and a second base station upon a reception of a first CSI-

RS resource from the first base station and a second CSI-RS resource from the second base station. The operations of 720 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of 720 may be performed by the UE 220 as described with reference to FIG. 2.

5 **[00165]** At 730, the method may include transmitting, to each of the first base station and the second base station, a CSI report comprising the DL phase offset. The operations of 730 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of 730 may be performed by the UE 220 as described with reference to FIG. 2.

10 **[00166]** At 740, the method may include transmitting, to each of the first base station and the second base station, at least one SRS resource based on the configuration. The operations of 740 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of 740 may be performed by the UE 220 as described with reference to FIG. 2.

15 **[00167]** FIG. 8 illustrates a flowchart of a method 800 performed by a base station in accordance with aspects of the present disclosure. The operations of the method 800 may be implemented by a device or its components as described herein. For example, the operations of the method 800 may be performed by the BS 210 in FIG. 2. In some implementations, the device may execute a set of instructions to control the function elements
20 of the device to perform the described functions. Additionally, or alternatively, the device may perform aspects of the described functions using special-purpose hardware.

[00168] At 810, the method may include transmitting, to a UE, a configuration of a phase offset report for reciprocity calibration, wherein the configuration indicates a CMR and associated SRS resource, and wherein the CMR comprises a resource set for a plurality of
25 CSI-RS resources. The operations of 810 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of 810 may be performed by the BS 210 as described with reference to FIG. 2.

[00169] At 820, the method may include receiving, from the UE, a CSI report comprising a DL phase offset between the base station and a second base station. The operations of 820
30 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of 820 may be performed by the BS 210 as described with reference to FIG. 2.

[00170] At 830, the method may include determining a UL phase offset based on at least one SRS resource from the UE and an SRS resource from the UE to the second base station. The operations of 830 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of 830 may be performed by the BS 210 as described with reference to FIG. 2.

[00171] At 840, the method may include determining a reciprocity calibration factor based on the DL phase offset and the UL phase offset. The operations of 840 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of 840 may be performed by the BS 210 as described with reference to FIG. 2.

[00172] FIG. 9 illustrates a flowchart of a method 900 performed by a UE in accordance with aspects of the present disclosure. The operations of the method 900 may be implemented by a device or its components as described herein. For example, the operations of the method 900 may be performed by the UE 220 in FIG. 2. In some implementations, the device may execute a set of instructions to control the function elements of the device to perform the described functions. Additionally, or alternatively, the device may perform aspects of the described functions using special-purpose hardware.

[00173] At 910, the method may include receiving, from a base station, a configuration of a joint delay offset and frequency offset report, wherein the configuration indicates a CMR which comprises a resource set for a plurality of TRS or CSI-RS resources. The operations of 910 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of 910 may be performed by the UE 220 as described with reference to FIG. 2.

[00174] At 920, the method may include receiving, from a plurality of TRPs, the plurality of TRS or CSI-RS resources respectively based on the configuration. The operations of 920 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of 920 may be performed by the UE 220 as described with reference to FIG. 2.

[00175] At 930, the method may include transmitting, to the base station, a CSI report comprising at least one of a delay offset or a frequency offset for the plurality of TRPs. The operations of 930 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of 930 may be performed by the UE 220 as described with reference to FIG. 2.

[00176] FIG. 10 illustrates a flowchart of a method 1000 performed by a base station in accordance with aspects of the present disclosure. The operations of the method 1000 may be implemented by a device or its components as described herein. For example, the operations of the method 1000 may be performed by the BS 210 in FIG. 2. In some
5 implementations, the device may execute a set of instructions to control the function elements of the device to perform the described functions. Additionally, or alternatively, the device may perform aspects of the described functions using special-purpose hardware.

[00177] At 1010, the method may include transmitting, to a UE, a configuration of a joint delay offset and frequency offset report, wherein the configuration indicates a CMR which
10 comprises a resource set for a plurality of TRS or CSI-RS resources. The operations of 1010 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of 1010 may be performed by the BS 210 as described with reference to FIG. 2.

[00178] At 1020, the method may include receiving, from the UE, a CSI report comprising
15 at least one of a delay offset or a frequency offset for the plurality of TRPs. The operations of 1020 may be performed in accordance with examples as described herein. In some implementations, aspects of the operations of 1020 may be performed by the BS 210 as described with reference to FIG. 2.

[00179] It should be noted that the methods described herein describes possible
20 implementations, and that the operations and the steps may be rearranged or otherwise modified and that other implementations are possible. Further, aspects from two or more of the methods may be combined.

[00180] The various illustrative blocks and components described in connection with the disclosure herein may be implemented or performed with a general-purpose processor, a DSP,
25 an ASIC, a CPU, an FPGA or other programmable logic device, discrete gate or transistor logic, discrete hardware components, or any combination thereof designed to perform the functions described herein. A general-purpose processor may be a microprocessor, but in the alternative, the processor may be any processor, controller, microcontroller, or state machine. A processor may also be implemented as a combination of computing devices
30 (e.g., a combination of a DSP and a microprocessor, multiple microprocessors, one or more microprocessors in conjunction with a DSP core, or any other such configuration.

[00181] The functions described herein may be implemented in hardware, software executed

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

[00182] Computer-readable media includes both non-transitory computer storage media and communication media including any medium that facilitates transfer of a computer program from one place to another. A non-transitory storage medium may be any available medium that may be accessed by a general-purpose or special-purpose computer. By way of example, non-transitory computer-readable media may include RAM, ROM, electrically erasable programmable ROM (EEPROM), flash memory, compact disk (CD) ROM or other optical disk storage, magnetic disk storage or other magnetic storage devices, or any other non-transitory medium that may be used to carry or store desired program code means in the form of instructions or data structures and that may be accessed by a general-purpose or special-purpose computer, or a general-purpose or special-purpose processor.

[00183] As used herein, including in the claims, an article “a” before an element is unrestricted and understood to refer to “at least one” of those elements or “one or more” of those elements. The terms “a,” “at least one,” “one or more,” and “at least one of one or more” may be interchangeable. As used herein, including in the claims, “or” as used in a list of items (e.g., a list of items prefaced by a phrase such as “at least one of” or “one or more of” or “one or both of”) indicates an inclusive list such that, for example, a list of at least one of A, B, or C means A or B or C or AB or AC or BC or ABC (i.e., A and B and C). Also, as used herein, the phrase “based on” shall not be construed as a reference to a closed set of conditions. For example, an example step that is described as “based on condition A” may be based on both a condition A and a condition B without departing from the scope of the present disclosure. In other words, as used herein, the phrase “based on” shall be construed in the same manner as the phrase “based at least in part on.” Further, as used herein, including in the claims, a “set” may include one or more elements.

[00184] The description herein is provided to enable a person having ordinary skill in the art to make or use the disclosure. Various modifications to the disclosure will be apparent to a

person having ordinary skill in the art, and the generic principles defined herein may be applied to other variations without departing from the scope of the disclosure. Thus, the disclosure is not limited to the examples and designs described herein but is to be accorded the broadest scope consistent with the principles and novel features disclosed herein.

CLAIMS

What is claimed is:

1. A user equipment (UE) comprising:

at least one memory; and

5 at least one processor coupled with the at least one memory and configured to cause the UE to:

receive, from a base station, a configuration of a joint delay offset and frequency offset report, wherein the configuration indicates a channel measurement resource (CMR) which comprises a resource set for a plurality of tracking reference signal (TRS) or channel state information (CSI) reference signal (RS) resources;

10 receive, from a plurality of transmission reception points (TRP), the plurality of TRS or CSI-RS resources respectively based on the configuration; and

transmit, to the base station, a CSI report comprising at least one of a delay offset or a frequency offset for the plurality of TRPs.

15

2. The UE of claim 1, wherein each of the plurality of TRS or CSI-RS resources is transmitted for multiple times in multiple adjacent slots.

3. The UE of claim 2, wherein a first slot in the multiple adjacent slots is determined based on a triggering offset configured for the resource set.

20

4. The UE of claim 2, wherein the plurality of TRS or CSI-RS resources for a time among the multiple times are transmitted in a same slot.

5. The UE of claim 1, wherein the plurality of TRS or CSI-RS resources are transmitted in a plurality of adjacent slots respectively.

25

6. The UE of claim 5, wherein one of the plurality of TRS or CSI-RS resources is transmitted for multiple times in multiple symbols of a same slot.

30

7. The UE of claim 1, wherein each of the plurality of TRS or CSI-RS resources is transmitted for multiple times in multiple symbols of a specific slot.

8. The UE of claim 1, wherein the plurality of TRS or CSI-RS resources comprise multiple groups of TRS or CSI-RS resources, the multiple groups of TRS or CSI-RS resources are transmitted in multiple adjacent slots respectively.

5 9. The UE of claim 1, wherein the CSI report comprises a frequency offset, and wherein each of the plurality of TRS or CSI-RS resources is quasi co-located (QCLed) with a synchronization signal block (SSB) or a further TRS with a QCL parameter of Doppler shift and/or Doppler spread.

10 10. The UE of claim 1, wherein the CSI report comprises a delay offset, and wherein each of the plurality of TRS or CSI-RS resources is QCLed with an SSB or a further TRS with a QCL parameter of average delay and/or delay spread.

15 11. The UE of claim 1, wherein the CSI report comprises both delay and frequency offsets, and wherein each of the plurality of TRS or CSI-RS resources is QCLed with an SSB or a further TRS with a QCL parameter of at least one of: Doppler shift, Doppler spread, average delay, or delay spread.

20 12. The UE of claim 1, wherein a number of CSI processing units (CPU) used for the CSI report is determined based on a number of the plurality of TRPs and a parameter associated with a capability of the UE.

25 13. A base station comprising:
at least one memory; and
at least one processor coupled with the at least one memory and configured to cause the base station to:
transmit, to a user equipment (UE), a configuration of a joint delay offset and frequency offset report, wherein the configuration indicates a channel measurement resource (CMR) which comprises a resource set for a plurality of tracking reference signal (TRS) or channel state information (CSI) reference signal (RS) resources; and
30 receive, from the UE, a CSI report comprising at least one of a delay offset or a frequency offset for the plurality of TRPs.

14. The base station of claim 13, wherein each of the plurality of TRS or CSI-RS

resources is transmitted for multiple times in multiple adjacent slots.

15. The base station of claim 13, wherein the plurality of TRS or CSI-RS resources are transmitted in a plurality of adjacent slots respectively.

5

16. The base station of claim 13, wherein each of the plurality of TRS or CSI-RS resources is transmitted for multiple times in multiple symbols of a specific slot.

17. The base station of claim 13, wherein the plurality of TRS or CSI-RS resources
10 comprise multiple groups of TRS or CSI-RS resources, the multiple groups of TRS or CSI-RS resources are transmitted in multiple adjacent slots respectively.

18. The base station of claim 13, wherein the CSI report comprises a frequency
offset, and wherein each of the plurality of TRS or CSI-RS resources is quasi co-located
15 (QCLed) with a synchronization signal block (SSB) or a further TRS with a QCL parameter of Doppler shift and/or Doppler spread.

19. The base station of claim 13, wherein the CSI report comprises a delay offset,
and wherein each of the plurality of TRS or CSI-RS resources is QCLed with an SSB or a
20 further TRS with a QCL parameter of average delay and/or delay spread.

20. The base station of claim 13, wherein the CSI report comprises both delay and
frequency offsets, and wherein each of the plurality of TRS or CSI-RS resources is QCLed
with an SSB or a further TRS with a QCL parameter of at least one of: Doppler shift, Doppler
25 spread, average delay, or delay spread.

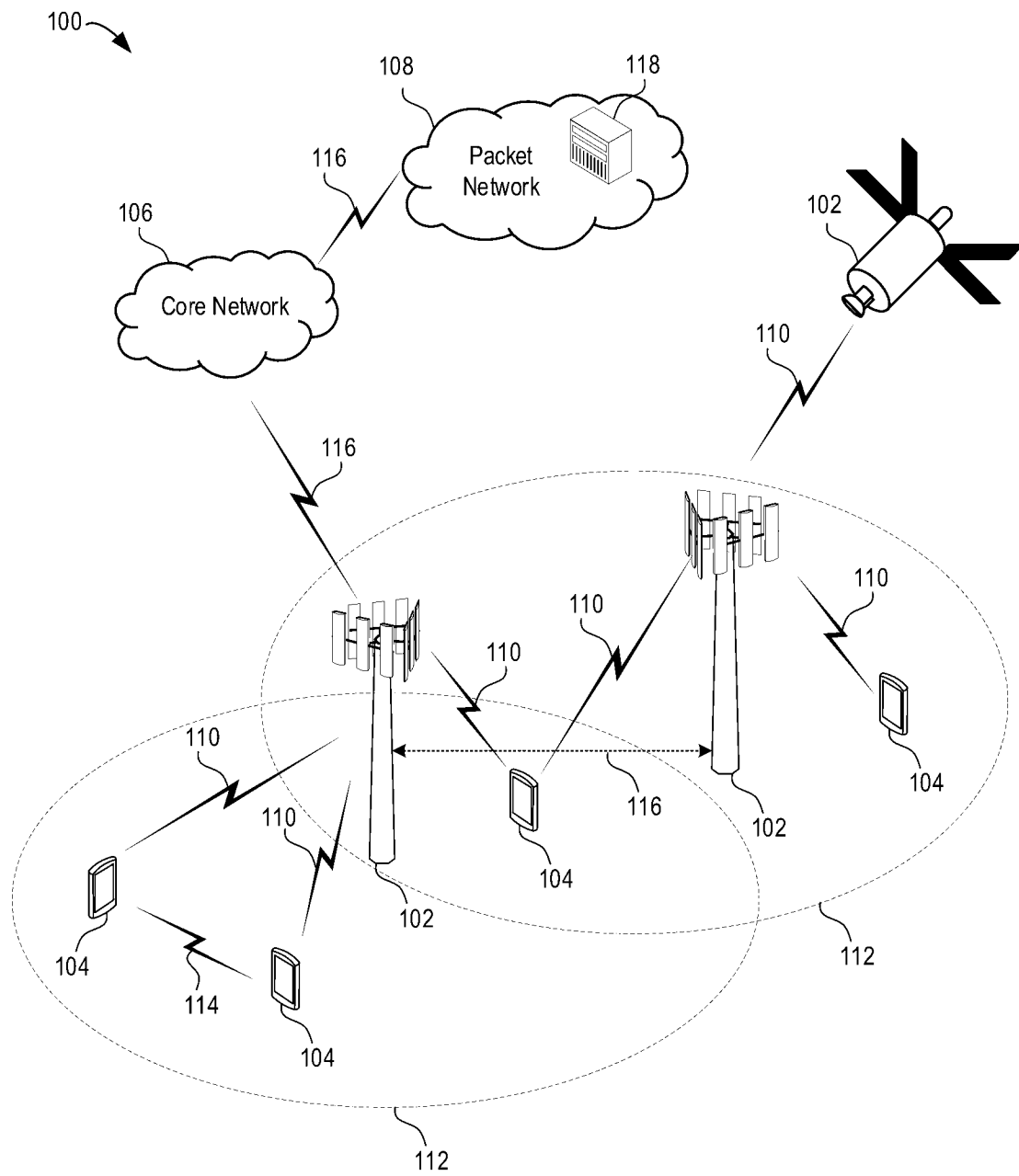


FIG. 1

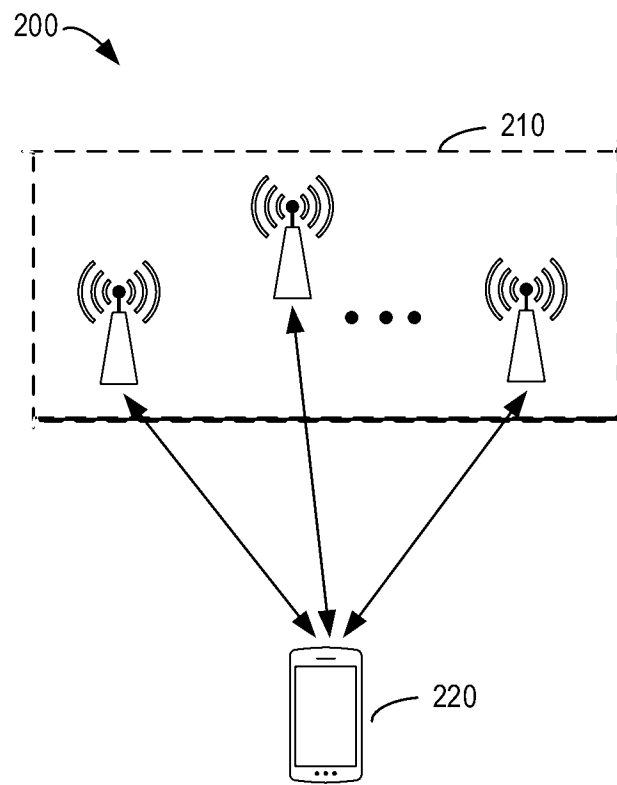


FIG. 2

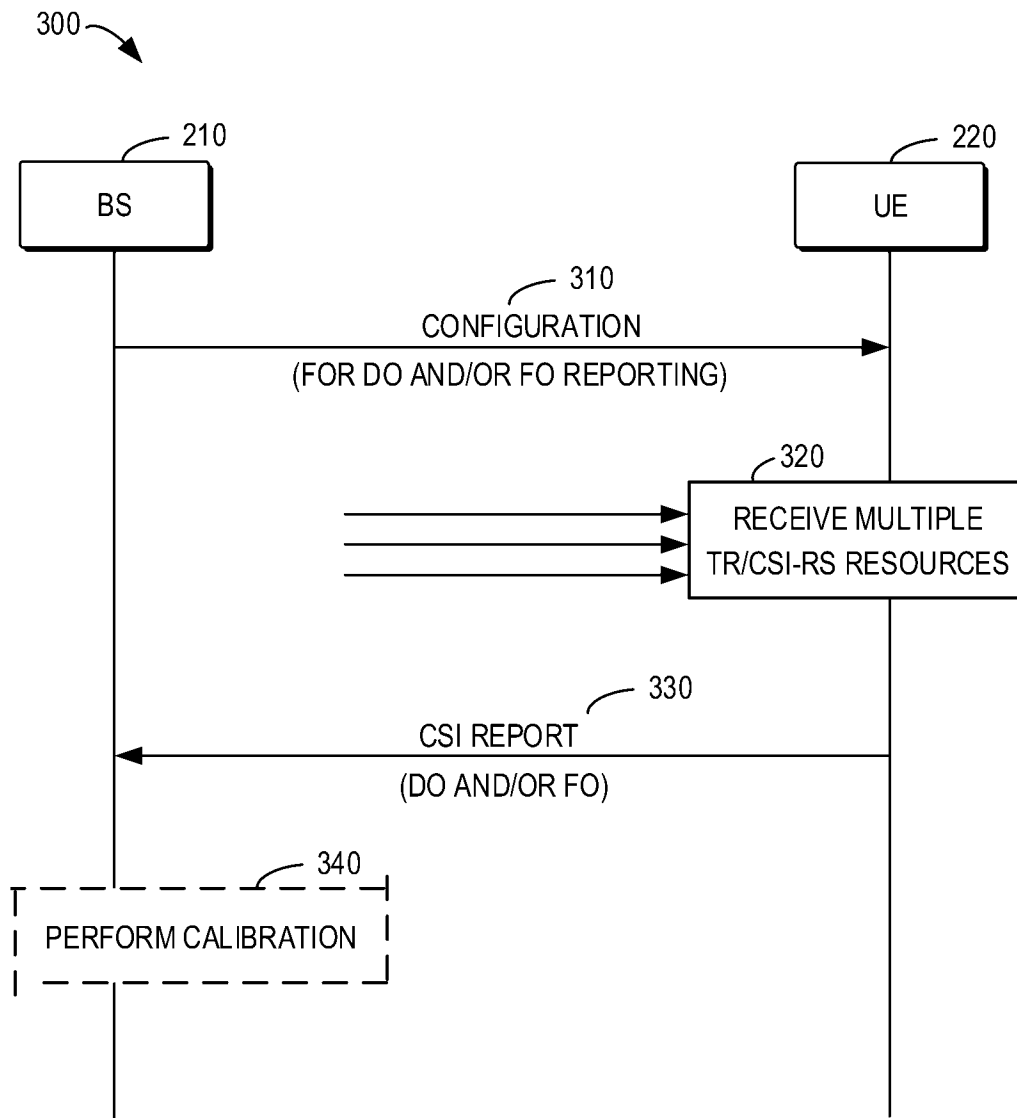


FIG. 3

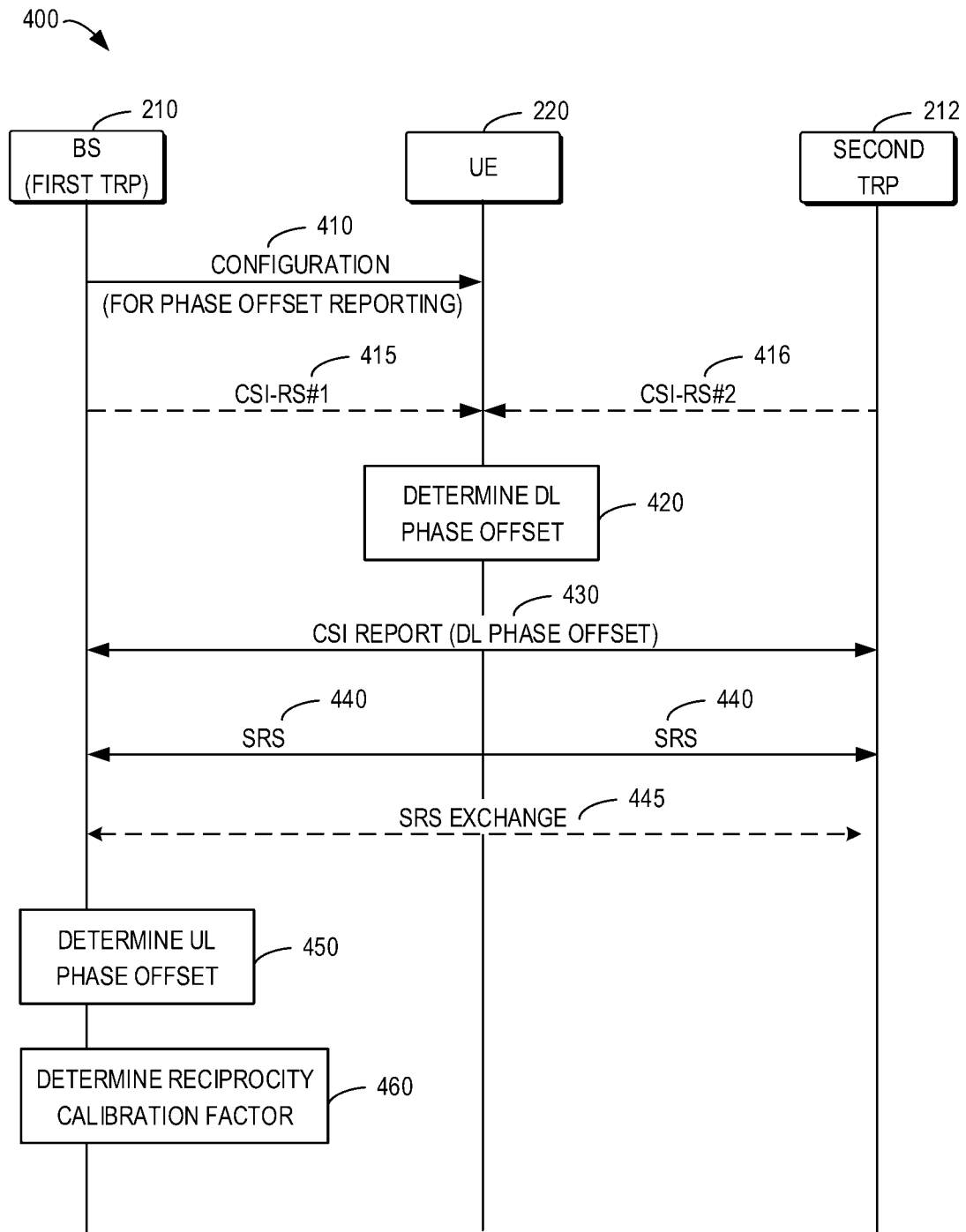


FIG. 4

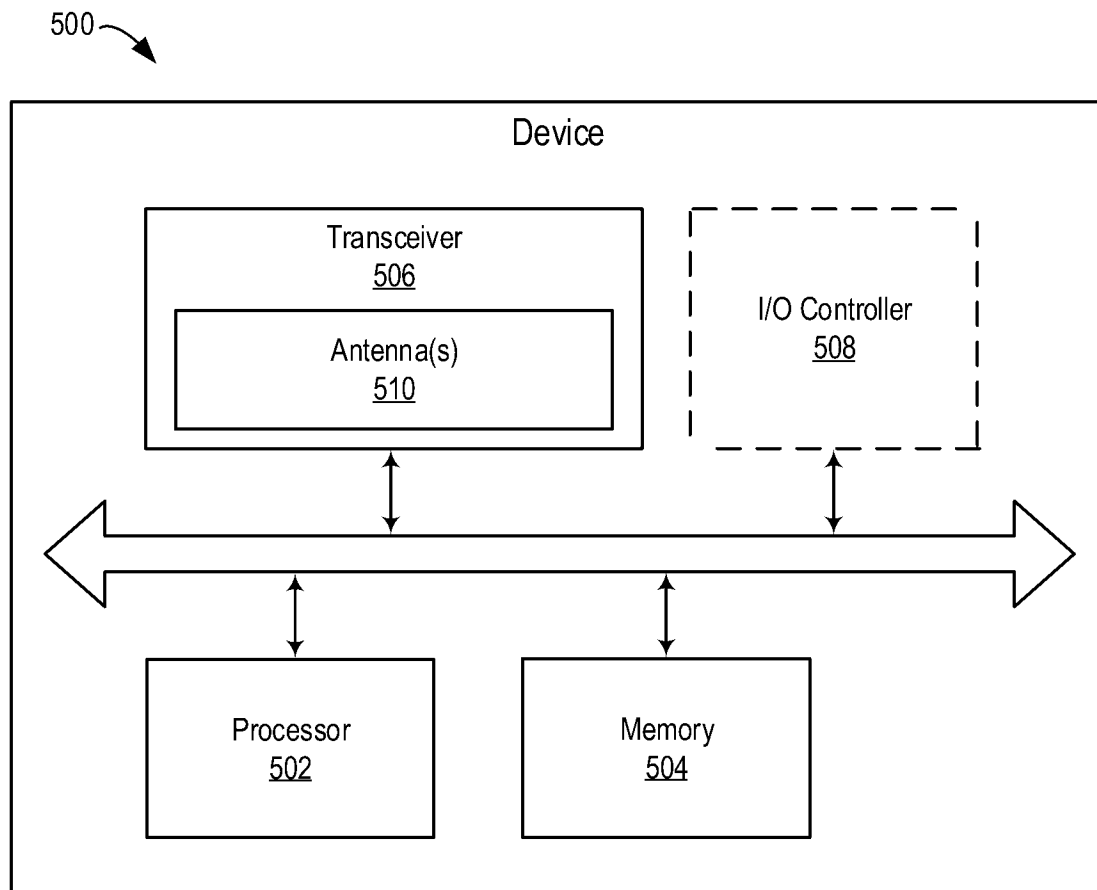


FIG. 5

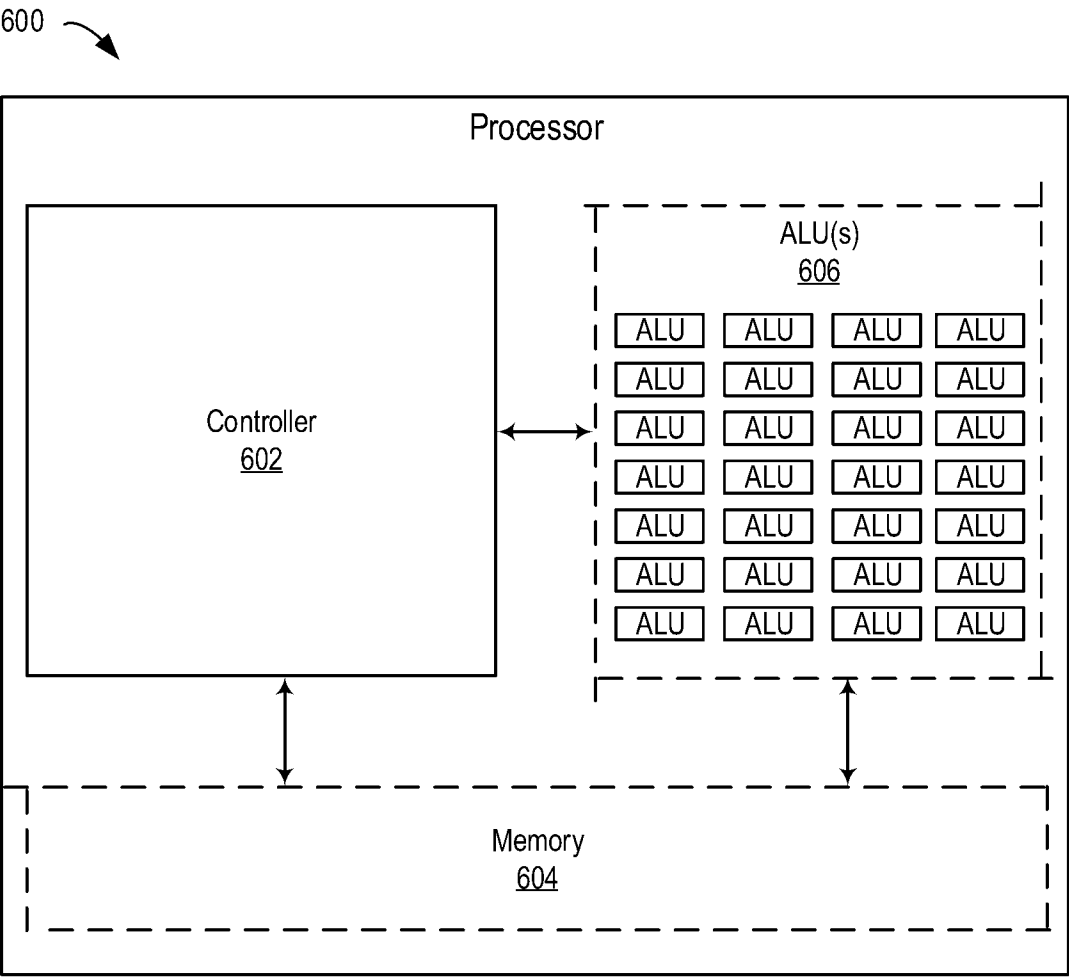


FIG. 6

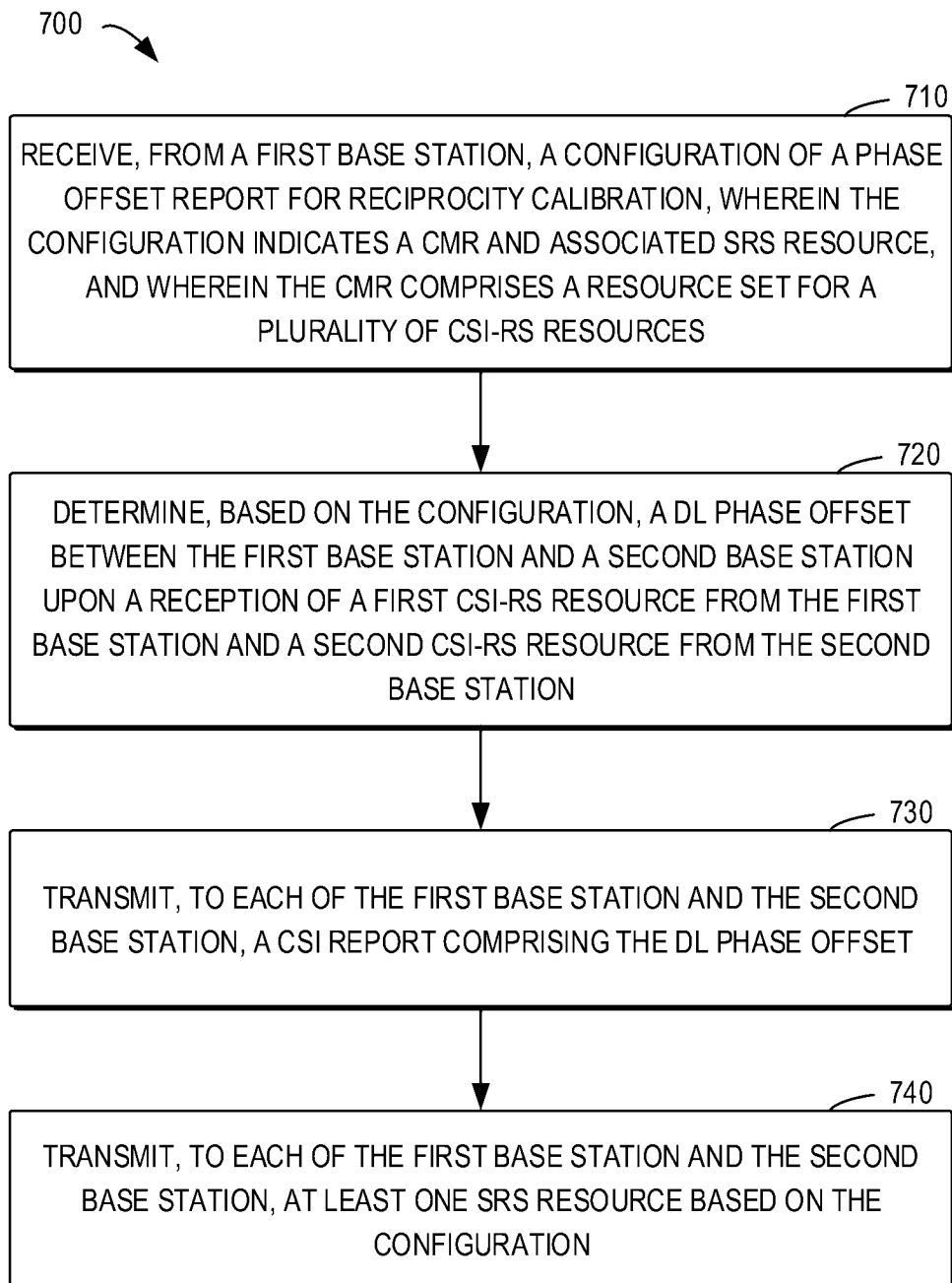


FIG. 7

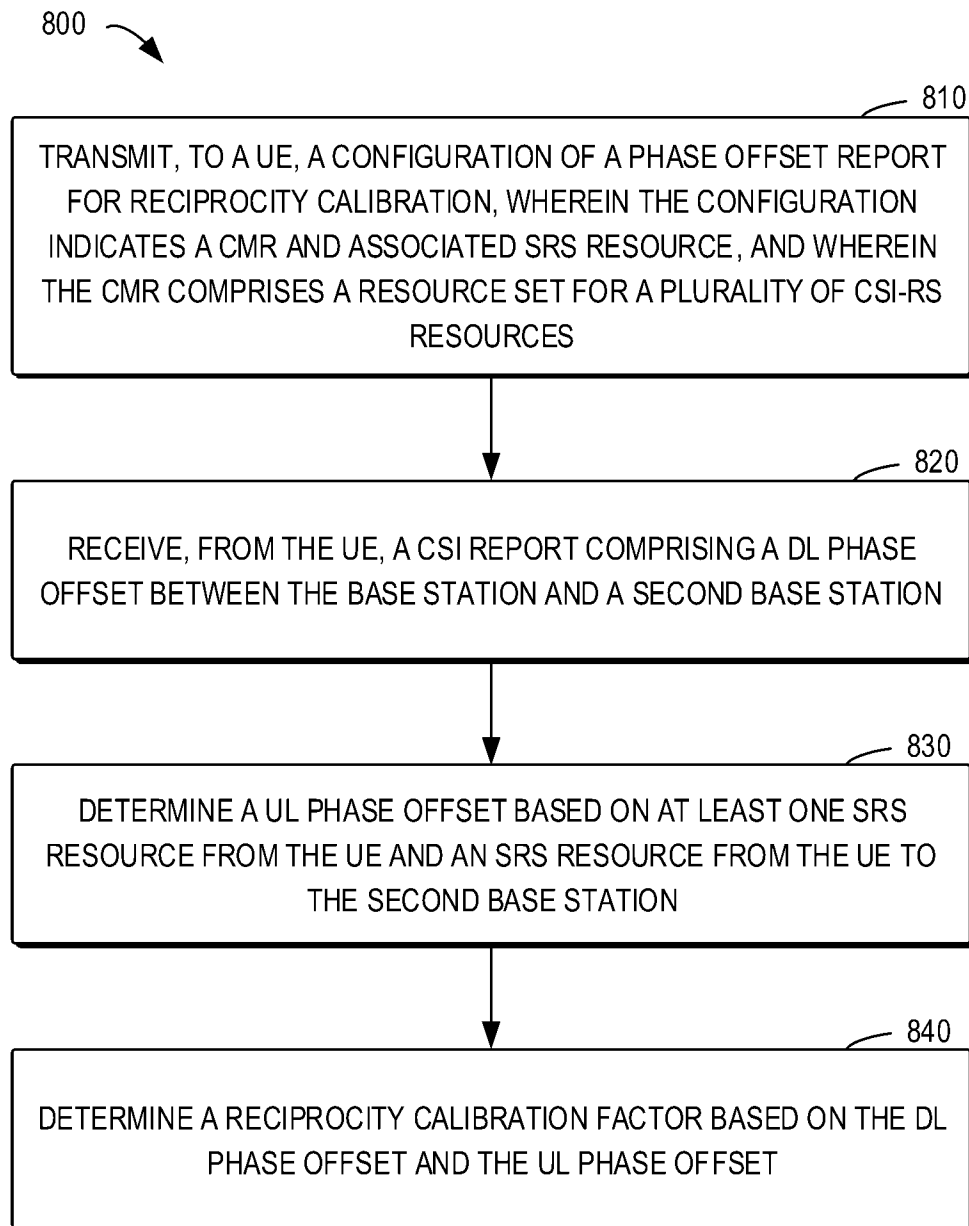


FIG. 8

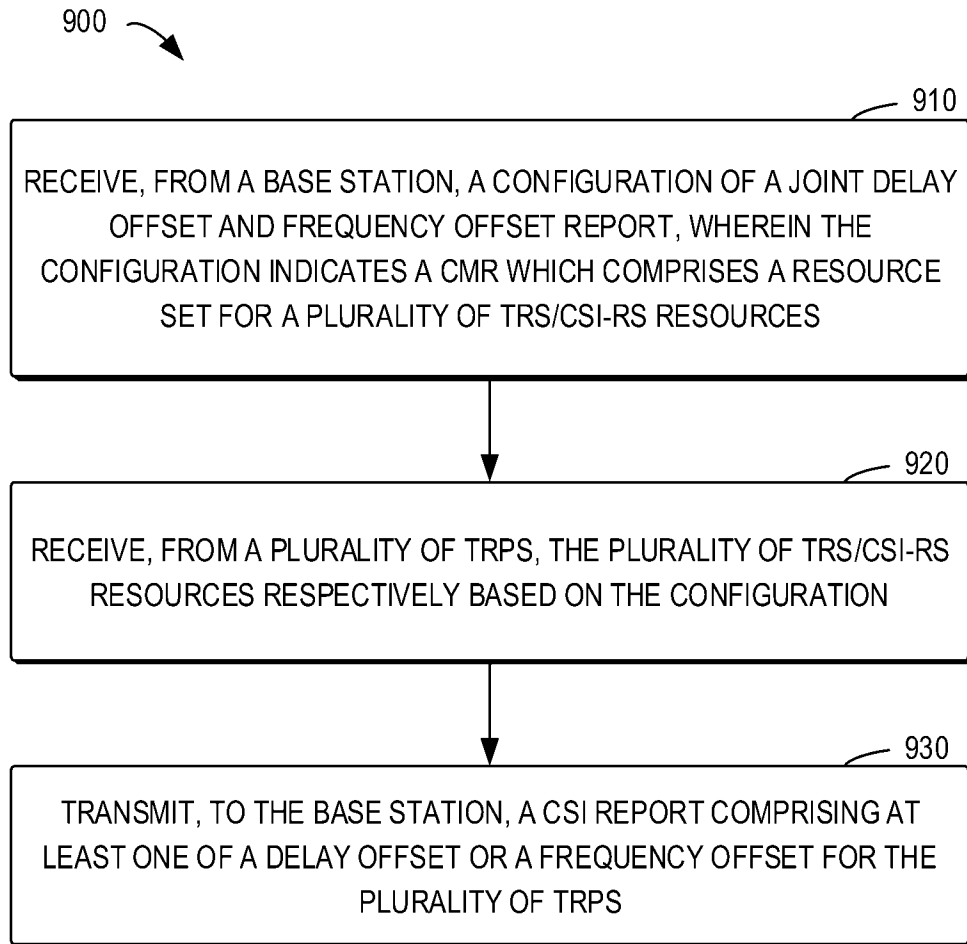


FIG. 9

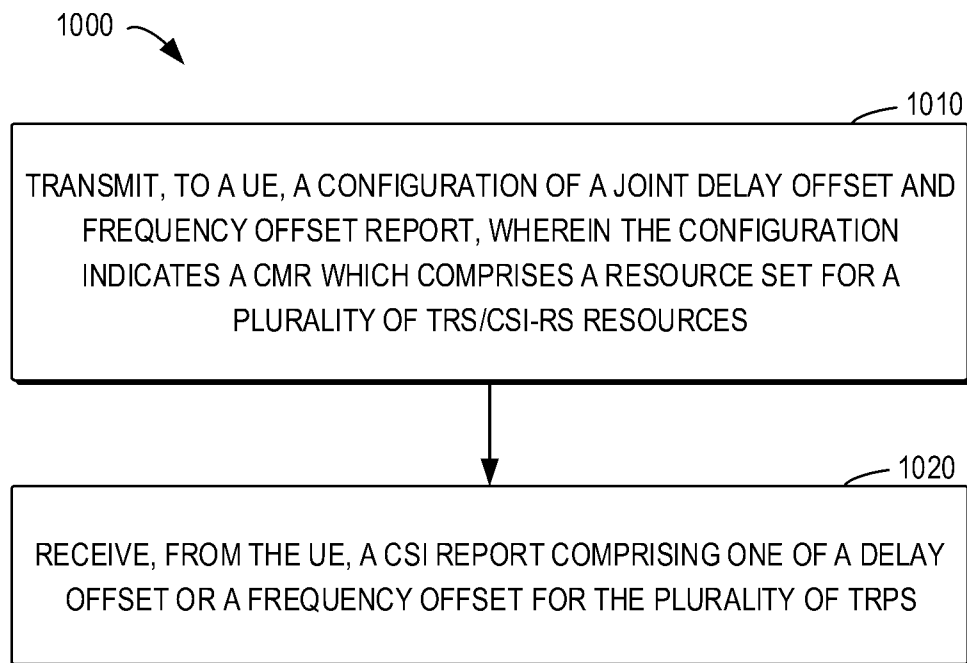


FIG. 10

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2024/085195

A. CLASSIFICATION OF SUBJECT MATTER

H04B7/06(2006.01)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)

IPC: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)

3GPP,DWPL,VCN,VEN:calibration, CMR, CSI, delay, frequency, offset, plurality, reception, RRHs, transmission, TRS, point?, report+, TRP?, CRI-RS, multi+, synchroni+

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2023239025 A1 (LG ELECTRONICS INC.) 27 July 2023 (2023-07-27) description, paragraphs 34-449, and figures 1-13	1-20
A	WO 2024031683 A1 (GOOGLE LLC) 15 February 2024 (2024-02-15) the whole document	1-20
A	NOKIA et al. "Enhancements for HST-SFN deployment" 3GPP TSG RAN WG1 #105-e Meeting R1-2108056, 27 August 2021 (2021-08-27), the whole document	1-20

☐ 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

"D" document cited by the applicant in the international application

"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

06 December 2024

Date of mailing of the international search report

23 December 2024

Name and mailing address of the ISA/CN

**CHINA NATIONAL INTELLECTUAL PROPERTY
ADMINISTRATION**
6, Xitucheng Rd., Jimen Bridge, Haidian District, Beijing
100088, China

Authorized officer

HU,RuiXian

Telephone No. (+86) 010-53961749

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CN2024/085195

Patent document cited in search report			Publication date (day/month/year)	Patent family member(s)			Publication date (day/month/year)
US	2023239025	A1	27 July 2023	KR	20230113128	A	28 July 2023
				EP	4216476	A1	26 July 2023
WO	2024031683	A1	15 February 2024	None			