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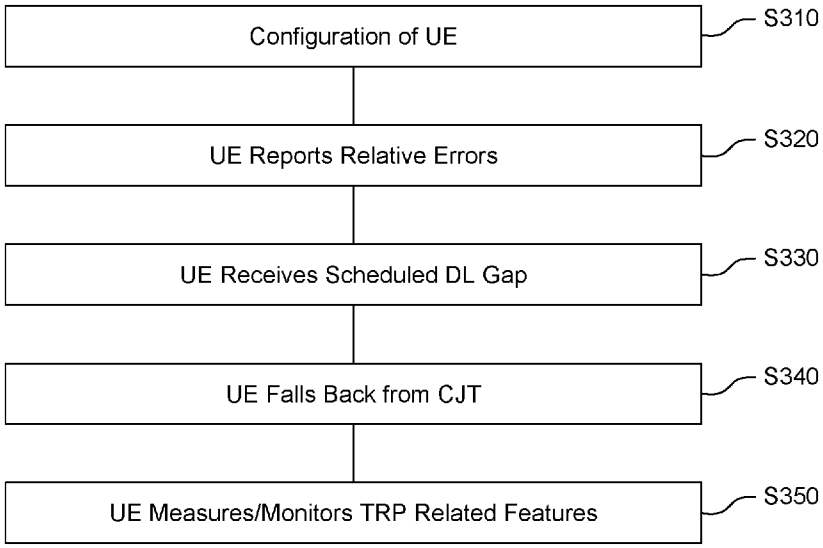


FIG. 3

(57) Abstract: Procedures, methods, architectures, apparatuses, systems, devices, and computer program products for transmission point relative error measurement and reporting are described. A wireless transmit/receive unit, WTRU, receives information indicative of a configuration for joint reception from a plurality of transmission points including a reference transmission point, and for reporting of measurements of relative errors related to received reference signals from at least one pair of transmission points of the plurality of transmission points, transmits information indicative of measured relative errors related to received reference signals from the at least one pair of transmission points, receives information indicative of at least one scheduled downlink gap, and during the at least one scheduled downlink gap, monitors received signals from a subset of the plurality of transmission points that satisfy a calibration condition.

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METHODS, ARCHITECTURES, APPARATUSES AND SYSTEMS FOR TRANSMISSION POINT RELATIVE ERROR MEASUREMENT AND REPORTING

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Provisional Application No. 63/609,947, filed 14 December 2023, which is incorporated herein by reference in its entirety.

BACKGROUND

[0002] The present disclosure is generally directed to the fields of communications, software and encoding, including, for example, to methods, architectures, apparatuses, systems directed to calibration of transmission/reception points using assistance from a wireless transmission/reception unit.

SUMMARY

[0003] In a first aspect, the present principles are directed to a method at a wireless transmit/receive unit, WTRU, comprising receiving information indicative of a configuration for joint reception from a plurality of transmission points including a reference transmission point, and for reporting of measurements of relative errors related to received reference signals from at least one pair of transmission points of the plurality of transmission points, transmitting information indicative of measured relative errors related to received reference signals from the at least one pair of transmission points, receiving information indicative of at least one scheduled downlink gap, and, during the at least one scheduled downlink gap, monitoring received signals from a subset of the plurality of transmission points that satisfy a calibration condition.

[0004] In a second aspect, the present principles are directed to a wireless transmit/receive unit, WTRU, comprising at least one processor configured to receive information indicative of a configuration for joint reception from a plurality of transmission points including a reference transmission point, and for reporting of measurements of relative errors related to received reference signals from at least one pair of transmission points of the plurality of transmission points, transmit information indicative of measured relative errors related to received reference signals from the at least one pair of transmission points, receive information indicative of at least one scheduled downlink gap, and, during the at least one scheduled downlink gap, monitor received signals from a subset of the plurality of transmission points that satisfy a calibration condition.

[0005] In a third aspect, the present principles are directed to a method at a wireless transmit/receive unit, WTRU, comprising receiving information indicative of a configuration for joint reception from a plurality of transmission points including a reference transmission point, and for reporting of measurements of relative errors related to received reference signals from at least one pair of transmission points of the plurality of transmission points, transmitting

information indicative of measured relative errors related to received reference signals from the at least one pair of transmission points, receiving information indicative of at least one scheduled downlink gap, during the at least one scheduled downlink gap, measuring received signals from the reference transmission point or a subset of the plurality of transmission points, and, after the at least one scheduled downlink gap, monitoring channel search spaces associated with the plurality of transmission points.

[0006] In a fourth aspect, the present principles are directed to a wireless transmit/receive unit, WTRU, comprising at least one processor configured to receive information indicative of a configuration for joint reception from a plurality of transmission points including a reference transmission point, and for reporting of measurements of relative errors related to received reference signals from at least one pair of transmission points of the plurality of transmission points, transmit information indicative of measured relative errors related to received reference signals from the at least one pair of transmission points, receive information indicative of at least one scheduled downlink gap, during the at least one scheduled downlink gap, measure received signals from the reference transmission point or a subset of the plurality of transmission points, and, after the at least one scheduled downlink gap, monitor channel search spaces associated with the plurality of transmission points.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] A more detailed understanding may be had from the detailed description below, given by way of example in conjunction with drawings appended hereto. Figures in such drawings, like the detailed description, are examples. As such, the Figures (FIGs.) and the detailed description are not to be considered limiting, and other equally effective examples are possible and likely. Furthermore, like reference numerals ("ref.") in the FIGs. indicate like elements, and wherein:

[0008] FIG. 1A is a system diagram illustrating an example communications system;

[0009] FIG. 1B is a system diagram illustrating an example wireless transmit/receive unit (WTRU) that may be used within the communications system illustrated in FIG. 1A;

[0010] FIG. 1C is a system diagram illustrating an example radio access network (RAN) and an example core network (CN) that may be used within the communications system illustrated in FIG. 1A;

[0011] FIG. 1D is a system diagram illustrating a further example RAN and a further example CN that may be used within the communications system illustrated in FIG. 1A;

[0012] FIG. 2 that receives and jointly demodulates PDSCH data coherently transmitted from two TRPs that are assumed synchronized in time and frequency;

[0013] FIG. 3 illustrates a flow chart of a method according to a first embodiment of the present principles;

[0014] FIG. 4 illustrates a flow chart of a method according to a second embodiment of the present principles; and

[0015] FIG. 5 illustrates the principle of special calibration SRS transmission according to the present principles.

DETAILED DESCRIPTION

[0016] In the following detailed description, numerous specific details are set forth to provide a thorough understanding of embodiments and/or examples disclosed herein. However, it will be understood that such embodiments and examples may be practiced without some or all of the specific details set forth herein. In other instances, well-known methods, procedures, components and circuits have not been described in detail, so as not to obscure the following description. Further, embodiments and examples not specifically described herein may be practiced in lieu of, or in combination with, the embodiments and other examples described, disclosed or otherwise provided explicitly, implicitly and/or inherently (collectively "provided") herein. Although various embodiments are described and/or claimed herein in which an apparatus, system, device, etc. and/or any element thereof carries out an operation, process, algorithm, function, etc. and/or any portion thereof, it is to be understood that any embodiments described and/or claimed herein assume that any apparatus, system, device, etc. and/or any element thereof is configured to carry out any operation, process, algorithm, function, etc. and/or any portion thereof.

[0017] **Example Communications System**

[0018] The methods, apparatuses and systems provided herein are well-suited for communications involving both wired and wireless networks. An overview of various types of wireless devices and infrastructure is provided with respect to FIGs. 1A-1D, where various elements of the network may utilize, perform, be arranged in accordance with and/or be adapted and/or configured for the methods, apparatuses and systems provided herein.

[0019] FIG. 1A is a system diagram illustrating an example communications system 100 in which one or more disclosed embodiments may be implemented. The communications system 100 may be a multiple access system that provides content, such as voice, data, video, messaging, broadcast, etc., to multiple wireless users. The communications system 100 may enable multiple wireless users to access such content through the sharing of system resources, including wireless bandwidth. For example, the communications systems 100 may employ one or more channel access methods, such as code division multiple access (CDMA), time division multiple access (TDMA), frequency division multiple access (FDMA), orthogonal FDMA (OFDMA), single-

carrier FDMA (SC-FDMA), zero-tail (ZT) unique-word (UW) discreet Fourier transform (DFT) spread OFDM (ZT UW DTS-s OFDM), unique word OFDM (UW-OFDM), resource block-filtered OFDM, filter bank multicarrier (FBMC), and the like.

[0020] As shown in FIG. 1A, the communications system 100 may include wireless transmit/receive units (WTRUs) 102a, 102b, 102c, 102d, a radio access network (RAN) 104/113, a core network (CN) 106/115, a public switched telephone network (PSTN) 108, the Internet 110, and other networks 112, though it will be appreciated that the disclosed embodiments contemplate any number of WTRUs, base stations, networks, and/or network elements. Each of the WTRUs 102a, 102b, 102c, 102d may be any type of device configured to operate and/or communicate in a wireless environment. By way of example, the WTRUs 102a, 102b, 102c, 102d, any of which may be referred to as a "station" and/or a "STA", may be configured to transmit and/or receive wireless signals and may include (or be) a user equipment (UE), a mobile station, a fixed or mobile subscriber unit, a subscription-based unit, a pager, a cellular telephone, a personal digital assistant (PDA), a smartphone, a laptop, a netbook, a personal computer, a wireless sensor, a hotspot or Mi-Fi device, an Internet of Things (IoT) device, a watch or other wearable, a head-mounted display (HMD), a vehicle, a drone, a medical device and applications (e.g., remote surgery), an industrial device and applications (e.g., a robot and/or other wireless devices operating in an industrial and/or an automated processing chain contexts), a consumer electronics device, a device operating on commercial and/or industrial wireless networks, and the like. Any of the WTRUs 102a, 102b, 102c and 102d may be interchangeably referred to as a UE.

[0021] The communications systems 100 may also include a base station 114a and/or a base station 114b. Each of the base stations 114a, 114b may be any type of device configured to wirelessly interface with at least one of the WTRUs 102a, 102b, 102c, 102d, e.g., to facilitate access to one or more communication networks, such as the CN 106/115, the Internet 110, and/or the networks 112. By way of example, the base stations 114a, 114b may be any of a base transceiver station (BTS), a Node-B (NB), an eNode-B (eNB), a Home Node-B (HNB), a Home eNode-B (HeNB), a gNode-B (gNB), a NR Node-B (NR NB), a site controller, an access point (AP), a wireless router, and the like. While the base stations 114a, 114b are each depicted as a single element, it will be appreciated that the base stations 114a, 114b may include any number of interconnected base stations and/or network elements.

[0022] The base station 114a may be part of the RAN 104/113, which may also include other base stations and/or network elements (not shown), such as a base station controller (BSC), a radio network controller (RNC), relay nodes, etc. The base station 114a and/or the base station 114b may be configured to transmit and/or receive wireless signals on one or more carrier frequencies, which may be referred to as a cell (not shown). These frequencies may be in licensed spectrum,

unlicensed spectrum, or a combination of licensed and unlicensed spectrum. A cell may provide coverage for a wireless service to a specific geographical area that may be relatively fixed or that may change over time. The cell may further be divided into cell sectors. For example, the cell associated with the base station 114a may be divided into three sectors. Thus, in an embodiment, the base station 114a may include three transceivers, i.e., one for each sector of the cell. In an embodiment, the base station 114a may employ multiple-input multiple output (MIMO) technology and may utilize multiple transceivers for each or any sector of the cell. For example, beamforming may be used to transmit and/or receive signals in desired spatial directions.

[0023] The base stations 114a, 114b may communicate with one or more of the WTRUs 102a, 102b, 102c, 102d over an air interface 116, which may be any suitable wireless communication link (e.g., radio frequency (RF), microwave, centimeter wave, micrometer wave, infrared (IR), ultraviolet (UV), visible light, etc.). The air interface 116 may be established using any suitable radio access technology (RAT).

[0024] More specifically, as noted above, the communications system 100 may be a multiple access system and may employ one or more channel access schemes, such as CDMA, TDMA, FDMA, OFDMA, SC-FDMA, and the like. For example, the base station 114a in the RAN 104/113 and the WTRUs 102a, 102b, 102c may implement a radio technology such as Universal Mobile Telecommunications System (UMTS) Terrestrial Radio Access (UTRA), which may establish the air interface 116 using wideband CDMA (WCDMA). WCDMA may include communication protocols such as High-Speed Packet Access (HSPA) and/or Evolved HSPA (HSPA+). HSPA may include High-Speed Downlink Packet Access (HSDPA) and/or High-Speed Uplink Packet Access (HSUPA).

[0025] In an embodiment, the base station 114a and the WTRUs 102a, 102b, 102c may implement a radio technology such as Evolved UMTS Terrestrial Radio Access (E-UTRA), which may establish the air interface 116 using Long Term Evolution (LTE) and/or LTE-Advanced (LTE-A) and/or LTE-Advanced Pro (LTE-A Pro).

[0026] In an embodiment, the base station 114a and the WTRUs 102a, 102b, 102c may implement a radio technology such as NR Radio Access, which may establish the air interface 116 using New Radio (NR).

[0027] In an embodiment, the base station 114a and the WTRUs 102a, 102b, 102c may implement multiple radio access technologies. For example, the base station 114a and the WTRUs 102a, 102b, 102c may implement LTE radio access and NR radio access together, for instance using dual connectivity (DC) principles. Thus, the air interface utilized by WTRUs 102a, 102b, 102c may be characterized by multiple types of radio access technologies and/or transmissions sent to/from multiple types of base stations (e.g., an eNB and a gNB).

[0028] In an embodiment, the base station 114a and the WTRUs 102a, 102b, 102c may implement radio technologies such as IEEE 802.11 (i.e., Wireless Fidelity (Wi-Fi), IEEE 802.16 (i.e., Worldwide Interoperability for Microwave Access (WiMAX)), CDMA2000, CDMA2000 1X, CDMA2000 EV-DO, Interim Standard 2000 (IS-2000), Interim Standard 95 (IS-95), Interim Standard 856 (IS-856), Global System for Mobile communications (GSM), Enhanced Data rates for GSM Evolution (EDGE), GSM EDGE (GERAN), and the like.

[0029] The base station 114b in FIG. 1A may be a wireless router, Home Node-B, Home eNode-B, or access point, for example, and may utilize any suitable RAT for facilitating wireless connectivity in a localized area, such as a place of business, a home, a vehicle, a campus, an industrial facility, an air corridor (e.g., for use by drones), a roadway, and the like. In an embodiment, the base station 114b and the WTRUs 102c, 102d may implement a radio technology such as IEEE 802.11 to establish a wireless local area network (WLAN). In an embodiment, the base station 114b and the WTRUs 102c, 102d may implement a radio technology such as IEEE 802.15 to establish a wireless personal area network (WPAN). In an embodiment, the base station 114b and the WTRUs 102c, 102d may utilize a cellular-based RAT (e.g., WCDMA, CDMA2000, GSM, LTE, LTE-A, LTE-A Pro, NR, etc.) to establish any of a small cell, picocell or femtocell. As shown in FIG. 1A, the base station 114b may have a direct connection to the Internet 110. Thus, the base station 114b may not be required to access the Internet 110 via the CN 106/115.

[0030] The RAN 104/113 may be in communication with the CN 106/115, which may be any type of network configured to provide voice, data, applications, and/or voice over internet protocol (VoIP) services to one or more of the WTRUs 102a, 102b, 102c, 102d. The data may have varying quality of service (QoS) requirements, such as differing throughput requirements, latency requirements, error tolerance requirements, reliability requirements, data throughput requirements, mobility requirements, and the like. The CN 106/115 may provide call control, billing services, mobile location-based services, pre-paid calling, Internet connectivity, video distribution, etc., and/or perform high-level security functions, such as user authentication. Although not shown in FIG. 1A, it will be appreciated that the RAN 104/113 and/or the CN 106/115 may be in direct or indirect communication with other RANs that employ the same RAT as the RAN 104/113 or a different RAT. For example, in addition to being connected to the RAN 104/113, which may be utilizing an NR radio technology, the CN 106/115 may also be in communication with another RAN (not shown) employing any of a GSM, UMTS, CDMA 2000, WiMAX, E-UTRA, or Wi-Fi radio technology.

[0031] The CN 106/115 may also serve as a gateway for the WTRUs 102a, 102b, 102c, 102d to access the PSTN 108, the Internet 110, and/or other networks 112. The PSTN 108 may include circuit-switched telephone networks that provide plain old telephone service (POTS). The Internet

110 may include a global system of interconnected computer networks and devices that use common communication protocols, such as the transmission control protocol (TCP), user datagram protocol (UDP) and/or the internet protocol (IP) in the TCP/IP internet protocol suite. The networks 112 may include wired and/or wireless communications networks owned and/or operated by other service providers. For example, the networks 112 may include another CN connected to one or more RANs, which may employ the same RAT as the RAN 104/114 or a different RAT.

[0032] Some or all of the WTRUs 102a, 102b, 102c, 102d in the communications system 100 may include multi-mode capabilities (e.g., the WTRUs 102a, 102b, 102c, 102d may include multiple transceivers for communicating with different wireless networks over different wireless links). For example, the WTRU 102c shown in FIG. 1A may be configured to communicate with the base station 114a, which may employ a cellular-based radio technology, and with the base station 114b, which may employ an IEEE 802 radio technology.

[0033] FIG. 1B is a system diagram illustrating an example WTRU 102. As shown in FIG. 1B, the WTRU 102 may include a processor 118, a transceiver 120, a transmit/receive element 122, a speaker/microphone 124, a keypad 126, a display/touchpad 128, non-removable memory 130, removable memory 132, a power source 134, a global positioning system (GPS) chipset 136, and/or other elements/peripherals 138, among others. It will be appreciated that the WTRU 102 may include any sub-combination of the foregoing elements while remaining consistent with an embodiment.

[0034] The processor 118 may be a general purpose processor, a special purpose processor, a conventional processor, a digital signal processor (DSP), a plurality of microprocessors, one or more microprocessors in association with a DSP core, a controller, a microcontroller, Application Specific Integrated Circuits (ASICs), Field Programmable Gate Arrays (FPGAs) circuits, any other type of integrated circuit (IC), a state machine, and the like. The processor 118 may perform signal coding, data processing, power control, input/output processing, and/or any other functionality that enables the WTRU 102 to operate in a wireless environment. The processor 118 may be coupled to the transceiver 120, which may be coupled to the transmit/receive element 122. While FIG. 1B depicts the processor 118 and the transceiver 120 as separate components, it will be appreciated that the processor 118 and the transceiver 120 may be integrated together, e.g., in an electronic package or chip.

[0035] The transmit/receive element 122 may be configured to transmit signals to, or receive signals from, a base station (e.g., the base station 114a) over the air interface 116. For example, in an embodiment, the transmit/receive element 122 may be an antenna configured to transmit and/or receive RF signals. In an embodiment, the transmit/receive element 122 may be an emitter/detector

configured to transmit and/or receive IR, UV, or visible light signals, for example. In an embodiment, the transmit/receive element 122 may be configured to transmit and/or receive both RF and light signals. It will be appreciated that the transmit/receive element 122 may be configured to transmit and/or receive any combination of wireless signals.

[0036] Although the transmit/receive element 122 is depicted in FIG. 1B as a single element, the WTRU 102 may include any number of transmit/receive elements 122. For example, the WTRU 102 may employ MIMO technology. Thus, in an embodiment, the WTRU 102 may include two or more transmit/receive elements 122 (e.g., multiple antennas) for transmitting and receiving wireless signals over the air interface 116.

[0037] The transceiver 120 may be configured to modulate the signals that are to be transmitted by the transmit/receive element 122 and to demodulate the signals that are received by the transmit/receive element 122. As noted above, the WTRU 102 may have multi-mode capabilities. Thus, the transceiver 120 may include multiple transceivers for enabling the WTRU 102 to communicate via multiple RATs, such as NR and IEEE 802.11, for example.

[0038] The processor 118 of the WTRU 102 may be coupled to, and may receive user input data from, the speaker/microphone 124, the keypad 126, and/or the display/touchpad 128 (e.g., a liquid crystal display (LCD) display unit or organic light-emitting diode (OLED) display unit). The processor 118 may also output user data to the speaker/microphone 124, the keypad 126, and/or the display/touchpad 128. In addition, the processor 118 may access information from, and store data in, any type of suitable memory, such as the non-removable memory 130 and/or the removable memory 132. The non-removable memory 130 may include random-access memory (RAM), read-only memory (ROM), a hard disk, or any other type of memory storage device. The removable memory 132 may include a subscriber identity module (SIM) card, a memory stick, a secure digital (SD) memory card, and the like. In other embodiments, the processor 118 may access information from, and store data in, memory that is not physically located on the WTRU 102, such as on a server or a home computer (not shown).

[0039] The processor 118 may receive power from the power source 134, and may be configured to distribute and/or control the power to the other components in the WTRU 102. The power source 134 may be any suitable device for powering the WTRU 102. For example, the power source 134 may include one or more dry cell batteries (e.g., nickel-cadmium (NiCd), nickel-zinc (NiZn), nickel metal hydride (NiMH), lithium-ion (Li-ion), etc.), solar cells, fuel cells, and the like.

[0040] The processor 118 may also be coupled to the GPS chipset 136, which may be configured to provide location information (e.g., longitude and latitude) regarding the current location of the WTRU 102. In addition to, or in lieu of, the information from the GPS chipset 136, the WTRU 102 may receive location information over the air interface 116 from a base station (e.g., base

stations 114a, 114b) and/or determine its location based on the timing of the signals being received from two or more nearby base stations. It will be appreciated that the WTRU 102 may acquire location information by way of any suitable location-determination method while remaining consistent with an embodiment.

[0041] The processor 118 may further be coupled to other elements/peripherals 138, which may include one or more software and/or hardware modules/units that provide additional features, functionality and/or wired or wireless connectivity. For example, the elements/peripherals 138 may include an accelerometer, an e-compass, a satellite transceiver, a digital camera (e.g., for photographs and/or video), a universal serial bus (USB) port, a vibration device, a television transceiver, a hands free headset, a Bluetooth® module, a frequency modulated (FM) radio unit, a digital music player, a media player, a video game player module, an Internet browser, a virtual reality and/or augmented reality (VR/AR) device, an activity tracker, and the like. The elements/peripherals 138 may include one or more sensors, the sensors may be one or more of a gyroscope, an accelerometer, a hall effect sensor, a magnetometer, an orientation sensor, a proximity sensor, a temperature sensor, a time sensor; a geolocation sensor; an altimeter, a light sensor, a touch sensor, a magnetometer, a barometer, a gesture sensor, a biometric sensor, and/or a humidity sensor.

[0042] The WTRU 102 may include a full duplex radio for which transmission and reception of some or all of the signals (e.g., associated with particular subframes for both the uplink (e.g., for transmission) and downlink (e.g., for reception) may be concurrent and/or simultaneous. The full duplex radio may include an interference management unit to reduce and or substantially eliminate self-interference via either hardware (e.g., a choke) or signal processing via a processor (e.g., a separate processor (not shown) or via processor 118). In an embodiment, the WTRU 102 may include a half-duplex radio for which transmission and reception of some or all of the signals (e.g., associated with particular subframes for either the uplink (e.g., for transmission) or the downlink (e.g., for reception)).

[0043] FIG. 1C is a system diagram illustrating the RAN 104 and the CN 106 according to an embodiment. As noted above, the RAN 104 may employ an E-UTRA radio technology to communicate with the WTRUs 102a, 102b, and 102c over the air interface 116. The RAN 104 may also be in communication with the CN 106.

[0044] The RAN 104 may include eNode-Bs 160a, 160b, 160c, though it will be appreciated that the RAN 104 may include any number of eNode-Bs while remaining consistent with an embodiment. The eNode-Bs 160a, 160b, 160c may each include one or more transceivers for communicating with the WTRUs 102a, 102b, 102c over the air interface 116. In an embodiment, the eNode-Bs 160a, 160b, 160c may implement MIMO technology. Thus, the eNode-B 160a, for

example, may use multiple antennas to transmit wireless signals to, and receive wireless signals from, the WTRU 102a.

[0045] Each of the eNode-Bs 160a, 160b, and 160c may be associated with a particular cell (not shown) and may be configured to handle radio resource management decisions, handover decisions, scheduling of users in the uplink (UL) and/or downlink (DL), and the like. As shown in FIG. 1C, the eNode-Bs 160a, 160b, 160c may communicate with one another over an X2 interface.

[0046] The CN 106 shown in FIG. 1C may include a mobility management entity (MME) 162, a serving gateway (SGW) 164, and a packet data network (PDN) gateway (PGW) 166. While each of the foregoing elements are depicted as part of the CN 106, it will be appreciated that any one of these elements may be owned and/or operated by an entity other than the CN operator.

[0047] The MME 162 may be connected to each of the eNode-Bs 160a, 160b, and 160c in the RAN 104 via an S1 interface and may serve as a control node. For example, the MME 162 may be responsible for authenticating users of the WTRUs 102a, 102b, 102c, bearer activation/deactivation, selecting a particular serving gateway during an initial attach of the WTRUs 102a, 102b, 102c, and the like. The MME 162 may provide a control plane function for switching between the RAN 104 and other RANs (not shown) that employ other radio technologies, such as GSM and/or WCDMA.

[0048] The SGW 164 may be connected to each of the eNode-Bs 160a, 160b, 160c in the RAN 104 via the S1 interface. The SGW 164 may generally route and forward user data packets to/from the WTRUs 102a, 102b, 102c. The SGW 164 may perform other functions, such as anchoring user planes during inter-eNode-B handovers, triggering paging when DL data is available for the WTRUs 102a, 102b, 102c, managing and storing contexts of the WTRUs 102a, 102b, 102c, and the like.

[0049] The SGW 164 may be connected to the PGW 166, which may provide the WTRUs 102a, 102b, 102c with access to packet-switched networks, such as the Internet 110, to facilitate communications between the WTRUs 102a, 102b, 102c and IP-enabled devices.

[0050] The CN 106 may facilitate communications with other networks. For example, the CN 106 may provide the WTRUs 102a, 102b, 102c with access to circuit-switched networks, such as the PSTN 108, to facilitate communications between the WTRUs 102a, 102b, 102c and traditional land-line communications devices. For example, the CN 106 may include, or may communicate with, an IP gateway (e.g., an IP multimedia subsystem (IMS) server) that serves as an interface between the CN 106 and the PSTN 108. In addition, the CN 106 may provide the WTRUs 102a, 102b, 102c with access to the other networks 112, which may include other wired and/or wireless networks that are owned and/or operated by other service providers.

[0051] Although the WTRU is described in FIGs. 1A-1D as a wireless terminal, it is contemplated that in certain representative embodiments that such a terminal may use (e.g., temporarily or permanently) wired communication interfaces with the communication network.

[0052] In representative embodiments, the other network 112 may be a WLAN.

[0053] A WLAN in infrastructure basic service set (BSS) mode may have an access point (AP) for the BSS and one or more stations (STAs) associated with the AP. The AP may have an access or an interface to a distribution system (DS) or another type of wired/wireless network that carries traffic into and/or out of the BSS. Traffic to STAs that originates from outside the BSS may arrive through the AP and may be delivered to the STAs. Traffic originating from STAs to destinations outside the BSS may be sent to the AP to be delivered to respective destinations. Traffic between STAs within the BSS may be sent through the AP, for example, where the source STA may send traffic to the AP and the AP may deliver the traffic to the destination STA. The traffic between STAs within a BSS may be considered and/or referred to as peer-to-peer traffic. The peer-to-peer traffic may be sent between (e.g., directly between) the source and destination STAs with a direct link setup (DLS). In certain representative embodiments, the DLS may use an 802.11e DLS or an 802.11z tunneled DLS (TDLS). A WLAN using an Independent BSS (IBSS) mode may not have an AP, and the STAs (e.g., all of the STAs) within or using the IBSS may communicate directly with each other. The IBSS mode of communication may sometimes be referred to herein as an "ad-hoc" mode of communication.

[0054] When using the 802.11ac infrastructure mode of operation or a similar mode of operations, the AP may transmit a beacon on a fixed channel, such as a primary channel. The primary channel may be a fixed width (e.g., 20 MHz wide bandwidth) or a dynamically set width via signaling. The primary channel may be the operating channel of the BSS and may be used by the STAs to establish a connection with the AP. In certain representative embodiments, Carrier sense multiple access with collision avoidance (CSMA/CA) may be implemented, for example in in 802.11 systems. For CSMA/CA, the STAs (e.g., every STA), including the AP, may sense the primary channel. If the primary channel is sensed/detected and/or determined to be busy by a particular STA, the particular STA may back off. One STA (e.g., only one station) may transmit at any given time in a given BSS.

[0055] High throughput (HT) STAs may use a 40 MHz wide channel for communication, for example, via a combination of the primary 20 MHz channel with an adjacent or nonadjacent 20 MHz channel to form a 40 MHz wide channel.

[0056] Very high throughput (VHT) STAs may support 20 MHz, 40 MHz, 80 MHz, and/or 160 MHz wide channels. The 40 MHz, and/or 80 MHz, channels may be formed by combining contiguous 20 MHz channels. A 160 MHz channel may be formed by combining 8 contiguous

20 MHz channels, or by combining two non-contiguous 80 MHz channels, which may be referred to as an 80+80 configuration. For the 80+80 configuration, the data, after channel encoding, may be passed through a segment parser that may divide the data into two streams. Inverse fast fourier transform (IFFT) processing, and time domain processing, may be done on each stream separately. The streams may be mapped on to the two 80 MHz channels, and the data may be transmitted by a transmitting STA. At the receiver of the receiving STA, the above-described operation for the 80+80 configuration may be reversed, and the combined data may be sent to a medium access control (MAC) layer, entity, etc.

[0057] Sub 1 GHz modes of operation are supported by 802.11af and 802.11ah. The channel operating bandwidths, and carriers, are reduced in 802.11af and 802.11ah relative to those used in 802.11n, and 802.11ac. 802.11af supports 5 MHz, 10 MHz and 20 MHz bandwidths in the TV white space (TVWS) spectrum, and 802.11ah supports 1 MHz, 2 MHz, 4 MHz, 8 MHz, and 16 MHz bandwidths using non-TVWS spectrum. According to a representative embodiment, 802.11ah may support meter type control/machine-type communications (MTC), such as MTC devices in a macro coverage area. MTC devices may have certain capabilities, for example, limited capabilities including support for (e.g., only support for) certain and/or limited bandwidths. The MTC devices may include a battery with a battery life above a threshold (e.g., to maintain a very long battery life).

[0058] WLAN systems, which may support multiple channels, and channel bandwidths, such as 802.11n, 802.11ac, 802.11af, and 802.11ah, include a channel which may be designated as the primary channel. The primary channel may have a bandwidth equal to the largest common operating bandwidth supported by all STAs in the BSS. The bandwidth of the primary channel may be set and/or limited by a STA, from among all STAs in operating in a BSS, which supports the smallest bandwidth operating mode. In the example of 802.11ah, the primary channel may be 1 MHz wide for STAs (e.g., MTC type devices) that support (e.g., only support) a 1 MHz mode, even if the AP, and other STAs in the BSS support 2 MHz, 4 MHz, 8 MHz, 16 MHz, and/or other channel bandwidth operating modes. Carrier sensing and/or network allocation vector (NAV) settings may depend on the status of the primary channel. If the primary channel is busy, for example, due to a STA (which supports only a 1 MHz operating mode), transmitting to the AP, the entire available frequency bands may be considered busy even though a majority of the frequency bands remains idle and may be available.

[0059] In the United States, the available frequency bands, which may be used by 802.11ah, are from 902 MHz to 928 MHz. In Korea, the available frequency bands are from 917.5 MHz to 923.5 MHz. In Japan, the available frequency bands are from 916.5 MHz to 927.5 MHz. The total bandwidth available for 802.11ah is 6 MHz to 26 MHz depending on the country code.

[0060] FIG. 1D is a system diagram illustrating the RAN 113 and the CN 115 according to an embodiment. As noted above, the RAN 113 may employ an NR radio technology to communicate with the WTRUs 102a, 102b, 102c over the air interface 116. The RAN 113 may also be in communication with the CN 115.

[0061] The RAN 113 may include gNBs 180a, 180b, 180c, though it will be appreciated that the RAN 113 may include any number of gNBs while remaining consistent with an embodiment. The gNBs 180a, 180b, 180c may each include one or more transceivers for communicating with the WTRUs 102a, 102b, 102c over the air interface 116. In an embodiment, the gNBs 180a, 180b, 180c may implement MIMO technology. For example, gNBs 180a, 180b may utilize beamforming to transmit signals to and/or receive signals from the WTRUs 102a, 102b, 102c. Thus, the gNB 180a, for example, may use multiple antennas to transmit wireless signals to, and/or receive wireless signals from, the WTRU 102a. In an embodiment, the gNBs 180a, 180b, 180c may implement carrier aggregation technology. For example, the gNB 180a may transmit multiple component carriers to the WTRU 102a (not shown). A subset of these component carriers may be on unlicensed spectrum while the remaining component carriers may be on licensed spectrum. In an embodiment, the gNBs 180a, 180b, 180c may implement Coordinated Multi-Point (CoMP) technology. For example, WTRU 102a may receive coordinated transmissions from gNB 180a and gNB 180b (and/or gNB 180c).

[0062] The WTRUs 102a, 102b, 102c may communicate with gNBs 180a, 180b, 180c using transmissions associated with a scalable numerology. For example, OFDM symbol spacing and/or OFDM subcarrier spacing may vary for different transmissions, different cells, and/or different portions of the wireless transmission spectrum. The WTRUs 102a, 102b, 102c may communicate with gNBs 180a, 180b, 180c using subframe or transmission time intervals (TTIs) of various or scalable lengths (e.g., including a varying number of OFDM symbols and/or lasting varying lengths of absolute time).

[0063] The gNBs 180a, 180b, 180c may be configured to communicate with the WTRUs 102a, 102b, 102c in a standalone configuration and/or a non-standalone configuration. In the standalone configuration, WTRUs 102a, 102b, 102c may communicate with gNBs 180a, 180b, 180c without also accessing other RANs (e.g., such as eNode-Bs 160a, 160b, 160c). In the standalone configuration, WTRUs 102a, 102b, 102c may utilize one or more of gNBs 180a, 180b, 180c as a mobility anchor point. In the standalone configuration, WTRUs 102a, 102b, 102c may communicate with gNBs 180a, 180b, 180c using signals in an unlicensed band. In a non-standalone configuration WTRUs 102a, 102b, 102c may communicate with/connect to gNBs 180a, 180b, 180c while also communicating with/connecting to another RAN such as eNode-Bs 160a, 160b, 160c. For example, WTRUs 102a, 102b, 102c may implement DC principles to communicate with

one or more gNBs 180a, 180b, 180c and one or more eNode-Bs 160a, 160b, 160c substantially simultaneously. In the non-standalone configuration, eNode-Bs 160a, 160b, 160c may serve as a mobility anchor for WTRUs 102a, 102b, 102c and gNBs 180a, 180b, 180c may provide additional coverage and/or throughput for servicing WTRUs 102a, 102b, 102c.

[0064] Each of the gNBs 180a, 180b, 180c may be associated with a particular cell (not shown) and may be configured to handle radio resource management decisions, handover decisions, scheduling of users in the UL and/or DL, support of network slicing, dual connectivity, interworking between NR and E-UTRA, routing of user plane data towards user plane functions (UPFs) 184a, 184b, routing of control plane information towards access and mobility management functions (AMFs) 182a, 182b, and the like. As shown in FIG. 1D, the gNBs 180a, 180b, 180c may communicate with one another over an Xn interface.

[0065] The CN 115 shown in FIG. 1D may include at least one AMF 182a, 182b, at least one UPF 184a, 184b, at least one session management function (SMF) 183a, 183b, and at least one Data Network (DN) 185a, 185b. While each of the foregoing elements are depicted as part of the CN 115, it will be appreciated that any of these elements may be owned and/or operated by an entity other than the CN operator.

[0066] The AMF 182a, 182b may be connected to one or more of the gNBs 180a, 180b, 180c in the RAN 113 via an N2 interface and may serve as a control node. For example, the AMF 182a, 182b may be responsible for authenticating users of the WTRUs 102a, 102b, 102c, support for network slicing (e.g., handling of different protocol data unit (PDU) sessions with different requirements), selecting a particular SMF 183a, 183b, management of the registration area, termination of NAS signaling, mobility management, and the like. Network slicing may be used by the AMF 182a, 182b, e.g., to customize CN support for WTRUs 102a, 102b, 102c based on the types of services being utilized WTRUs 102a, 102b, 102c. For example, different network slices may be established for different use cases such as services relying on ultra-reliable low latency (URLLC) access, services relying on enhanced massive mobile broadband (eMBB) access, services for MTC access, and/or the like. The AMF 162 may provide a control plane function for switching between the RAN 113 and other RANs (not shown) that employ other radio technologies, such as LTE, LTE-A, LTE-A Pro, and/or non-3GPP access technologies such as Wi-Fi.

[0067] The SMF 183a, 183b may be connected to an AMF 182a, 182b in the CN 115 via an N11 interface. The SMF 183a, 183b may also be connected to a UPF 184a, 184b in the CN 115 via an N4 interface. The SMF 183a, 183b may select and control the UPF 184a, 184b and configure the routing of traffic through the UPF 184a, 184b. The SMF 183a, 183b may perform other functions, such as managing and allocating UE IP address, managing PDU sessions, controlling policy

enforcement and QoS, providing downlink data notifications, and the like. A PDU session type may be IP-based, non-IP based, Ethernet-based, and the like.

[0068] The UPF 184a, 184b may be connected to one or more of the gNBs 180a, 180b, 180c in the RAN 113 via an N3 interface, which may provide the WTRUs 102a, 102b, 102c with access to packet-switched networks, such as the Internet 110, e.g., to facilitate communications between the WTRUs 102a, 102b, 102c and IP-enabled devices. The UPF 184, 184b may perform other functions, such as routing and forwarding packets, enforcing user plane policies, supporting multi-homed PDU sessions, handling user plane QoS, buffering downlink packets, providing mobility anchoring, and the like.

[0069] The CN 115 may facilitate communications with other networks. For example, the CN 115 may include, or may communicate with, an IP gateway (e.g., an IP multimedia subsystem (IMS) server) that serves as an interface between the CN 115 and the PSTN 108. In addition, the CN 115 may provide the WTRUs 102a, 102b, 102c with access to the other networks 112, which may include other wired and/or wireless networks that are owned and/or operated by other service providers. In an embodiment, the WTRUs 102a, 102b, 102c may be connected to a local Data Network (DN) 185a, 185b through the UPF 184a, 184b via the N3 interface to the UPF 184a, 184b and an N6 interface between the UPF 184a, 184b and the DN 185a, 185b.

[0070] In view of FIGs. 1A-1D, and the corresponding description of FIGs. 1A-1D, one or more, or all, of the functions described herein with regard to any of: WTRUs 102a-d, base stations 114a-b, eNode-Bs 160a-c, MME 162, SGW 164, PGW 166, gNBs 180a-c, AMFs 182a-b, UPFs 184a-b, SMFs 183a-b, DNs 185a-b, and/or any other element(s)/device(s) described herein, may be performed by one or more emulation elements/devices (not shown). The emulation devices may be one or more devices configured to emulate one or more, or all, of the functions described herein. For example, the emulation devices may be used to test other devices and/or to simulate network and/or WTRU functions.

[0071] The emulation devices may be designed to implement one or more tests of other devices in a lab environment and/or in an operator network environment. For example, the one or more emulation devices may perform the one or more, or all, functions while being fully or partially implemented and/or deployed as part of a wired and/or wireless communication network in order to test other devices within the communication network. The one or more emulation devices may perform the one or more, or all, functions while being temporarily implemented/deployed as part of a wired and/or wireless communication network. The emulation device may be directly coupled to another device for purposes of testing and/or may performing testing using over-the-air wireless communications.

[0072] The one or more emulation devices may perform the one or more, including all, functions while not being implemented/deployed as part of a wired and/or wireless communication network. For example, the emulation devices may be utilized in a testing scenario in a testing laboratory and/or a non-deployed (e.g., testing) wired and/or wireless communication network in order to implement testing of one or more components. The one or more emulation devices may be test equipment. Direct RF coupling and/or wireless communications via RF circuitry (e.g., which may include one or more antennas) may be used by the emulation devices to transmit and/or receive data.

[0073] **Introduction**

[0074] Currently a UE supports multi-Transmission / Reception Point (TRP) reception in either single Downlink Control Information (sDCI) or multiple DCI (mDCI) modes. In the sDCI mode, there is support for simultaneous receptions from two non-collocated TRPs under a Coherent Joint Transmissions (CJT) scenario. Both configurations completely overlap in the frequency domain, using the same channel and channel bandwidth. In the 3GPP 5G Rel-18 discussion, the maximum number of configured TRPs in the CJT is four. The UE may report the Channel State Information (CSI) feedback based on a gNB configured mode or based on the UE selective CSI report, using a bitmap model. The UE receives data on a Physical Data Shared Channel (PDSCH) from two TRPs and performs joint reception and demodulation as the TRPs are assumed to be synchronized in frequency and time within a Cyclic Prefix (CP). It is expected that these multi-TRP coherent transmissions will increase the Signal-to-Noise Ratio (SNR) and thus improve the Block Error Rate (BLER) of the received PDSCH data. The synchronization with the network always relies on an anchor TRP (anchor serving cell), while the other TRPs Reference Signals (RSs) (TRS – tracking RS) are monitored and measured for CSI feedback and beamforming purposes.

[0075] FIG. 2 illustrates a UE that receives and jointly demodulates PDSCH data coherently transmitted from two TRPs that are assumed synchronized in time and frequency. The UE 210 receives a first DL beam 220 from TRP 1 and a second DL beam 230 from TRP 2.

[0076] The current frequency accuracy for the base stations is +/- 0.05 ppm, while the UE is supposed to be in the +/- 0.1 ppm range. Also, the timing accuracy is within a CP as the UE will always measure a Primary Synchronization Signal (PSS) and a Secondary Synchronization Signal (SSS) and get the first significant path as reference. While this is sufficiently good for single TRP/cell reception as all the channels are assumed synchronized with the PSS/SSS at the TRP level, when CJT is configured, there are two TRPs transmitting and when differences in frequency and timing synchronizations occur, a significant degradation of data reception (up to 25% BLER when a combined frequency and time is involved) has been observed for the joint demodulation.

[0077] In this context, it has been observed that as the Precoding Matrix Indicator (PMI) sub-band increases, the maximum delay spread that can be handled decreases. Also, a slight frequency drift within the 0.05 ppm of the base station over 5 ms can lead to phase shifts that may create cancelation points/regions within the equalized received signal, leading to demodulation errors.

[0078] Since the CJT scenario has more stringent time and frequency accuracy requirements than other deployment types, to fulfill its goals, there is a need for UE assistance to help the TRPs calibrate their transmissions in time and frequency. The UE assistance can materialize as feedback measurements or triggered measurements for the TRP calibration.

[0079] As mentioned, the CJT related CSI feedback supports up to four configured TRP candidates CSI reporting. There are two supported CSI reporting modes: one configured by gNB and another where the UE reports CSI for the CJT configuration using a bitmap model.

[0080] However, there is no information related to the relative frequency or timing drift values that would help a TRP calibration process in support of CJT configuration.

[0081] In a CJT configuration there is no UE report/feedback information for the time and frequency drift. This information is needed for TRP calibration in support of CJT performance. The methods that will be described cover the UE assistance reporting, the TRP calibration and the UE behavior during this process.

[0082] Relative timing and frequency error measurement reporting and TRP calibration process

[0083] In mTRP CJT operation, a UE performs CSI measurement/reporting for configured TRPs. As assistance information, the UE measures and reports relative time/frequency errors between configured TRPs in support of the calibration process. After receiving assistance information at the gNB, to calibrate for the TRP with error, a time gap is required during which mTRP CJT operation cannot be supported for the TRPs under calibration.

[0084] However, no time gap for calibration is supported currently. No UE behavior is defined after error reporting and/or during the time gap configured or indicated by the gNB (e.g., for calibration) when the UE is under mTRP CJT operation.

[0085] In a first embodiment, the UE receives configuration information for CJT operation (up to 4 TRPs) and with a new triggered CSI measurement report based on configured TRS resources for relative time and frequency errors between a first and a second TRP, a first and a third, etc. or between any indicated pair of TRPs. The measurements may be periodic or triggered aperiodic/semi-persistent. One of the TRPs may be configured/indicated as the reference/anchor/default/primary for measurements of reference signals (for example CSI-RS).

[0086] When aperiodic/semi-persistent, the UE gets triggered, for example by a MAC-CE or DCI order, by a semi-statically CSI-RS configuration and measurements for timing and frequency error reporting.

[0087] When periodic, the UE behavior (e.g., reporting) may be triggered by one of a combination of the following conditions: a relative timing error exceeds a configured value, a frequency error exceeds a configured value and PDSCH BLER error exceeds a configured value.

[0088] The UE reports the relative errors between TRPs. (e.g., between each TRP and the default/anchor/primary or among pairs of TRPs)

[0089] The UE receives a scheduled DL gap that may be a single scheduled gap or a series of gaps to start for TRP calibration (frequency and/or timing) (e.g., that involves a change in the gNB Phase Locked Loop (PLL) tracking or DL timing adjustment) that may render the CJT inoperable.

[0090] After reporting relative errors and upon reception of the DL scheduled gap, the UE may perform different actions.

[0091] During the scheduled gap(s) for a specific TRP(s) the UE may fall back from CJT (two TRPs reception based) operation to a default operation mode. The default operation mode may be the single TRP operation with a default/primary/anchor configured TRP between the error reporting and the end of calibration gap, or the mTRP CJT operation with a subset of configured TRPs which satisfy one or more conditions (e.g., time/frequency error within a range, meeting the BLER performance, e.g., 10%).

[0092] During the default operation mode, the UE may perform various measurement or monitoring actions.

[0093] The UE may perform CSI measurement/reporting for the default TRP or the subset of configured TRPs which satisfy the conditions. After reporting the relative errors, the UE may receive a MAC-CE indicating the Channel Measurement Resource (CMR) restriction for CSI feedback restricted to a subset of CMR indices (by activating/deactivating CMRs from CSI report, dropping the deactivated CMR indices or use a bitmap where the restricted CMRs are excluded.

[0094] The UE may monitor a subset of PDCCH search spaces associated with the default TRP or the subset of configured TRPs which satisfy the conditions.

[0095] The UE may measure a subset of reference signals (e.g. for Radio Link Monitoring/Radio Resource Management (RLM/RRM)) associated with default/primary/anchor TRP or the subset of configured TRPs which satisfy the conditions.

[0096] After the time gap configured or indicated by gNB, the UE may perform at least one of CSI measurement/reporting for all configured TRPs, monitoring of all PDCCH search spaces associated with all configured TRPs, measurement of reference signals for RLM/RRM associated with all configured TRPs.

[0097] Triggered Sounding Reference Signal (SRS) based TRP calibration process

[0098] During mTRP CJT operation, a UE may measure and report relative time/frequency errors between configured TRPs in support of calibration process.

[0099] However, no relative time/frequency error for mTRP reporting format has been defined. Explicit reporting of relative time/frequency error values require excessive feedback overhead.

[0100] A UE is configured for CJT operation and configured to perform TRP frequency/timing relative measurements using a configured RS per TRP. A TRP is indicated/configured as a reference/anchor TRP. The UE is configured with a set of Sounding Reference Signal (SRS) resources where each SRS resource is associated with a SRS Resource Indicator (SRI) and each SRI is associated with a TRP index.

[0101] The UE performs measurements for frequency/timing errors for each TRP pair, including a first TRP and a second TRP, where the first TRP (e.g., of each pair) may be the anchor/reference TRP.

[0102] The UE may flag/indicate excessive relative frequency/timing errors between a first and a second measured TRP, when the difference exceeds a configured threshold. The UE may indicate the TRP index of the second TRP.

[0103] After transmitting the frequency/timing error indication, the UE may receive a "special calibration SRS" transmission request. The SRS request DCI may contain at least one of a "SRS calibration indication flag" and the SRI corresponding to the second TRP, an SRI corresponding to an SRS resource associated with the second TRP, a Transmission Configuration Indicator (TCI) state associated with the first TRP (e.g., the reference/anchor TRP), and a set of N SRIs corresponding to respective N SRS resources where each SRS resource is associated with a respective TRP. The TCI state informs the UE how to associate the RS and SSBs in terms of quasi collocation (QCL) of the transmitted signals and how the spatial filters are to be used or applied by the UE (beams etc.)

[0104] In response to receiving the special SRS request, the UE may transmit a first SRS in a resource associated to the first TRP (e.g., reference TRP) using the frequency and timing associated with the first (e.g., reference TRP) TRP.

[0105] In response to receiving the special SRS request, the UE may transmit a second SRS using the indicated SRS resource and adjusting the time and/or frequency of the transmission based on the measured time and/or the frequency errors determined for the second TRP relative to the first TRP.

[0106] If a set of N SRIs is indicated to the UE in the SRS calibration request, the UE may transmit an SRS in each of the SRS resources corresponding to N SRIs, where the time and/or frequency for each SRS transmission is adjusted based on measured time and/or frequency error for the corresponding TRP relative to the reference/first TRP.

[0107] The SRS transmission or the N SRS transmissions may be based on indicated TCI state (e.g., may use a spatial filter based on the indicated TCI state).

TRS based measurements reporting and calibration gap UE behavior

[0108] FIG. 3 illustrates a method according to a first embodiment of the present principles.

[0109] In step S310, A UE receives configuration information for CJT operation (up to 4 TRPs) and with a new triggered CSI measurement report based on configured TRS resources for relative time and frequency errors between a first and a second TRP, a first and a third, etc. or between any indicated pair of TRPs. The measurements may be periodic or triggered aperiodic/semi-persistent. One of the TRPs may be configured/indicated as the anchor/default/primary for measurements reference signals (for example CSI-RS).

[0110] When aperiodic/semi-persistent, the UE gets triggered, for example by a MAC-CE or DCI order, by a semi-statically CSI-RS configuration and measurements for timing and frequency error reporting.

[0111] When periodic, the UE behavior (e.g., reporting) may be triggered by one of a combination of the following conditions: a relative timing error exceeds a configured value, a frequency error exceeds a configured value and PDSCH BLER error exceeds a configured value.

[0112] In step S320, The UE reports the relative errors between TRPs. (e.g., between each TRP and the default/anchor/primary or among pairs of TRPs)

[0113] In step S330, The UE receives information indicative of a scheduled DL gap that may be a single scheduled gap or a series of gaps to start for TRP calibration (frequency and/or timing) (e.g. that involves a change in the gNB PLL tracking or DL timing adjustment) that may render the CJT operation inoperable.

[0114] In step S340, after reporting relative errors and upon reception of the information indicative of the DL scheduled gap, the UE may perform different actions.

[0115] During the scheduled gap(s) for a specific TRP(s) the UE may fall back from CJT (two TRPs reception based) operation to a default operation mode. The default operation mode may be the single TRP operation with a default/primary/anchor configured TRP between the error reporting and the end of calibration gap, or the mTRP CJT operation with a subset of configured TRPs which satisfy one or more conditions (e.g., time/frequency error within a range, meeting the BLER performance, e.g., 10%).

[0116] During the default operation mode, the UE may perform various measurement or monitoring actions.

[0117] The UE may perform CSI measurement/reporting for the default TRP or the subset of configured TRPs which satisfy the conditions. After reporting the relative errors, the UE may receive a MAC-CE indicating the CMR restriction for CSI feedback restricted to a subset of CMR

indices (by activating/deactivating CMRs from CSI report, dropping the deactivated CMR indices or use a bitmap where the restricted CMRs are excluded.

[0118] The UE may monitor a subset of PDCCH search spaces associated with the default TRP or the subset of configured TRPs which satisfy the conditions.

[0119] The UE may measure a subset of reference signals (e.g., for RLM/RRM) associated with default/primary/anchor TRP or the subset of configured TRPs which satisfy the conditions.

[0120] In step S350, after the time gap configured or indicated by gNB, the UE may perform at least one of CSI measurement/reporting for all configured TRPs, monitoring of PDCCH search spaces associated with all configured TRPs, and measurement of reference signals for RLM/RRM associated with all configured TRPs.

[0121] In CJT mode operation, a UE is configured to jointly receive PDSCHs from N TRPs indicated by $x = \{trp_1, trp_2, \ldots, trp_N\}$. In the UE configuration, the number of TRPs may be limited, for example N <= 4. From the set of configured TRPs, one TRP may be configured as a default/primary/anchor TRP for the UE. The UE may be configured with one TRS per each TRP. This TRS may be configured as aperiodic/semi-persistent or periodic being associated to each TRPs or a sub-set pair of TRPs (e.g., first and second TRP where the first is the anchor TRP, first and third TRP, etc.) in set x.

[0122] The configured TRS per TRP may be dedicated to synchronization measurements, or the UE may use the configured CSI-RS or SSBs to derive the CJT related synchronization measurements. Alternatively, the UE may use the Demodulation Reference Signal (DM-RS) that come embedded in the PDSCH.

[0123] When TRS are configured for CJT synchronization, the CSI-RS configuration may be allocated in the same symbol with a granularity of at least one occurrence each for each measurement/reporting interval of time (for example for each 5 ms reporting interval) in time domain. In the frequency domain, the CSI-RS may or may not overlap.

[0124] When the TRS are configured for aperiodic/semi-persistent measurements in a semi-static mode, the network may use DCI or MAC-CE activation commands. In this case, the activation of the TRS-es may be activated for a specific pair or pairs of TRPs (a pair of TRPs may be for example a first default/primary/anchor and a second TRP). Alternatively, all TRS-es for all TRPs may be activated for a complete set of CJT measurements report.

[0125] First, the UE calculates the time and frequency error from the default/primary/anchor TRP. Then, the UE calculates the relative frequency and time errors from the remaining TRPs in x with respect to the default/primary/anchor TRP. To properly work in CJT mode operation, a UE requires fine synchronization, meaning below a defined threshold among at least two TRPs in set x.

[0126] The frequency and/or timing error threshold(s) may be or specified and/or configured by the network. Additionally, or alternatively, the UE may be configured with a CJT related BLER threshold/triggers for measurements reporting.

[0127] In one embodiment, the synchronization is relative to the default/primary/anchor TRP. The TRS per TRP may be configured permanently by the network following the CJT configuration or being part of the CJT configuration, along with defined triggers.

[0128] In this embodiment, the UE may measure/evaluate periodically the CJT synchronization and report the out-of-synchronization threshold sub-set of configured TRPs based on one or more triggers.

[0129] The UE may be configured with synchronization error thresholds in both time T_{th} and frequency F_{th} and may trigger a report for the TRPs or TRP pairs with relative time and frequency errors with respect to the default/primary/anchor TRP exceeding any T_{th}/F_{th} or both T_{th} and F_{th}.

[0130] Alternatively, the UE may trigger a synchronization error report when a specified/configured BLER threshold is exceeded. The BLER threshold may be a standalone trigger for CJT synchronization error reporting. The BLER threshold may be activated only when the last two TRPs or all TRPs in set x exceed the time- and/or frequency- CJT-related threshold.

[0131] The UE may be configured with a RSRP threshold R_{th} and T_{th}/F_{th} or both T_{th} and F_{th} and trigger synchronization error report upon identification of the TRPs whose errors in time and frequency are below T_{th}/F_{th} or both T_{th} and F_{th} and whose RSRPs are above R_{th}.

[0132] The UE may trigger synchronization error report upon identification of the TRPs whose RSRPs are above R_{th} and report the identified TRPs with their corresponding time/frequency error or both time and frequency errors.

[0133] The UE may omit synchronization compliant TRPs or TRP pairs in the set x and report the remaining TRPs or TRP pairs in error.

[0134] In an embodiment, the UE may, based on the configured (or indicated) set x (e.g., {trp1, trp2, …, trpN}), determine a first TRP as an anchor (e.g., primary, main, default) TRP while a second TRP is determined by an aperiodic/semi-persistent trigger (e.g., via a DCI), e.g., transmitted from a gNB.

[0135] In an example, the UE may determine the first TRP as a TRP of the serving-cell, e.g., where the UE monitors the PDCCH to be received via a CORESET from the TRP. The UE may determine the first TRP as a TRP associated with a CORESETpoolID value. The CORESETpoolID value may be fixed as a lowest ID (e.g., CORESETpoolID = 0). The CORESETpoolID value may be configured or indicated for determining the first TRP, e.g., CORESETpoolID may be 0 or 1, or another value, which may provide benefits depending on

network implementation in terms of operational flexibility for the UE to set the TRP to be any of TRPs within the set x.

[0136] Based on determining the first TRP (e.g., a TRP within the set x), the UE may determine a set y comprised of N-1 (or less than N-1) TRPs within the set x excluding the first TRP. For example, if the first TRP is determined as trp1, the UE may determine the set y as {trp2, ..., trpN}. If the first TRP is determined as trpN, the UE may determine the set y as {trp1, trp2, ..., trp(N-1)}.

[0137] The UE may receive an indication (e.g., from the gNB) triggering an aperiodic/semi-persistent measurement (and/or reporting) the time and frequency errors for a pair of TRPs. The indication may be received via a DCI (and/or via a MAC-CE). The DCI may be a UL grant, or a group-common DCI. The UE may (be configured to) determine at least one field in the indication (e.g., DCI), where the at least one field indicates one or more TRPs within the set y.

[0138] The UE may determine a first pair of TRPs as the first TRP and a second TRP included in the set y. Based on receiving the indication (e.g., DCI), the UE may determine the second TRP out of the set y. Based on determining the second TRP, the UE may perform a first aperiodic/semi-persistent measurement (and/or reporting) for the time and frequency errors for the first pair of TRPs (between the first and second TRPs).

[0139] The UE may determine a second pair of TRPs as the first TRP and a third TRP included in the set y. Based on receiving the indication (e.g., DCI), the UE may determine the third TRP out of the set y. Based on determining the third TRP, the UE may perform a second aperiodic/semi-persistent measurement (and/or reporting) for the time and frequency errors for the second pair of TRPs (between the first and third TRPs).

[0140] In an example, the UE may (be configured to) report both of the first and second aperiodic/semi-persistent measurements based on the indication (e.g., DCI). In another example, the UE may (be configured to) report a selective aperiodic/semi-persistent measurement (among multiple aperiodic/semi-persistent measurements, e.g., the first and second aperiodic/semi-persistent measurements). The UE may determine the selective aperiodic/semi-persistent measurement based on a configuration or a pre-configured (or defined) function. The configuration or the function may indicate to determine the selective aperiodic/semi-persistent measurement based on a pair of TRPs representing the largest (or larger than a threshold for) time and frequency errors between TRPs associated with the pair. In another example, the configuration or the function may indicate to determine the selective aperiodic/semi-persistent measurement based on a pair of TRPs representing the smallest (or smaller than a threshold for) time and frequency errors between TRPs associated with the pair.

[0141] The aperiodic/semi-persistent inter-TRP synchronization measurements and reporting may be triggered by the network when detecting UE PDSCH CJT operation-related BLER exceeding a certain threshold.

[0142] Alternatively, the UE may send an CJT synchronization error indication. This indication format may be configured as a single bit indication or it may be a complete bitmap for the N TRPs, configured pairs of TRPs, or a bitmap relative to the default/primary/anchor configured TRP. The synchronization error indication may be sent for example using PUCCH, PUSCH UCI or MAC CE. Alternatively, it may be an Radio Resource Control (RRC) triggered error indication.

[0143] As the synchronization error measurements are done at the physical layer, the triggering of such an indication may be based on a defined number of successive errors detected. The out-of-synchronization states may have a network configured/defined counter Nout. This counter may be reset by an in-synchronization instance detection for a pair of TRPs. The counter may be configurable, or a simple specified value may be followed by the UE for triggering a synchronization error indication.

[0144] Upon triggering the synchronization error indication, the UE may be expected to receive an aperiodic/semi-persistent synchronization measurement order by MAC-CE or DCI that may include at least one of a targeted pair or TRPs for measurements, the TRPs relative to the default/primary/anchor TRP, a sub-set of pairs of TRPs, the slot offset activation of the RRC configured TRS, a one-shot measurement, a specific measurement duration (for example in number of slots), and a start of measurements with a stop ordered by network (e.g., MAC CE semi-static measurement deactivation)

[0145] After executing the CJT related aperiodic/semi-persistent measurement order, the UE may send the measurement report. The measurement report may be tailored and may contain the required information (e.g., a measurement instance for each measured TRP pair that may contain the delta frequency error and/or timing error) with a defined granularity for the time and/or frequency as requested/configured by network. The quantified measurement report may be sent by PUCCH, PUSCH UCI or MAC-CE. Alternatively, a layer 3 RRC measurement report may be sent with all the above-described information.

[0146] After receiving a UE-relative timing and/or frequency error report (assistance information), the gNB may decide to perform calibration such as frequency and timing adjustments. As the changes in frequency and timing require a Phase Locked Loop (PLL) for frequency fine-tuning and for timing adjustment, i.e., a suspension of the RF front end, the gNB may schedule a DL calibration gap.

[0147] A gNB decision to schedule a DL calibration gap may be based on the level of time/frequency calibration that is required. The gNB also need to account for the priority and

potential conflicts with other activities like Hybrid Automatic Repeat Request (HARQ) processes or scheduled UL transmissions.

[0148] The DL calibration gap can be a single gap or a gap burst. A gap burst may be scheduled to accommodate larger changes in timing. In an embodiment, the gNB schedules a series of gaps, where smaller timing changes are performed sequentially to accommodate the autonomous timing adjustments step and rate of the UEs connected to the CJT-involved TRPs.

[0149] The UE may receive the DL calibration gap through DCI, providing opportunity for the gNB to adapt the DL calibration gap settings based on real-time network conditions and UE feedback. The DCI indication may include one or more of a single gap or gap burst, start and duration or multiple start slots and durations, and expected UE behavior, which will now be described in more detail.

[0150] A single gap or a gap burst: In one embodiment, semi-persistent scheduling may be indicated for recurring DL calibration gaps at regular intervals, which can reduce the signaling overhead with UE not needing to monitor control channels continuously.

[0151] Start and duration (in slots) of the DL calibration gap in terms of a DL slot or only the DL part of a slot. In one embodiment, the indication of the DL calibration gap may be received in slot “n” for the TRP calibration in at slot offset “n+G”.

[0152] In the case of a gap burst, multiple start slots and durations, outlining each gap in the burst sequence, may be indicated. Ine one embodiment, the periodicity of the gaps in the gap burst is indicated.

[0153] Expected UE behavior during the DL calibration gap: In one embodiment, the DCI includes information such as resource blocks that are not to be used by the UE for UL transmission during the DL calibration gap.

[0154] Alternatively, the UE may receive the DL calibration gap settings through higher-layer signaling such as RRC or MAC-CE. This is less flexible than dynamic scheduling but may be used when calibration needs are predictable and consistent.

[0155] In another embodiment, the gNB may employ predefined patterns (known to the gNB and UE) for DL calibration gaps which align with other periodic events in the network, e.g., SSB transmissions.

[0156] Within the DL calibration gap time window, mTRP CJT mode of operation is not supported for the TRPs that are undergoing calibration. The UE may interpret its behavior within a DL calibration gap to act in one or more of the following ways.

[0157] The UE may abstain from monitoring PDCCH (e.g., the UE does not look for scheduling decisions or HARQ during the time window).

[0158] The UE may abstain from performing any UL transmission (e.g., PUCCH, PUSCH, PRACH, SRS, etc.).

[0159] The UE may use the calibration gap to adjust its TA value.

[0160] The UE may keep from expecting PDSCH from a specific TRP or group of TRPs that are determined to be uncalibrated (e.g., out of mTRP CJT functional range).

[0161] The UE may reset the frequency and timing relative measurements and related timer(s).

[0162] The UE may deprioritize, not accumulate, or measure any RS from a specific TRP or group of TRPs that are determined to be uncalibrated. In one embodiment, the CSI reporting priority for CJT configuration may be set to a minimum. For example, if CJT is part of a CC that is part of a CA configuration, then during the DL calibration time window, the CJT frequency/time measurements priority goes to zero. In one embodiment, the CSI reports for CJT may be suspended entirely, until correct synchronized RS are received by the UE. This CSI report suspension can be determined by the report triggering moment and the end of the configured calibration gap plus at least the duration to the first calibrated RS reception.

[0163] In addition, the gNB may send a CSI feedback restriction on a subset of CMR indices by activating/deactivating CMRs from the CSI report. This CSI feedback configuration to be received by the UE to restrict it to measure CSI only on a subset of CMR indices can be signaled through MAC-CE. The UE behavior in this case can include at least one of the following actions.

[0164] The UE drops the CSI for the deactivated CMR indices. In one embodiment, the number of selected CSI-RS resources is $N = N_{TRP}$.

[0165] The UE considers a restricted bitmap where it does not measure CSI for the deactivated CMR indices. In one embodiment, the UE is expected to select N CSI-RS resources, where $1 \leq N \leq N_{TRP}$. The UE selection is reported with an N_{TRP}-bit bitmap, $b_{N_{TRP}}, \ldots, b_1$, where the CSI-RS resources are mapped from bit b_1 to bit $b_{N_{TRP}}$ by their ordering in the resource set and the first of the N selected CSI-RS resources corresponds to the nonzero bit with lowest index.

[0166] Towards the end of the DL calibration gap, the UE prepares to resume normal operations, such as re-enabling UL transmissions and monitoring the PDCCH.

[0167] After having reported the relative frequency/time errors and the end of calibration gap, the UE may behave in different ways, as will now be described.

[0168] The UE may determine that the network performs calibration of one or more of the TRPs during the DL scheduled gap. The UE may determine that the DL scheduled gap applies to one or more TRPs from the set of TRPs configured for CJT based on an association between the DL scheduled gap and TRPs. During the DL scheduled gap, one or more TRPs may not be able to participate in a CJT mode of operation.

[0169] In one embodiment, the UE may fall back from the CJT mode to a default mode of operation after reporting relative errors and upon reception of the DL scheduled gap. The default mode of operation may include one or more TRPs from the set of TRPs configured for CJT. Alternatively, the default TRP may be outside the CJT set. The UE may operate in the fallback mode for a duration of time given by the length of the DL scheduled gap, or by a timer that is configured with the DL scheduled gap. The UE determines the default/primary/anchor TRP and one or more TRPs based on a restriction on the CSI-RS Measurement Resources (CMRs). A UE can restrict the CMR indices to a subset of indices based on one or more of the following ways.

[0170] The UE may be preconfigured with indices (e.g., lowest CMR, UTCI state, coresetPoolIndex, RS) that form the default set of restricted TRPs.

[0171] The UE may receive a MAC-CE after reporting the relative synchronization errors. The MAC-CE may include the indices of the CMR or CMR pairs that may be restricted. The MAC-CE may include a bitmap to indicate the active/inactive/dropped CMR indices.

[0172] The UE may be configured to count the number of times a measurement condition is satisfied, and may initiate the restriction after the count exceeds a configured number. One or more of the following may be considered as a measurement condition for at least one resource in a CMR: the signal quality (e.g., Reference Signal Received Power (RSRP), Signal-to-Interference-Plus-Noise (SINR), Signal-to-Noise Ratio (SNR)) is above a configured threshold for at least one resource in a CMR, and the time/frequency synchronization error per TRP or relative error between TRPs is above a configured threshold.

[0173] The default mode of operation may be that the UE falls back to a single TRP mode of operation where the single TRP is the default/primary/anchor TRP. The UE may report CSI only considering the single TRP hypothesis. For example, a UE may be configured with a CSI report for multi-TRP (CJT or NCJT) where the UE may be expected to report a CSI for single TRP and for multi-TRP. The UE may prioritize reporting CSI for single TRP, and may drop the contents for the multi-TRP hypothesis. The UE may consider QCL assumptions or spatial filters for reception that are configured for single TRP. For example, a UE may receive a PDSCH with an ULTCI configured with two states. The UE may determine that the first TCI state is activated, and that the second TCI state is deactivated during the DL scheduled gap. The UE may resume the activation of both TCI states at the end of the DL scheduled gap.

[0174] The UE may also (alternatively or in addition) fall back to a mode of operation that considers a subset of TRPs. The UE may receive an association between the DL scheduled gap and the TRP indices. The UE may determine that the TRPs that are not associated with the DL scheduled gap are active, and that the TRPs that are associated with the DL scheduled gap are inactive. The UE may prioritize reporting CSI for the subset of TRPs in the restricted set.

[0175] To initiate the restriction, the UE may determine that only the restricted CMR indices remain active and may be expected to perform measurements or monitoring of RSs only for the activated CMR indices.

[0176] As an example, the UE may be configured with CMR1 and CMR2. The UE determines a restriction where CMR1 remains active, and CMR2 is deactivated. The UE may consider CSI reporting configurations based on measurements from CMR1, and may consider measurements based on CMR2 only after determining to reactivate CMR2 (e.g., UE-determined or based on a network command to activate the CMR2, or based on a timer configured for the duration of the DL scheduled gap).

[0177] As another example, the UE may be expected to perform monitoring/measurement of RSs only on active CMR indices, and may be expected to resume monitoring/measurement of RSs on inactive CMR indices at the end of the DL scheduled gap. The DL RSs may be configured for the purpose of RRM/RLM, beam management, CSI reporting, etc. The UE may also be expected to only transmit UL RSs to activated TRPs, and to resume transmission to inactive TRPs at the end of the DL scheduled gap.

[0178] In an embodiment, the UE may be expected to monitor a subset of PDDCH search spaces according to the active CMRs/TRPs in the DL measurement gap, and resume monitoring of all CMRs/TRPs at the end of the DL scheduled gap.

[0179] After reporting of the relative errors by the UE and/or upon reception of the DL scheduled gap, the UE may fall back from a joint transmission (e.g., from CJT or NCJT) based reception mode to a default mode. The default operation mode may be reception from a single TRP, or it may be reception from a pair of TRPs. The UE may perform one or more of the following during the default operation mode. One or more CMRs or TRP indices in the default operation mode for CSI measurement may be dynamically configured/indicated (e.g., by DCI and/or MAC-CE). Alternatively, the UE may dynamically determine one or more TRP indices for operation in the default mode and report it to the gNB in a CSI report.

[0180] When a UE is configured with a codebook-based CJT operation mode, e.g., txconfig='type-II-CJT-r18' or txconfig='typeII-CJT-PortSelection-r18', the UE in the default operation mode may do one or more of codebook subset restriction (CBSR) and management of uplink resources for UCI reporting.

[0181] Codebook subset restriction (CBSR): In Rel-18 CJT, up to four TRPs can be configured for CJT operation. CBSR in Rel-18 CJT is configured for at least one TRP, whereas CBSR configuration for the remaining TRPs is optional. When CBSR is configured for one TRP and the index of that TRP is not included in the set of TRP(s) operating in the default operation mode, one

or more of the following embodiments may apply for configuring CBSR for one or more TRPs included in the default operation mode:

[0182] In an embodiment, the UE may dynamically (e.g., by DCI) receive a new CBSR configuration for at least one TRP index in the set of TRPs for the default operation mode. The UE may receive indices of one or more DFT-beams and/or codepoints in the grid-of-beams (GoB) and one or more thresholds for restricting one or more beams in the GoB. The received new CBSR configuration may be associated with an anchor/primary TRP index in the default operation mode, where the anchor/primary TRP index be the first TRP index or the last TRP index among the set of TRPs included in default operation mode.

[0183] In another embodiment, the UE may dynamically receive an index of a TRP among the set of TRPs for the default operation mode. The UE may assume that the received TRP index is associated with the CBSR configuration received in the CJT operation mode, e.g., the CBSR configuration received in the CJT operation mode before the default operation mode. In an example, the DFT-beam indices and the thresholds configured in the CBSR configuration may be equally valid for the received TRP index and/or the index of the primary/anchor TRP.

[0184] In an embodiment, the UE may receive a CBSR configuration for the primary/anchor TRP in the CJT operation mode. The primary/anchor TRP is also included in the default mode. In the default operation mode, the UE then may assume that the CBSR configuration in the CJT mode is valid in the default mode. Alternatively, a separate CBSR may be configured for each TRP in the CJT operation mode, e.g., a separate CBSR configuration for each TRP in the set [TRP1, TRP2, TRP3, TRP4]. In an example, the set of TRPs in the default operation may include TRP2 and TRP4. The UE may assume that the CBSR configured for a TRP (e.g., for TRP2 and TRP4) in the CJT operation mode are valid for the same TRP(s) (e.g., for TRP2 and TRP4) in the default operation mode.

[0185] Management of uplink resources for UCI reporting: In Rel-18 CJT, the UE may select the spatial domain basis across the configured TRPs. The UE may also select the frequency domain basis for frequency domain compression. Further, the UE may also report indices of frequency and spatial domain basis of non-zero coefficients. The number of time and/or frequency domain resources needed to report indices of frequency and spatial domain basis or indices of non-zero coefficients is a function of the number of selected spatial domain basis and the frequency domain basis. Resources needed to report part 2 of a CJT CSI report (see hereinafter) is determined by the RRC or DCI configured beta_CSI_Part2 values. The UE may have an excess number of resources for part 2 of a CSI report in case it is semi-statically configured in one or more of the following ways.

[0186] The UE may be semi-statically (e.g., by RRC) configured to determine and report different number of spatial domain basis in CJT mode and in fall back mode. For example, the UE may be configured to determine M1 number of spatial domain basis and/or DFT-beam in CJT mode and M2<M1 number of spatial domain basis and/or DFT-beams in fall back mode.

[0187] The UE may be semi-statically (e.g., by RRC) configured to determine and report equal number of spatial domain basis in CJT mode and in fall back mode.

[0188] The UE may be semi-statically (e.g., by RRC) configured to with a single value of beta_CSI_part2 for CJT mode and for fall back mode. For example, a UE may be configured with a beta_CSI_part2 value which is valid for both CJT and fallback mode.

[0189] The UE may be semi-statically (e.g., by RRC) configured to with a first beta_CSI_part2 value for CJT mode and a second beta_CSI_part2 value for fall back mode. In an example, the UE is configured for a first beta_CSI_part2 value for CJT mode and a second beta_CSI_part2 value for all the fallback modes in a burst of DL scheduled gaps.

[0190] In case the UE is configured to use the beta_CSI_Part1 value configured for the CJT mode in the fallback mode, then part 2 of the CSI report may have resources more than needed, as the bitmap size to report the indices of the non-zero coefficients reduces due to the reduced number of spatial domain basis.

[0191] In an embodiment, the UE may do one or more of the following in the fallback mode,

[0192] The UE may determine to report group 1 part 2 of a CSI report in full and if there are some resources left, the UE determines to repeat reporting of one or more elements in group 1 part 2 (e.g., repeat reporting of wideband coefficients, subband coefficients, phase coeffcieints, etc in the same CSI report).

[0193] The UE may determine to report group 0 part 2 in full, and then repeat reporting of group 0 part 2 for the purpose of reliability enhancement.

[0194] The UE may use the excess resources to report the determined time and frequency synchronization measurements with a higher granularity. In an example, the UE may utilize the excess resources to repeat the reporting of time and frequency synchronization measurements.

[0195] The UE may report group 0, 1, and 2 in full and if there are still resources available, the UE may re-report group 0 in full and/or full or part of group 2 in full.

[0196] Description of part 1 and part 2 of a CSI report: A CSI report has two parts, i.e., part 1 and part 2. Part 2 of the CSI report is further divided into three groups, i.e., group 0, 1, and 2. In the current system (i.e., Rel-17/18), a UE reports group 0 with a higher priority than groups 1 and 2, and reports group 1 with a higher priority than group 2.

Triggered SRS based TRP calibration process

[0197] FIG. 4 illustrates a method according to a first embodiment of the present principles with implicit relative time/frequency error reporting using special SRS transmission.

[0198] In step S410, a UE is configured for CJT operation and configured to perform TRP frequency/timing-relative measurements using a configured RS per TRP. A TRP is indicated/configured as a reference/anchor TRP. The UE is configured with a set of SRS resources where each SRS resource is associated with an SRI and each SRI is associated with a TRP index.

[0199] In step S420, the UE performs measurements for frequency/timing errors for each TRP pair, including a first TRP and a second TRP, where the first TRP (e.g., of each pair) may be the anchor/reference TRP.

[0200] In step S430, the UE may flag/indicate excessive relative frequency/timing errors between a first and a second measured TRP to the network, when the difference exceeds a configured threshold. The UE may indicate the TRP index of the second TRP.

[0201] After transmitting the frequency/timing error indication, in step S440, the UE may receive a "special calibration SRS" transmission request. The SRS request DCI may include at least one of a "SRS calibration indication flag" and the SRI corresponding to the second TRP, a SRI corresponding to a SRS resource associated with the second TRP, a TCI state associated with the first TRP (e.g. the reference/anchor TRP), and a set of N SRIs corresponding to a respective N SRS resource where each SRS resource is associated with a respective TRP.

[0202] In response to receiving the special SRS request, in step S450, the UE may transmit a first SRS in a resource associated to the first TRP (e.g. reference TRP) using the frequency and timing associated with the first (e.g. reference TRP) TRP.

[0203] In response to receiving the special SRS request, in step S460, the UE may also transmit a second SRS using the indicated SRS resource and adjusting the time and/or frequency of the transmission based on the measured time and/or the frequency errors determined for the second TRP relative to the first TRP. If a set of N SRIs is indicated to the UE in the SRS calibration request, the UE may transmit an SRS in each of the SRS resources corresponding to N SRIs, where the time and/or frequency for each SRS transmission is adjusted based on measured time and/or frequency error for the corresponding TRP relative to the reference/first TRP. The SRS transmission or the N SRS transmissions may be based on indicated TCI state (e.g. may use a spatial filter based on the indicated TCI state).

[0204] In an embodiment, the UE receives configuration information for operation in a CJT mode, where the configuration may include at least one or more of the following,

[0205] The configuration may include the number of TRP candidates considered for CJT operation, from which, a subset of TRPs may be selected for transmission.

[0206] Based on the configuration, there may be at least one TCI state or configured downlink reference signal associated to each TRP.

[0207] Further, the configuration may include at least one SRS resource set, wherein, each SRS resource identified by an SRI, may be associated with one of the configured TRPs in the CJT set. The SRS configuration may also contain, information about some preconfigured transmission opportunities, e.g., a periodic pattern, a configured pattern, etc.

[0208] The configuration may include a configured performance metric threshold that may be used to trigger a frequency and/or measurement that may be based on one or more of the following,

[0209] The configuration may include a configured threshold for examining relative frequency timing error(s).

[0210] The configuration may include a configured threshold for examining relative frequency error(s).

[0211] The configuration may include a configured threshold for examining Error Vector Magnitude (EVM) error(s).

[0212] The configuration may include a configured threshold for system performance, e.g., RSRP, a representative indication of capacity, throughput, BLER, etc.

[0213] The configuration may include a configured time-related information for determination of frequency and/or timing error measurement opportunities, e.g., periodicity, timer, etc.

[0214] The configuration may include one or more uplink resources for reporting information related to frequency and/or timing errors, where each may be associated to one or more of TRPs. The uplink resources may be used for indicating the TRPs with excessive errors, indicating partial information related to frequency/time errors, e.g., only time or only frequency errors, etc.

[0215] In an embodiment, using at least one of the configured downlink reference signals for each TRP, the UE may perform frequency and/or timing measurement to determine relative frequency and/or timing errors of each TRP to a reference TRP, e.g., anchor/serving TRP. A UE may perform the measurement, based on one or more of the following.

[0216] The measurement may be based on an aperiodic/semi-persistent trigger, for example based on a performance metric, load balancing, etc., a gNB may indicate to perform a frequency and/or timing error measurement.

[0217] The measurement may be based on a deterministic pattern, for example, the UE may be configured with a periodicity, a timer, or pre-defined measurement opportunities, e.g., a time patter, to perform frequency and/or timing error measurements.

[0218] The measurement may be based on a system reconfiguration, for example, a reconfiguration of TRP candidate set in CJT configuration, carrier, Bandwidth Part (BWP), etc.

[0219] The measurement may be based on a performance metric, for example, when a UE observes the downlink performance has deteriorated, and the downlink performance metric, e.g., number of NACKs, measured RSRP, etc., has met a configured threshold.

[0220] In an embodiment, once the UE has performed a frequency/timing error measurement, if the measured error exceeds a configured threshold, the UE may indicate the TRP index associated to the excessive error. The indication of the TRP with an excessive frequency/time error, may be by indicating an index associated to a downlink or uplink reference signal. In a solution, the UE may also indicate the measured frequency or time error associated to the TRP.

[0221] FIG. 5 illustrates the principle of special calibration SRS transmission according to the present principles. In an embodiment, after determination of an excessive frequency/time error exhibited by a second TRP relative to a first TRP, i.e., reference TRP, a UE may receive a dynamic indication as a "special calibration SRS" transmission request. The dynamic indication, e.g., a DCI may include one or more of the following.

[0222] An indication flag corresponding to the second TRP that exhibits an excessive relative time/frequency error, the indication may be an SRI, or a TCI state associated to the second TRP.

[0223] A SRI corresponding to a SRS resource associated with the second TRP. In an embodiment, upon detection of an excessive relative time/frequency error exhibited by a second TRP, the UE may receive a set of N SRIs corresponding to a respective N SRS resource where each SRS resource is associated with a respective TRP.

[0224] A TCI state associated with the first TRP (e.g. the reference/anchor TRP).

[0225] When the UE receives a "special calibration SRS" request, the UE may perform one or more of the following.

[0226] The UE may transmit a first SRS using the SRS resource associated to the first TRP (e.g., reference TRP). The transmission may be according to the frequency and timing associated with the first (e.g., reference TRP) TRP.

[0227] If the "special calibration SRS" request indicates a single SRI, the UE may transmit a second SRS using the indicated SRS resource, e.g., to the first TRP. For the transmission of the second SRS, the transmission may be based on the frequency and timing associated with the second TRP.

[0228] If the "special calibration SRS" request indicates more than one SRI, e.g., N SRIs, the UE may transmit N SRS using the N SRS resources corresponding to N SRIs, where the transmission of each SRS resource may be based on the frequency and timing associated with each of corresponding TRP.

[0229] In an alternative embodiment, the UE may embark on transmission of a "special calibration SRS" without receiving an "special calibration SRS" request, using preconfigured transmission opportunities, as explained hereinbefore.

Solution Summary

[0230] In an embodiment, a method at a wireless transfer/receive unit, WTRU, includes receiving information indicative of a configuration for joint reception from a plurality of transmission points including a reference transmission point, and for reporting of measurements of relative errors related to received reference signals from at least one pair of transmission points of the plurality of transmission points; transmitting information indicative of measured relative errors related to received reference signals from the at least one pair of transmission points; receiving information indicative of at least one scheduled downlink gap; during the at least one scheduled downlink gap, measuring received signals from the reference transmission point or a subset of the plurality of transmission points; and after the at least one scheduled downlink gap, measuring received signals from the plurality of transmission points.

[0231] The relative errors can be related to at least one of time errors and frequency errors.

[0232] The measurements of relative errors can be periodic.

[0233] The measurements of relative errors can be aperiodic.

[0234] The at least one pair of transmission points can include the reference transmission point.

[0235] The scheduled downlink gap can be a single gap or a series of gaps.

[0236] The subset can satisfy at least one configured condition including time error within an indicated range, frequency error within an indicated range, and error rate below an indicated value.

[0237] Measuring received signals from at least one of the reference transmission point and a subset of the plurality of transmission points can include at least one of measuring channel state information for the plurality of transmission points, and measuring reference signals associated with the plurality of transmission points.

[0238] Measuring received signals from the plurality of transmission points can include at least one of measuring channel state information for the plurality of transmission points, and measuring reference signals associated with the plurality of transmission points.

[0239] The method can further include measuring the relative errors.

[0240] In an embodiment, a wireless transfer/receive unit, WTRU, includes at least one processor configured to receive information indicative of a configuration for joint reception from a plurality of transmission points including a reference transmission point, and for reporting of measurements of relative errors related to received reference signals from at least one pair of transmission points of the plurality of transmission points; transmit information indicative of measured relative errors related to received reference signals from the at least one pair of transmission points; receive

information indicative of at least one scheduled downlink gap; during the at least one scheduled downlink gap, measure received signals from the reference transmission point or a subset of the plurality of transmission points; and after the at least one scheduled downlink gap, measure received signals from the plurality of transmission points.

[0241] The relative errors can be related to at least one of time errors and frequency errors.

[0242] The measurements of relative errors can be periodic.

[0243] The measurements of relative errors can be aperiodic.

[0244] The at least one pair of transmission points can include the reference transmission point.

[0245] The scheduled downlink gap can be a single gap or a series of gaps.

[0246] The subset can satisfy at least one configured condition including time error within an indicated range, frequency error within an indicated range, and error rate below an indicated value.

[0247] Measure received signals from at least one of the reference transmission point and a subset of the plurality of transmission points can include at least one of measure channel state information for the plurality of transmission points, and measure reference signals associated with the plurality of transmission points.

[0248] Measure received signals from the plurality of transmission points can include at least one of measure channel state information for the plurality of transmission points, and measure reference signals associated with the plurality of transmission points.

[0249] The at least one processor can be further configured to measure the relative errors.

[0250] In an embodiment, a method at a wireless transfer/receive unit, WTRU, includes receiving information indicative of a configuration for joint reception from a plurality of transmission points including a reference transmission point, and for reporting of measurements of relative errors related to received reference signals from at least one pair of transmission points of the plurality of transmission points; transmitting information indicative of measured relative errors related to received reference signals from the at least one pair of transmission points; receiving information indicative of at least one scheduled downlink gap; during the at least one scheduled downlink gap, measuring received signals from the reference transmission point or a subset of the plurality of transmission points; and after the at least one scheduled downlink gap, monitoring channel search spaces associated with the plurality of transmission points.

[0251] The relative errors can be related to at least one of time errors and frequency errors.

[0252] The measurements of relative errors can be periodic.

[0253] The measurements of relative errors can be aperiodic.

[0254] The at least one pair of transmission points can include the reference transmission point.

[0255] The scheduled downlink gap can be a single gap or a series of gaps.

[0256] The subset can satisfy at least one configured condition including time error within an indicated range, frequency error within an indicated range, and error rate below an indicated value.

[0257] The method can further include measuring the relative errors.

[0258] In an embodiment, a wireless transfer/receive unit, WTRU, includes at least one processor configured to receive information indicative of a configuration for joint reception from a plurality of transmission points including a reference transmission point, and for reporting of measurements of relative errors related to received reference signals from at least one pair of transmission points of the plurality of transmission points; transmit information indicative of measured relative errors related to received reference signals from the at least one pair of transmission points; receive information indicative of at least one scheduled downlink gap; during the at least one scheduled downlink gap, measure received signals from the reference transmission point or a subset of the plurality of transmission points; and after the at least one scheduled downlink gap, monitor channel search spaces associated with the plurality of transmission points.

[0259] The relative errors can be related to at least one of time errors and frequency errors.

[0260] The measurements of relative errors can be periodic.

[0261] The measurements of relative errors can be aperiodic.

[0262] The at least one pair of transmission points can include the reference transmission point.

[0263] The scheduled downlink gap can be a single gap or a series of gaps.

[0264] The subset can satisfy at least one configured condition including time error within an indicated range, frequency error within an indicated range, and error rate below an indicated value.

[0265] The at least one processor can be further configured to measure the relative errors.

[0266] In an embodiment, a method at a wireless transfer/receive unit, WTRU, includes receiving information indicative of a configuration for joint reception from a plurality of transmission points including a reference transmission point, and for reporting of measurements of relative errors related to received reference signals from at least one pair of transmission points of the plurality of transmission points; transmitting information indicative of measured relative errors related to received reference signals from the at least one pair of transmission points; upon determination that a relative error exceeds a given value, transmitting information indicative of the exceeding relative error; receiving information indicative of a request for transmission of a calibration signal to at least one transmission point of the plurality of transmission points; and transmitting the calibration signal according to the request.

[0267] The information indicative of the exceeding relative error can include an identifier of at least one transmission point of the corresponding pair of transmission points.

[0268] The request can include at least one of an indicator of a reference signal corresponding to a transmission point of a pair for which the relative error exceeds the given value, and a TCI state associated with the reference transmission point.

[0269] The calibration signal can be transmitted to the reference transmission point.

[0270] The calibration signal can be transmitted to the transmission point that is not the reference transmission point, wherein at least one of a time or frequency of the calibration signal is based on the relative error.

[0271] In an embodiment, a wireless transfer/receive unit, WTRU, includes at least one processor configured to receive information indicative of a configuration for joint reception from a plurality of transmission points including a reference transmission point, and for reporting of measurements of relative errors related to received reference signals from at least one pair of transmission points of the plurality of transmission points; transmitting information indicative of measured relative errors related to received reference signals from the at least one pair of transmission points; upon determination that a relative error exceeds a given value, transmitting information indicative of the exceeding relative error; receiving information indicative of a request for transmission of a calibration signal to at least one transmission point of the plurality of transmission points; and transmitting the calibration signal according to the request.

[0272] The information indicative of the exceeding relative error can include an identifier of at least one transmission point of the corresponding pair of transmission points.

[0273] The request can include at least one of an indicator of a reference signal corresponding to a transmission point of a pair for which the relative error exceeds the given value, and a TCI state associated with the reference transmission point.

[0274] The calibration signal can be transmitted to the reference transmission point.

[0275] The calibration signal can be transmitted to the transmission point that is not the reference transmission point, wherein at least one of a time or frequency of the calibration signal is based on the relative error.

[0276] **Conclusion**

[0277] Although features and elements are provided above in particular combinations, one of ordinary skill in the art will appreciate that each feature or element can be used alone or in any combination with the other features and elements. The present disclosure is not to be limited in terms of the particular embodiments described in this application, which are intended as illustrations of various aspects. Many modifications and variations may be made without departing from its spirit and scope, as will be apparent to those skilled in the art. No element, act, or instruction used in the description of the present application should be construed as critical or essential to the invention unless explicitly provided as such. Functionally equivalent methods and

apparatuses within the scope of the disclosure, in addition to those enumerated herein, will be apparent to those skilled in the art from the foregoing descriptions. Such modifications and variations are intended to fall within the scope of the appended claims. The present disclosure is to be limited only by the terms of the appended claims, along with the full scope of equivalents to which such claims are entitled. It is to be understood that this disclosure is not limited to particular methods or systems.

[0278] The foregoing embodiments are discussed, for simplicity, with regard to the terminology and structure of infrared capable devices, i.e., infrared emitters and receivers. However, the embodiments discussed are not limited to these systems but may be applied to other systems that use other forms of electromagnetic waves or non-electromagnetic waves such as acoustic waves.

[0279] It is also to be understood that the terminology used herein is for the purpose of describing particular embodiments only, and is not intended to be limiting. As used herein, the term "video" or the term "imagery" may mean any of a snapshot, single image and/or multiple images displayed over a time basis. As another example, when referred to herein, the terms "user equipment" and its abbreviation "UE", the term "remote" and/or the terms "head mounted display" or its abbreviation "HMD" may mean or include (i) a wireless transmit and/or receive unit (WTRU); (ii) any of a number of embodiments of a WTRU; (iii) a wireless-capable and/or wired-capable (e.g., tetherable) device configured with, inter alia, some or all structures and functionality of a WTRU; (iii) a wireless-capable and/or wired-capable device configured with less than all structures and functionality of a WTRU; or (iv) the like. Details of an example WTRU, which may be representative of any WTRU recited herein, are provided herein with respect to FIGs. 1A-1D. As another example, various disclosed embodiments herein *supra* and *infra* are described as utilizing a head mounted display. Those skilled in the art will recognize that a device other than the head mounted display may be utilized and some or all of the disclosure and various disclosed embodiments can be modified accordingly without undue experimentation. Examples of such other device may include a drone or other device configured to stream information for providing the adapted reality experience.

[0280] In addition, the methods provided herein may be implemented in a computer program, software, or firmware incorporated in a computer-readable medium for execution by a computer or processor. Examples of computer-readable media include electronic signals (transmitted over wired or wireless connections) and computer-readable storage media. Examples of computer-readable storage media include, but are not limited to, a read only memory (ROM), a random access memory (RAM), a register, cache memory, semiconductor memory devices, magnetic media such as internal hard disks and removable disks, magneto-optical media, and optical media such as CD-ROM disks, and digital versatile disks (DVDs). A processor in association with

software may be used to implement a radio frequency transceiver for use in a WTRU, UE, terminal, base station, RNC, or any host computer.

[0281] Variations of the method, apparatus and system provided above are possible without departing from the scope of the invention. In view of the wide variety of embodiments that can be applied, it should be understood that the illustrated embodiments are examples only, and should not be taken as limiting the scope of the following claims. For instance, the embodiments provided herein include handheld devices, which may include or be utilized with any appropriate voltage source, such as a battery and the like, providing any appropriate voltage.

[0282] Moreover, in the embodiments provided above, processing platforms, computing systems, controllers, and other devices that include processors are noted. These devices may include at least one Central Processing Unit ("CPU") and memory. In accordance with the practices of persons skilled in the art of computer programming, reference to acts and symbolic representations of operations or instructions may be performed by the various CPUs and memories. Such acts and operations or instructions may be referred to as being "executed," "computer executed" or "CPU executed."

[0283] One of ordinary skill in the art will appreciate that the acts and symbolically represented operations or instructions include the manipulation of electrical signals by the CPU. An electrical system represents data bits that can cause a resulting transformation or reduction of the electrical signals and the maintenance of data bits at memory locations in a memory system to thereby reconfigure or otherwise alter the CPU's operation, as well as other processing of signals. The memory locations where data bits are maintained are physical locations that have particular electrical, magnetic, optical, or organic properties corresponding to or representative of the data bits. It should be understood that the embodiments are not limited to the above-mentioned platforms or CPUs and that other platforms and CPUs may support the provided methods.

[0284] The data bits may also be maintained on a computer readable medium including magnetic disks, optical disks, and any other volatile (e.g., Random Access Memory (RAM)) or non-volatile (e.g., Read-Only Memory (ROM)) mass storage system readable by the CPU. The computer readable medium may include cooperating or interconnected computer readable medium, which exist exclusively on the processing system or are distributed among multiple interconnected processing systems that may be local or remote to the processing system. It should be understood that the embodiments are not limited to the above-mentioned memories and that other platforms and memories may support the provided methods.

[0285] In an illustrative embodiment, any of the operations, processes, etc. described herein may be implemented as computer-readable instructions stored on a computer-readable medium. The

computer-readable instructions may be executed by a processor of a mobile unit, a network element, and/or any other computing device.

[0286] There is little distinction left between hardware and software implementations of aspects of systems. The use of hardware or software is generally (but not always, in that in certain contexts the choice between hardware and software may become significant) a design choice representing cost versus efficiency tradeoffs. There may be various vehicles by which processes and/or systems and/or other technologies described herein may be effected (e.g., hardware, software, and/or firmware), and the preferred vehicle may vary with the context in which the processes and/or systems and/or other technologies are deployed. For example, if an implementer determines that speed and accuracy are paramount, the implementer may opt for a mainly hardware and/or firmware vehicle. If flexibility is paramount, the implementer may opt for a mainly software implementation. Alternatively, the implementer may opt for some combination of hardware, software, and/or firmware.

[0287] The foregoing detailed description has set forth various embodiments of the devices and/or processes via the use of block diagrams, flowcharts, and/or examples. Insofar as such block diagrams, flowcharts, and/or examples include one or more functions and/or operations, it will be understood by those within the art that each function and/or operation within such block diagrams, flowcharts, or examples may be implemented, individually and/or collectively, by a wide range of hardware, software, firmware, or virtually any combination thereof. In an embodiment, several portions of the subject matter described herein may be implemented via Application Specific Integrated Circuits (ASICs), Field Programmable Gate Arrays (FPGAs), digital signal processors (DSPs), and/or other integrated formats. However, those skilled in the art will recognize that some aspects of the embodiments disclosed herein, in whole or in part, may be equivalently implemented in integrated circuits, as one or more computer programs running on one or more computers (e.g., as one or more programs running on one or more computer systems), as one or more programs running on one or more processors (e.g., as one or more programs running on one or more microprocessors), as firmware, or as virtually any combination thereof, and that designing the circuitry and/or writing the code for the software and or firmware would be well within the skill of one of skill in the art in light of this disclosure. In addition, those skilled in the art will appreciate that the mechanisms of the subject matter described herein may be distributed as a program product in a variety of forms, and that an illustrative embodiment of the subject matter described herein applies regardless of the particular type of signal bearing medium used to actually carry out the distribution. Examples of a signal bearing medium include, but are not limited to, the following: a recordable type medium such as a floppy disk, a hard disk drive, a CD, a DVD, a digital tape, a computer memory, etc., and a transmission type medium such as a digital and/or an analog

communication medium (e.g., a fiber optic cable, a waveguide, a wired communications link, a wireless communication link, etc.).

[0288] Those skilled in the art will recognize that it is common within the art to describe devices and/or processes in the fashion set forth herein, and thereafter use engineering practices to integrate such described devices and/or processes into data processing systems. That is, at least a portion of the devices and/or processes described herein may be integrated into a data processing system via a reasonable amount of experimentation. Those having skill in the art will recognize that a typical data processing system may generally include one or more of a system unit housing, a video display device, a memory such as volatile and non-volatile memory, processors such as microprocessors and digital signal processors, computational entities such as operating systems, drivers, graphical user interfaces, and applications programs, one or more interaction devices, such as a touch pad or screen, and/or control systems including feedback loops and control motors (e.g., feedback for sensing position and/or velocity, control motors for moving and/or adjusting components and/or quantities). A typical data processing system may be implemented utilizing any suitable commercially available components, such as those typically found in data computing/communication and/or network computing/communication systems.

[0289] The herein described subject matter sometimes illustrates different components included within, or connected with, different other components. It is to be understood that such depicted architectures are merely examples, and that in fact many other architectures may be implemented which achieve the same functionality. In a conceptual sense, any arrangement of components to achieve the same functionality is effectively "associated" such that the desired functionality may be achieved. Hence, any two components herein combined to achieve a particular functionality may be seen as "associated with" each other such that the desired functionality is achieved, irrespective of architectures or intermedial components. Likewise, any two components so associated may also be viewed as being "operably connected", or "operably coupled", to each other to achieve the desired functionality, and any two components capable of being so associated may also be viewed as being "operably couplable" to each other to achieve the desired functionality. Specific examples of operably couplable include but are not limited to physically mateable and/or physically interacting components and/or wirelessly interactable and/or wirelessly interacting components and/or logically interacting and/or logically interactable components.

[0290] With respect to the use of substantially any plural and/or singular terms herein, those having skill in the art can translate from the plural to the singular and/or from the singular to the plural as is appropriate to the context and/or application. The various singular/plural permutations may be expressly set forth herein for sake of clarity.

[0291] It will be understood by those within the art that, in general, terms used herein, and especially in the appended claims (e.g., bodies of the appended claims) are generally intended as "open" terms (e.g., the term "including" should be interpreted as "including but not limited to," the term "having" should be interpreted as "having at least," the term "includes" should be interpreted as "includes but is not limited to," etc.). It will be further understood by those within the art that if a specific number of an introduced claim recitation is intended, such an intent will be explicitly recited in the claim, and in the absence of such recitation no such intent is present. For example, where only one item is intended, the term "single" or similar language may be used. As an aid to understanding, the following appended claims and/or the descriptions herein may include usage of the introductory phrases "at least one" and "one or more" to introduce claim recitations. However, the use of such phrases should not be construed to imply that the introduction of a claim recitation by the indefinite articles "a" or "an" limits any particular claim including such introduced claim recitation to embodiments including only one such recitation, even when the same claim includes the introductory phrases "one or more" or "at least one" and indefinite articles such as "a" or "an" (e.g., "a" and/or "an" should be interpreted to mean "at least one" or "one or more"). The same holds true for the use of definite articles used to introduce claim recitations. In addition, even if a specific number of an introduced claim recitation is explicitly recited, those skilled in the art will recognize that such recitation should be interpreted to mean at least the recited number (e.g., the bare recitation of "two recitations," without other modifiers, means at least two recitations, or two or more recitations). Furthermore, in those instances where a convention analogous to "at least one of A, B, and C, etc." is used, in general such a construction is intended in the sense one having skill in the art would understand the convention (e.g., "a system having at least one of A, B, and C" would include but not be limited to systems that have A alone, B alone, C alone, A and B together, A and C together, B and C together, and/or A, B, and C together, etc.). In those instances where a convention analogous to "at least one of A, B, or C, etc." is used, in general such a construction is intended in the sense one having skill in the art would understand the convention (e.g., "a system having at least one of A, B, or C" would include but not be limited to systems that have A alone, B alone, C alone, A and B together, A and C together, B and C together, and/or A, B, and C together, etc.). It will be further understood by those within the art that virtually any disjunctive word and/or phrase presenting two or more alternative terms, whether in the description, claims, or drawings, should be understood to contemplate the possibilities of including one of the terms, either of the terms, or both terms. For example, the phrase "A or B" will be understood to include the possibilities of "A" or "B" or "A and B." Further, the terms "any of" followed by a listing of a plurality of items and/or a plurality of categories of items, as used herein, are intended to include "any of," "any combination of," "any multiple of," and/or "any combination

of multiples of" the items and/or the categories of items, individually or in conjunction with other items and/or other categories of items. Moreover, as used herein, the term "set" is intended to include any number of items, including zero. Additionally, as used herein, the term "number" is intended to include any number, including zero. And the term "multiple", as used herein, is intended to be synonymous with "a plurality".

[0292] In addition, where features or aspects of the disclosure are described in terms of Markush groups, those skilled in the art will recognize that the disclosure is also thereby described in terms of any individual member or subgroup of members of the Markush group.

[0293] As will be understood by one skilled in the art, for any and all purposes, such as in terms of providing a written description, all ranges disclosed herein also encompass any and all possible subranges and combinations of subranges thereof. Any listed range can be easily recognized as sufficiently describing and enabling the same range being broken down into at least equal halves, thirds, quarters, fifths, tenths, etc. As a non-limiting example, each range discussed herein may be readily broken down into a lower third, middle third and upper third, etc. As will also be understood by one skilled in the art all language such as "up to," "at least," "greater than," "less than," and the like includes the number recited and refers to ranges which can be subsequently broken down into subranges as discussed above. Finally, as will be understood by one skilled in the art, a range includes each individual member. Thus, for example, a group having 1-3 cells refers to groups having 1, 2, or 3 cells. Similarly, a group having 1-5 cells refers to groups having 1, 2, 3, 4, or 5 cells, and so forth.

[0294] Moreover, the claims should not be read as limited to the provided order or elements unless stated to that effect. In addition, use of the terms "means for" in any claim is intended to invoke 35 U.S.C. §112, ¶ 6 or means-plus-function claim format, and any claim without the terms "means for" is not so intended.

CLAIMS

What is claimed is:

1. A method at a wireless transmit/receive unit, WTRU, the method comprising:

receiving information indicative of a configuration for joint reception from a plurality of transmission points including a reference transmission point, and for reporting of measurements of relative errors related to received reference signals from at least one pair of transmission points of the plurality of transmission points;

transmitting information indicative of measured relative errors related to received reference signals from the at least one pair of transmission points;

receiving information indicative of at least one scheduled downlink gap; and

during the at least one scheduled downlink gap, monitoring received signals from a subset of the plurality of transmission points that satisfy a calibration condition.

2. The method of claim 1, wherein the relative errors are related to at least one of time errors and frequency errors.

3. The method of claim 1 or 2, wherein the measurements of relative errors are periodic.

4. The method of claim 1 or 2, wherein the measurements of relative errors are aperiodic.

5. The method of any one of claims 1-4, wherein the at least one pair of transmission points includes the reference transmission point.

6. The method of any one of claims 1-5, wherein the scheduled downlink gap is a single gap or a series of gaps.

7. The method of any one of claims 1-6, wherein the calibration condition comprises at least one of measured time error within an indicated range, measured frequency error within an indicated range, and measured error rate below an indicated value.

8. The method of any one of claims 1-7, wherein monitoring the received signals from the subset of the plurality of transmission points comprises at least one of measuring channel state information for the subset of the plurality of transmission points and measuring reference signals associated with the subset of the plurality of transmission points.

9. The method of any one of claims 1-8, further comprising measuring the relative errors.

10. A wireless transmit/receive unit, WTRU, comprising at least one processor configured to:

receive information indicative of a configuration for joint reception from a plurality of transmission points including a reference transmission point, and for reporting of measurements of relative errors related to received reference signals from at least one pair of transmission points of the plurality of transmission points;

transmit information indicative of measured relative errors related to received reference signals from the at least one pair of transmission points;

receive information indicative of at least one scheduled downlink gap; and

during the at least one scheduled downlink gap, monitor received signals from a subset of the plurality of transmission points that satisfy a calibration condition.

11. The WTRU of claim 10, wherein the relative errors are related to at least one of time errors and frequency errors.

12. The WTRU of claim 10 or 11, wherein the at least one processor is configured to make periodic measurements of relative errors.

13. The WTRU of claim 10 or 11, wherein the at least one processor is configured to make aperiodic measurements of relative errors.

14. The WTRU of any one of claims 10-13, wherein the at least one pair of transmission points includes the reference transmission point.

15. The WTRU of any one of claims 10-14, wherein the scheduled downlink gap is a single gap or a series of gaps.

16. The WTRU of any one of claims 10-15, wherein the calibration condition comprises at least one of measured time error within an indicated range, measured frequency error within an indicated range, and measured error rate below an indicated value.

17. The WTRU of any one of claims 10-16, wherein monitor the received signals from the subset of the plurality of transmission points comprises at least one of measure channel state information

for the subset of the plurality of transmission points and measure reference signals associated with the subset of the plurality of transmission points.

18. The WTRU of any one of claims 10-17, wherein the at least one processor is further configured to measure the relative errors.

19. A method at a wireless transmit/receive unit, WTRU, the method comprising:

receiving information indicative of a configuration for joint reception from a plurality of transmission points including a reference transmission point, and for reporting of measurements of relative errors related to received reference signals from at least one pair of transmission points of the plurality of transmission points;

transmitting information indicative of measured relative errors related to received reference signals from the at least one pair of transmission points;

receiving information indicative of at least one scheduled downlink gap;

during the at least one scheduled downlink gap, measuring received signals from the reference transmission point or a subset of the plurality of transmission points; and

after the at least one scheduled downlink gap, monitoring channel search spaces associated with the plurality of transmission points.

20. The method of claim 19, wherein the relative errors are related to at least one of time errors and frequency errors.

21. The method of claim 19 or 20, wherein the measurements of relative errors are periodic.

22. The method of claim 19 or 20, wherein the measurements of relative errors are aperiodic.

23. The method of any one of claims 19-22, wherein the at least one pair of transmission points includes the reference transmission point.

24. The method of any one of claims 19-23, wherein the scheduled downlink gap is a single gap or a series of gaps.

25. The method of any one of claims 19-24, wherein the subset satisfies at least one configured condition including time error within an indicated range, frequency error within an indicated range, and error rate below an indicated value.

26. The method of any one of claims 19-25, further comprising measuring the relative errors.

27. A wireless transmit/receive unit, WTRU, comprising at least one processor configured to:

receive information indicative of a configuration for joint reception from a plurality of transmission points including a reference transmission point, and for reporting of measurements of relative errors related to received reference signals from at least one pair of transmission points of the plurality of transmission points;

transmit information indicative of measured relative errors related to received reference signals from the at least one pair of transmission points;

receive information indicative of at least one scheduled downlink gap;

during the at least one scheduled downlink gap, measure received signals from the reference transmission point or a subset of the plurality of transmission points; and

after the at least one scheduled downlink gap, monitor channel search spaces associated with the plurality of transmission points.

28. The WTRU of claim 27, wherein the relative errors are related to at least one of time errors and frequency errors.

29. The WTRU of claim 27 or 28, wherein the measurements of relative errors are periodic.

30. The WTRU of claim 27 or 28, wherein the measurements of relative errors are aperiodic.

31. The WTRU of any one of claims 27-30, wherein the at least one pair of transmission points includes the reference transmission point.

32. The WTRU of any one of claims 27-31, wherein the scheduled downlink gap is a single gap or a series of gaps.

33. The WTRU of any one of claims 27-32, wherein the subset satisfies at least one configured condition including time error within an indicated range, frequency error within an indicated range, and error rate below an indicated value.

34. The WTRU of any one of claims 27-33, wherein the at least one processor is further configured to measure the relative errors.

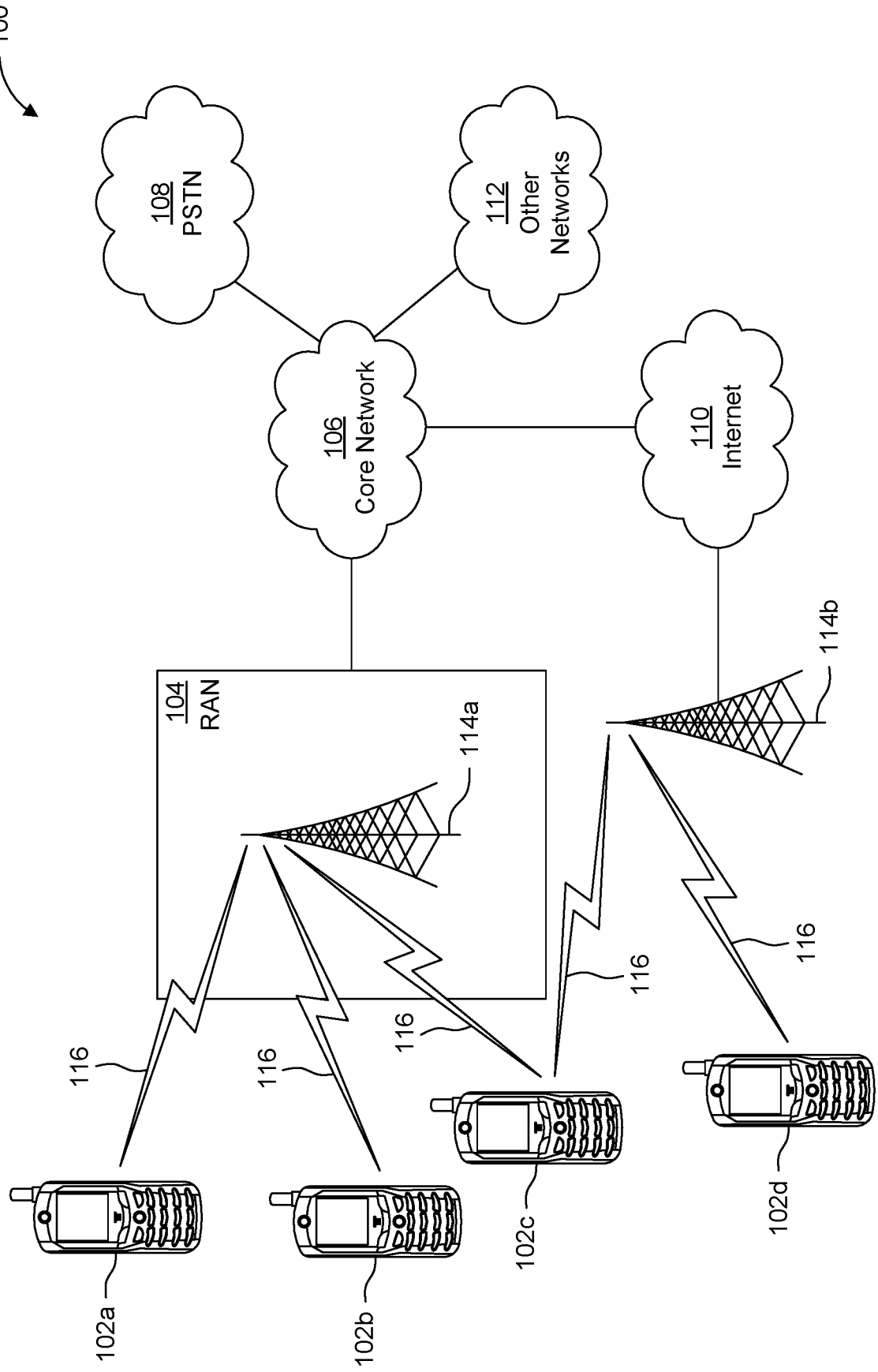

100
108 PSTN
112 Other Networks
106 Core Network
110 Internet
104 RAN
114a
114b
116
116
116
116
102a
102b
102c
102d

FIG. 1A

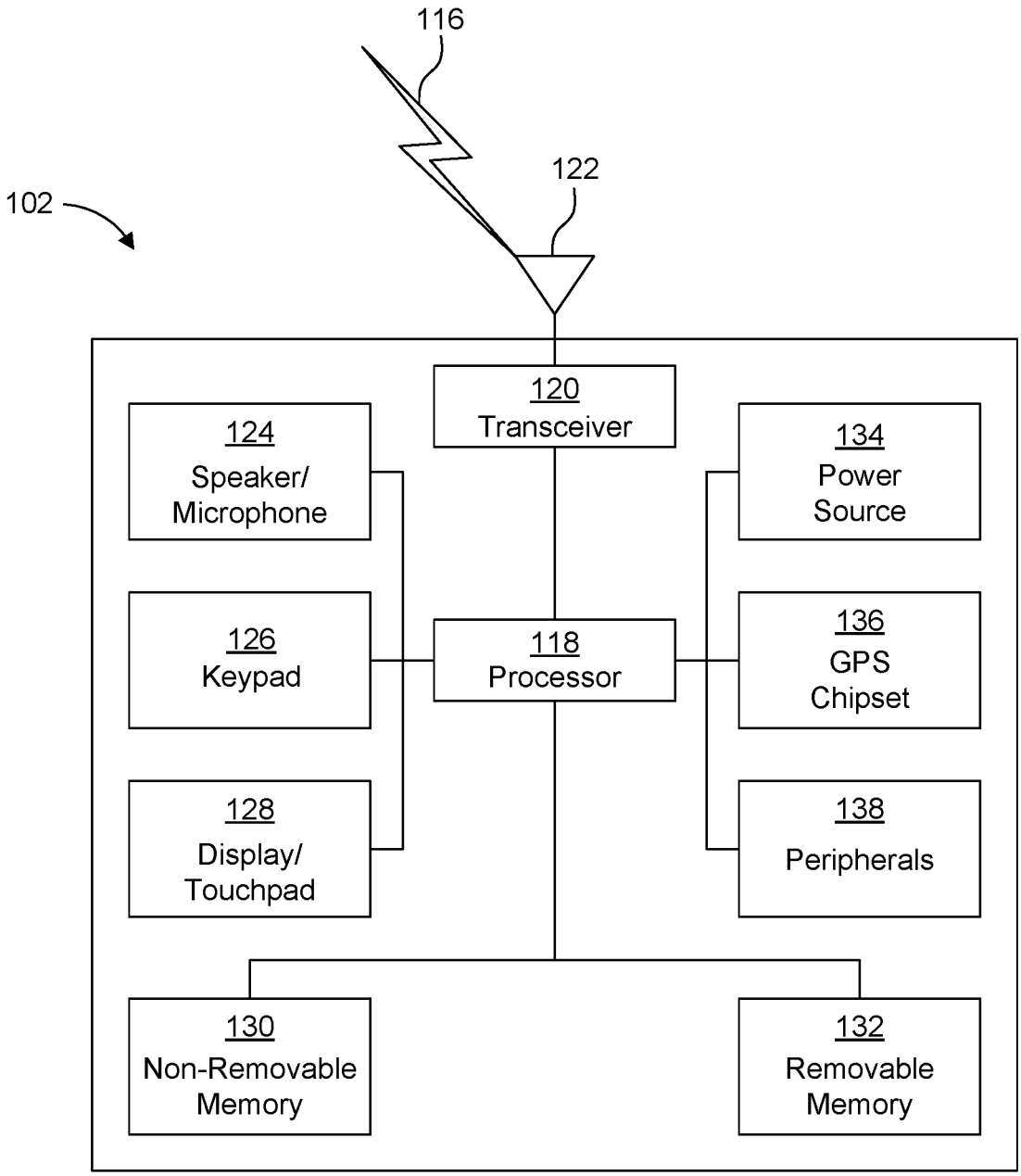

116
122
102
120
Transceiver
124
Speaker/
Microphone
134
Power
Source
126
Keypad
118
Processor
136
GPS
Chipset
128
Display/
Touchpad
138
Peripherals
130
Non-Removable
Memory
132
Removable
Memory

FIG. 1B

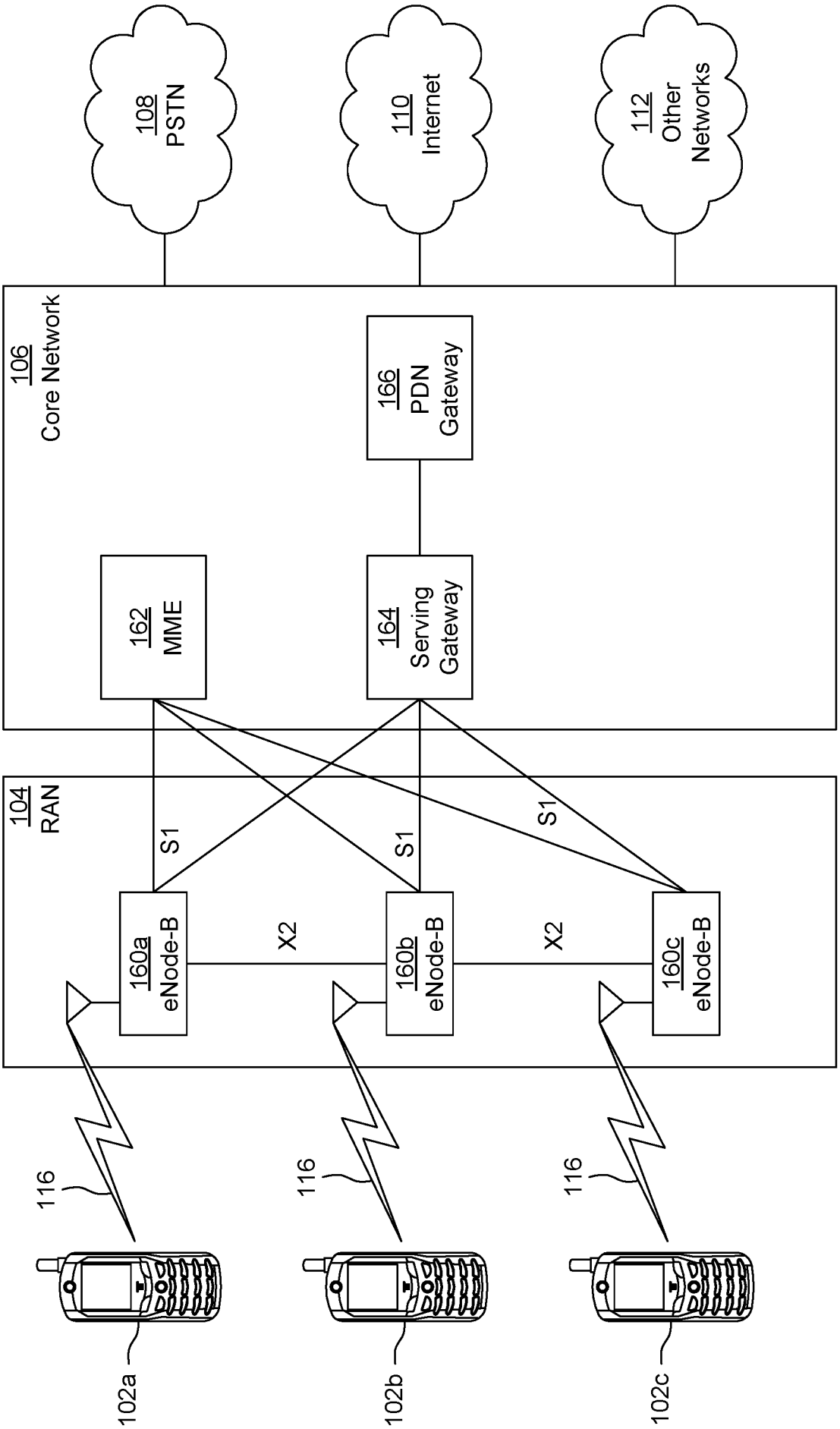

108 PSTN
110 Internet
112 Other Networks
106 Core Network
166 PDN Gateway
162 MME
164 Serving Gateway
104 RAN
S1
S1
S1
160a eNode-B
160b eNode-B
160c eNode-B
X2
X2
116
116
116
102a
102b
102c

FIG. 1C

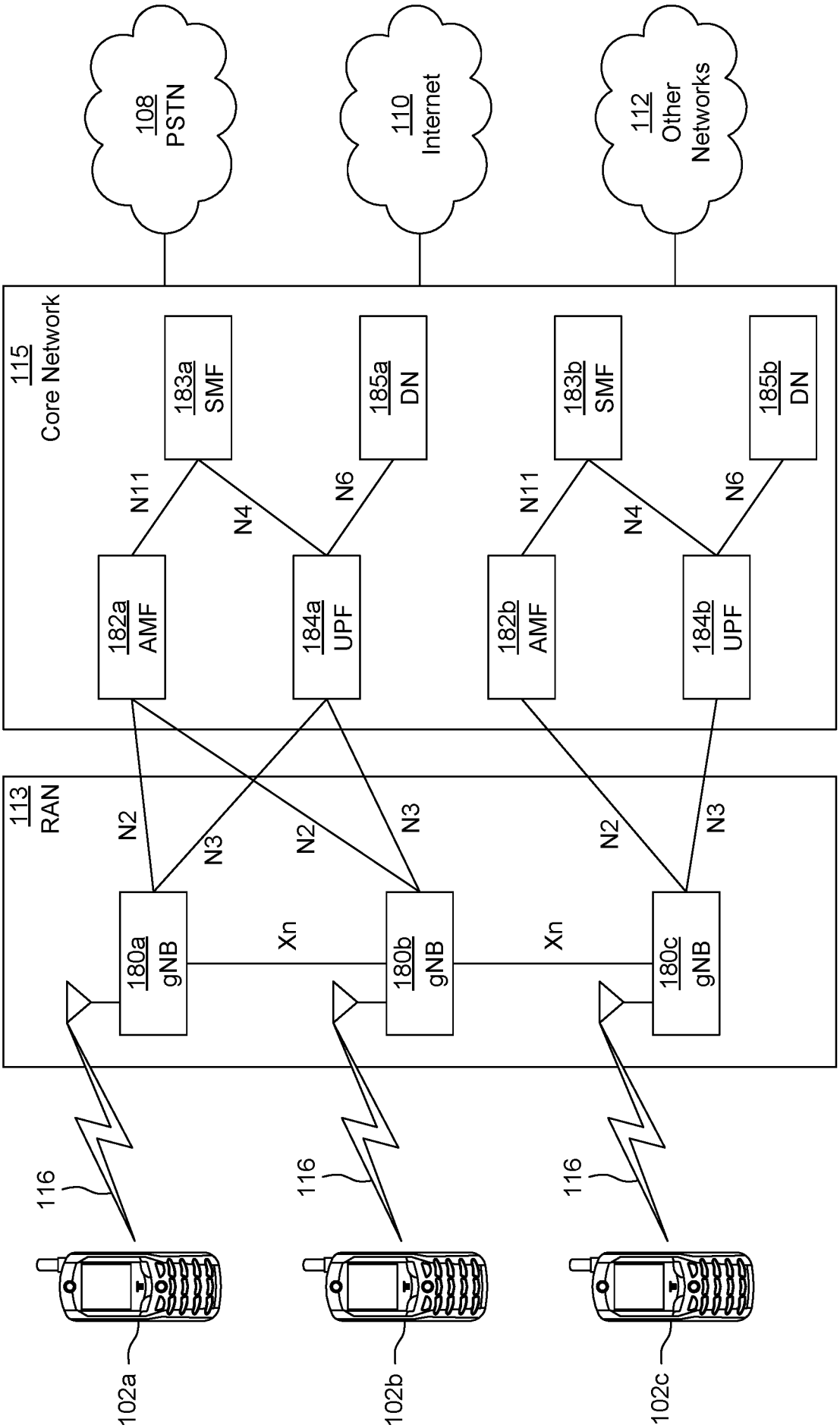

108 PSTN
110 Internet
112 Other Networks
115 Core Network
183a SMF
185a DN
183b SMF
185b DN
N11
N4
N6
N11
N4
N6
182a AMF
184a UPF
182b AMF
184b UPF
113 RAN
N2
N3
N2
N3
N2
N3
180a gNB
Xn
180b gNB
Xn
180c gNB
116
116
116
102a
102b
102c

FIG. 1D

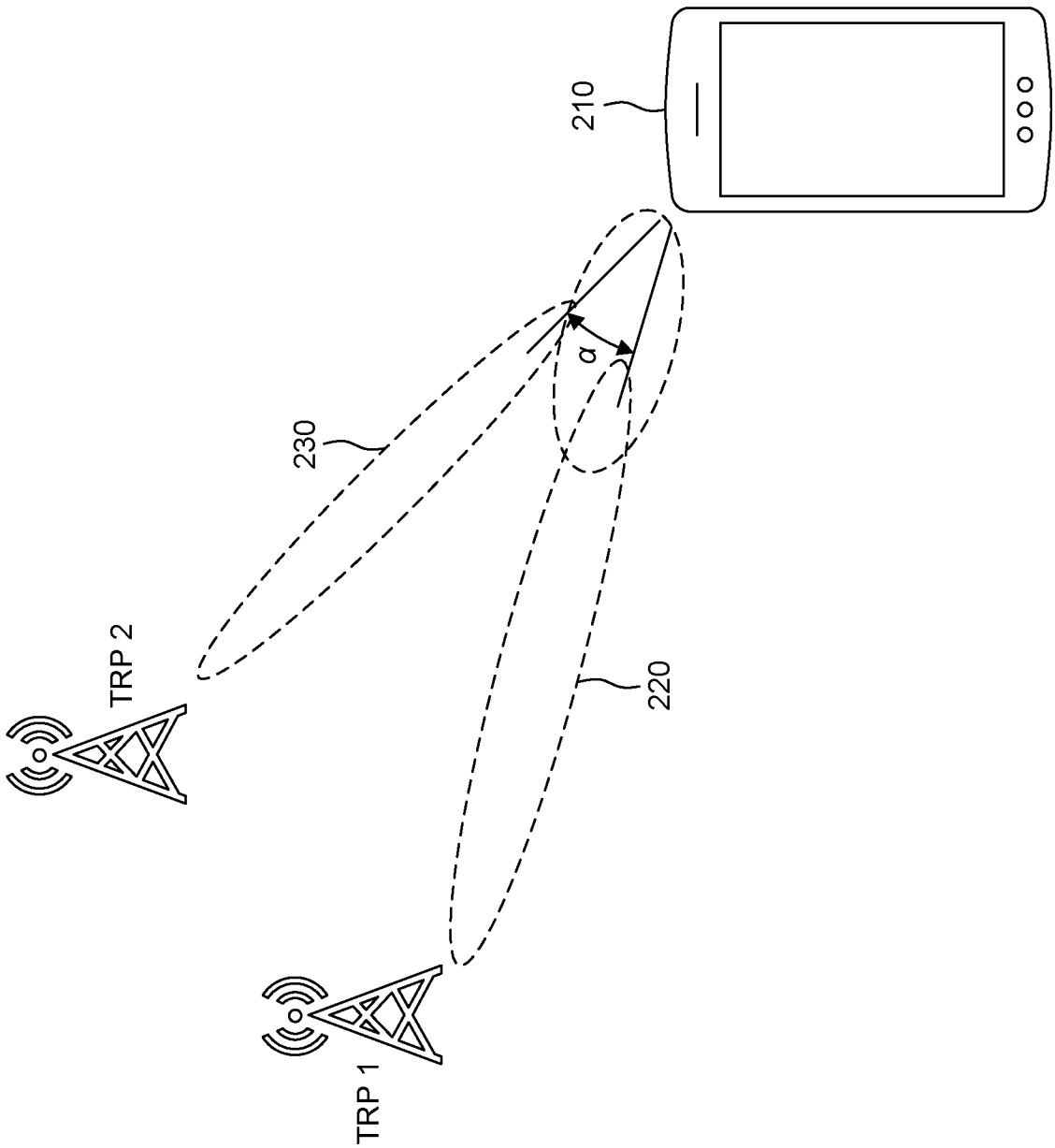


FIG. 2

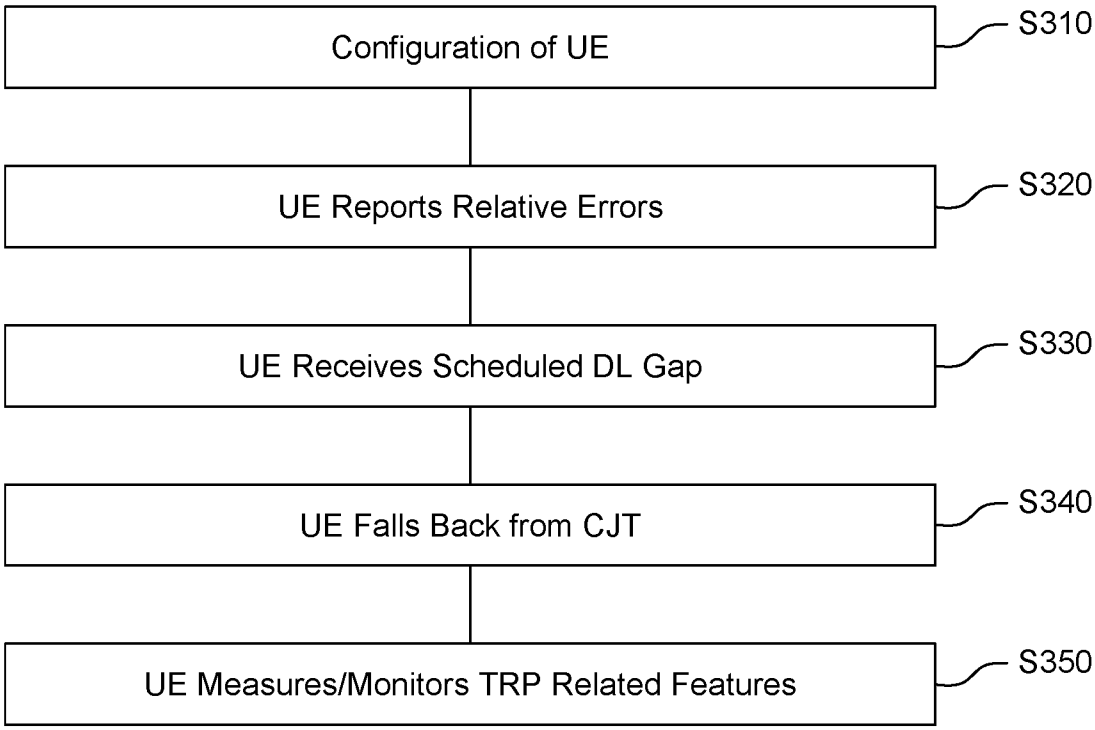

Configuration of UE
S310
UE Reports Relative Errors
S320
UE Receives Scheduled DL Gap
S330
UE Falls Back from CJT
S340
UE Measures/Monitors TRP Related Features
S350

FIG. 3

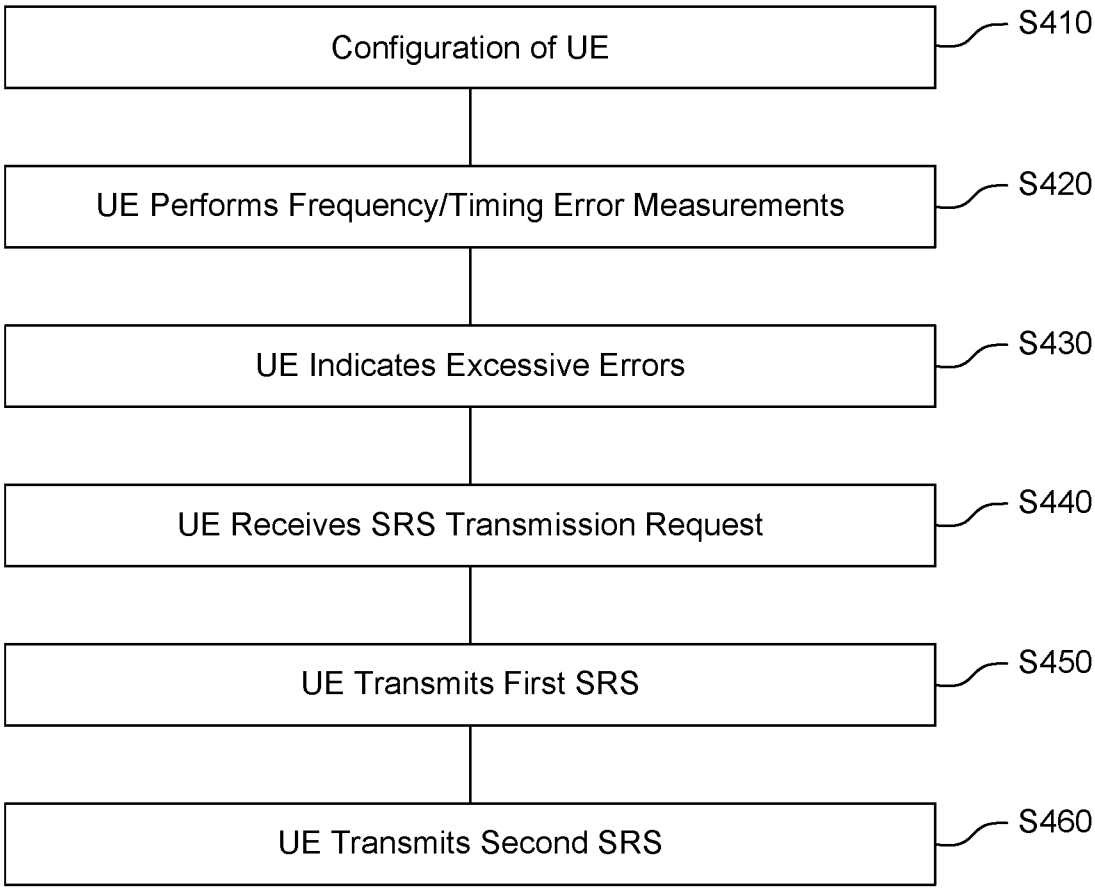

Configuration of UE
S410
UE Performs Frequency/Timing Error Measurements
S420
UE Indicates Excessive Errors
S430
UE Receives SRS Transmission Request
S440
UE Transmits First SRS
S450
UE Transmits Second SRS
S460

FIG. 4

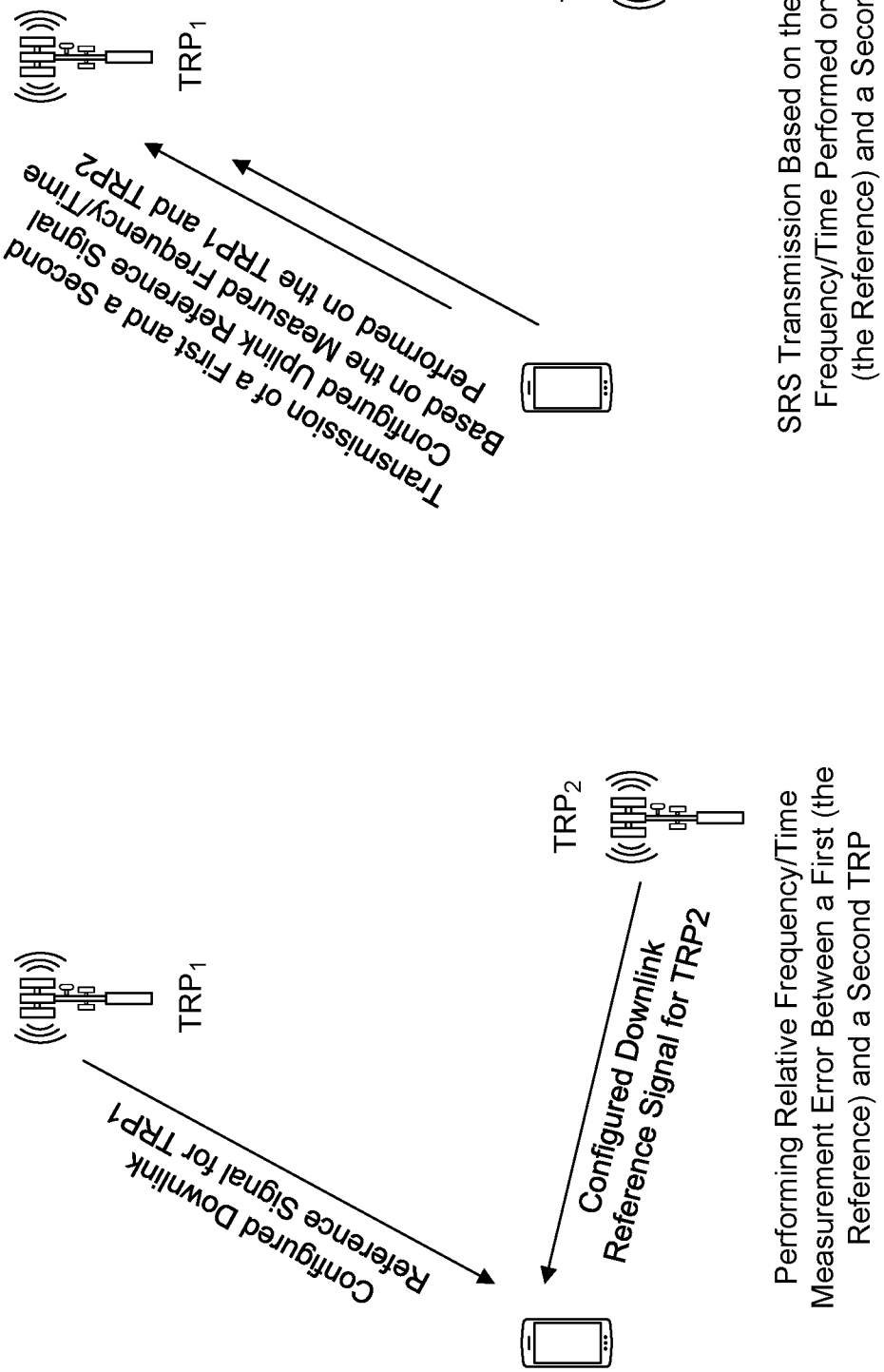

TRP1
TRP2
Configured Downlink Reference Signal for TRP1
Configured Downlink Reference Signal for TRP2
Performing Relative Frequency/Time Measurement Error Between a First (the Reference) and a Second TRP
Transmission of a First and a Second Configured Uplink Reference Signal Based on the Measured Frequency/Time Performed on the TRP1 and TRP2
SRS Transmission Based on the Measured Frequency/Time Performed on the First (the Reference) and a Second TRP

FIG. 5

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2024/059524

A. CLASSIFICATION OF SUBJECT MATTER

INV. H04B17/11 H04B17/24 H04B17/20
ADD.

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H04B

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

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2021/409128 A1 (RAGHAVAN VASANTHAN [US] ET AL) 30 December 2021 (2021-12-30)	1,2, 6-11, 15-20, 24-28, 32-34
A	paragraph [0006] - paragraph [0022] paragraph [0040] - paragraph [0041] paragraph [0046] - paragraph [0047] paragraph [0080] - paragraph [0082]	3-5, 12-14, 21-23, 29-31

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[x] Further documents are listed in the continuation of Box C.

[x] See patent family annex.

* Special categories of cited documents :

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"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

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
7 March 2025	19/03/2025

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

1

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INTERNATIONAL SEARCH REPORT

International application No
PCT/US2024/059524

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	WO 2023/179837 A1 (ERICSSON TELEFON AB L M [SE]) 28 September 2023 (2023-09-28)	1,2, 6-11, 15-20, 24-28, 32-34
A	page 2, line 19 - page 3, line 26 page 8, line 20 - page 9, line 11 page 14, line 24 - page 16, line 6	3-5, 12-14, 21-23, 29-31

A	US 2021/250786 A1 (LUO TAO [US] ET AL) 12 August 2021 (2021-08-12) paragraph [0006] - paragraph [0014] paragraph [0040] paragraph [0076] paragraph [0079] paragraph [0082] paragraph [0086] - paragraph [0087] paragraph [0099] - paragraph [0100] paragraph [0121] - paragraph [0122]; claim 8	1-34

A	US 10 110 407 B2 (WANG HAI [CN]; HU YANG [CN] ET AL.) 23 October 2018 (2018-10-23) column 1, line 5 - line 11 column 2, line 26 - column 6, line 2; claim 1	1-34

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/US2024/059524

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		EP 4173176 A2	03-05-2023
		KR 20230027025 A	27-02-2023
		US 2021409128 A1	30-12-2021
		WO 2021262391 A2	30-12-2021
WO 2023179837 A1	28-09-2023	EP 4497280 A1	29-01-2025
		WO 2023179837 A1	28-09-2023
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		CN 115053486 A	13-09-2022
		CN 118101150 A	28-05-2024
		EP 4104375 A1	21-12-2022
		KR 20220131934 A	29-09-2022
		TW 202139772 A	16-10-2021
		US 2021250786 A1	12-08-2021
		US 2024187886 A1	06-06-2024
		WO 2021162993 A1	19-08-2021
US 10110407 B2	23-10-2018	EP 2742626 A1	18-06-2014
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		WO 2013023334 A1	21-02-2013