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

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
11 June 2020 (11.06.2020)

WIPO | PCT

(10) International Publication Number
WO 2020/113547 A1

(51) International Patent Classification:
H04B 7/0456 (2017.01) *H04B 17/373* (2015.01)

(21) International Application Number:
PCT/CN2018/119726

(22) International Filing Date:
07 December 2018 (07.12.2018)

(25) Filing Language: English

(26) Publication Language: English

(71) Applicant: **QUALCOMM INCORPORATED** [US/US]; Attn: International IP Administration, 5775 Morehouse Drive, San Diego, California 92121-1714 (US).

(72) Inventors; and
(71) Applicants *(for US only)*: **WU, Liangming** [CN/CN]; 5775 Morehouse Drive, San Diego, California 92121-1714 (US). **HAO, Chenxi** [CN/CN]; 5775 Morehouse Drive, San Diego, California 92121-1714 (US). **LI, Qiaoyu** [CN/CN]; 5775 Morehouse Drive, San Diego, California 92121-1714 (US). **HUANG, Min** [CN/CN]; 5775 Morehouse Drive, San Diego, California 92121-1714 (US). **SORIA-GA, Joseph Binamira** [US/US]; 5775 Morehouse Drive, San Diego, California 92121-1714 (US). **CHEN, Wanshi** [CN/US]; 5775 Morehouse Drive, San Diego, California 92121-1714 (US).

(74) Agent: **NTD PATENT & TRADEMARK AGENCY LTD.**; 10th Floor, Tower C, Beijing Global Trade Center, 36 North Third Ring Road East, Dongcheng District, Beijing 100013 (CN).

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

(54) Title: CODEBOOK SUBSET RESTRICTION FOR FREQUENCY DOMAIN COMPRESSION

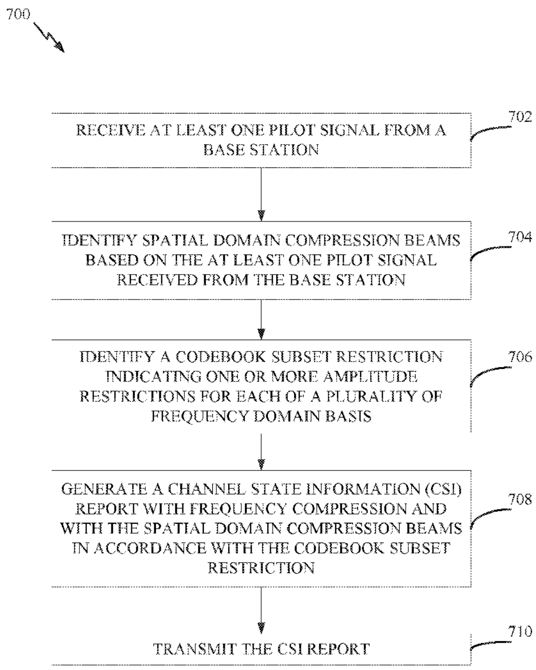

FIG. 7

(57) Abstract: Certain aspects of the present disclosure generally relate to methods and apparatus for channel estimation with frequency compression. One example method for wireless communication generally includes receiving at least one pilot signal from a base station, identifying spatial domain compression beams based on the at least one pilot signal, identifying a codebook subset restriction indicating one or more amplitude restrictions for each of a plurality of frequency domain basis, generating a channel state information (CSI) report with frequency compression and with the spatial domain compression beams in accordance with the codebook subset restriction, and transmitting the CSI report.

WO 2020/113547 A1

[Continued on next page]

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

Declarations under Rule 4.17:
— *of inventorship (Rule 4.17(iv))*

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

CODEBOOK SUBSET RESTRICTION FOR FREQUENCY DOMAIN COMPRESSION

INTRODUCTION

[0001] Aspects of the present disclosure relate to wireless communication, and more particularly, to communication of techniques for performing channel estimation.

[0002] Wireless communication systems are widely deployed to provide various telecommunication services such as telephony, video, data, messaging, and broadcasts. Typical wireless communication systems may employ multiple-access technologies capable of supporting communication with multiple users by sharing available system resources (e.g., bandwidth, transmit power). Examples of such multiple-access technologies include Long Term Evolution (LTE) systems, code division multiple access (CDMA) systems, time division multiple access (TDMA) systems, frequency division multiple access (FDMA) systems, orthogonal frequency division multiple access (OFDMA) systems, single-carrier frequency division multiple access (SC-FDMA) systems, and time division synchronous code division multiple access (TD-SCDMA) systems.

[0003] In some examples, a wireless multiple-access communication system may include a number of base stations, each simultaneously supporting communication for multiple communication devices, otherwise known as user equipment (UEs). In LTE or LTE-A network, a set of one or more base stations may define an e NodeB (eNB). In other examples (e.g., in a next generation or 5G network), a wireless multiple access communication system may include a number of distributed units (DUs) (e.g., edge units (EUs), edge nodes (ENs), radio heads (RHs), smart radio heads (SRHs), transmission reception points (TRPs), etc.) in communication with a number of central units (CUs) (e.g., central nodes (CNs), access node controllers (ANCs), etc.), where a set of one or more distributed units, in communication with a central unit, may define an access node (e.g., a new radio base station (NR BS), a new radio node-B (NR NB), a network node, 5G NB, gNB, etc.). A base station or DU may communicate with a set of UEs on downlink channels (e.g., for transmissions from a base station or to a UE) and uplink channels (e.g., for transmissions from a UE to a BS or DU).

[0004] These multiple access technologies have been adopted in various telecommunication standards to provide a common protocol that enables different wireless devices to communicate on a municipal, national, regional, and even global level. An example of an emerging telecommunication standard is new radio (NR), for example, 5G radio access. NR is a set of enhancements to the LTE mobile standard promulgated by Third Generation Partnership Project (3GPP). It is designed to better support mobile broadband Internet access by improving spectral efficiency, lowering costs, improving services, making use of new spectrum, and better integrating with other open standards using OFDMA with a cyclic prefix (CP) on the downlink (DL) and on the uplink (UL) as well as support beamforming, multiple-input multiple-output (MIMO) antenna technology, and carrier aggregation.

[0005] However, as the demand for mobile broadband access continues to increase, there exists a need for further improvements in NR technology. Preferably, these improvements should be applicable to other multi-access technologies and the telecommunication standards that employ these technologies.

SUMMARY

[0006] The systems, methods, and devices of the disclosure each have several aspects, no single one of which is solely responsible for its desirable attributes. Without limiting the scope of this disclosure as expressed by the claims which follow, some features will now be discussed briefly. After considering this discussion, and particularly after reading the section entitled "Detailed Description" one will understand how the features of this disclosure provide advantages that include improved communications between access points and stations in a wireless network.

[0007] Certain aspects of the present disclosure generally relate to methods and apparatus for channel estimation with frequency compression.

[0008] One example method for wireless communication generally includes receiving at least one pilot signal from a base station, identifying spatial domain compression beams based on the at least one pilot signal received from the base station, identifying a codebook subset restriction indicating one or more amplitude restrictions for each of a plurality of frequency domain basis, generating channel state information (CSI) report with frequency compression and with the spatial domain compression beams in accordance with the codebook subset restriction, and transmitting the CSI report.

[0009] One example method for wireless communication generally includes identifying, for each of spatial domain compression beams, a codebook subset restriction indicating one or more amplitude restrictions for a plurality of frequency domain basis, transmitting the codebook subset restriction, transmitting at least one pilot signal for identification of the spatial domain compression beams at a UE, and receiving the CSI report after the transmission of the at least one pilot signal, the CSI report being in accordance with the codebook subset restriction.

[0010] Aspects generally include methods, apparatus, systems, computer program products, and processing systems, as substantially described herein with reference to and as illustrated by the accompanying drawings.

[0011] To the accomplishment of the foregoing and related ends, the one or more aspects comprise the features hereinafter fully described and particularly pointed out in the claims. The following description and the annexed drawings set forth in detail certain illustrative features of the one or more aspects. These features are indicative, however, of but a few of the various ways in which the principles of various aspects may be employed, and this description is intended to include all such aspects and their equivalents.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] So that the manner in which the above-recited features of the present disclosure can be understood in detail, a more particular description, briefly summarized above, may be had by reference to aspects, some of which are illustrated in the appended drawings. It is to be noted, however, that the appended drawings illustrate only certain typical aspects of this disclosure and are therefore not to be considered limiting of its scope, for the description may admit to other equally effective aspects.

[0013] FIG. 1 is a block diagram conceptually illustrating an example telecommunications system, in accordance with certain aspects of the present disclosure.

[0014] FIG. 2 is a block diagram illustrating an example logical architecture of a distributed radio access network (RAN), in accordance with certain aspects of the present disclosure.

[0015] FIG. 3 is a diagram illustrating an example physical architecture of a distributed RAN, in accordance with certain aspects of the present disclosure.

[0016] FIG. 4 is a block diagram conceptually illustrating a design of an example base station (BS) and user equipment (UE), in accordance with certain aspects of the present disclosure.

[0017] FIG. 5 is a diagram showing examples for implementing a communication protocol stack, in accordance with certain aspects of the present disclosure.

[0018] FIG. 6 illustrates an example of a frame format for a new radio (NR) system, in accordance with certain aspects of the present disclosure.

[0019] FIG. 7 is a flow diagram illustrating example operations for wireless communication by a user-equipment (UE), in accordance with certain aspects of the present disclosure.

[0020] FIG. 8 is a flow diagram illustrating example operations for wireless communication by a base station, in accordance with certain aspects of the present disclosure.

[0021] To facilitate understanding, identical reference numerals have been used, where possible, to designate identical elements that are common to the figures. It is contemplated that elements disclosed in one aspect may be beneficially utilized on other aspects without specific recitation.

DETAILED DESCRIPTION

[0022] Aspects of the present disclosure provide apparatus, methods, processing systems, and computer readable mediums for performing channel estimation with frequency compression.

[0023] The following description provides examples, and is not limiting of the scope, applicability, or examples set forth in the claims. Changes may be made in the function and arrangement of elements discussed without departing from the scope of the disclosure. Various examples may omit, substitute, or add various procedures or components as appropriate. For instance, the methods described may be performed in an order different from that described, and various steps may be added, omitted, or combined. Also, features described with respect to some examples may be combined in some other examples. For example, an apparatus may be implemented or a method may be practiced using any number of the aspects set forth herein. In addition, the scope of the disclosure is intended to cover such an apparatus or method which is practiced using other structure, functionality, or structure and functionality in addition to or other than the various aspects of the disclosure set forth herein. It should be understood that any aspect of the disclosure disclosed herein may be embodied by one or more elements of a claim. The word "exemplary" is used herein to mean "serving as an example, instance, or illustration." Any aspect described herein as "exemplary" is not necessarily to be construed as preferred or advantageous over other aspects.

[0024] The techniques described herein may be used for various wireless communication networks such as LTE, CDMA, TDMA, FDMA, OFDMA, SC-FDMA and other networks. The terms "network" and "system" are often used interchangeably. A CDMA network may implement a radio technology such as Universal Terrestrial Radio Access (UTRA), cdma2000, etc. UTRA includes Wideband CDMA (WCDMA) and other variants of CDMA. cdma2000 covers IS-2000, IS-95 and IS-856 standards. A TDMA network may implement a radio technology such as Global System for Mobile Communications (GSM). An OFDMA network may implement a radio technology such as NR (e.g. 5G RA), Evolved UTRA (E-UTRA), Ultra Mobile Broadband (UMB), IEEE 802.11 (Wi-Fi), IEEE 802.16 (WiMAX), IEEE 802.20, Flash-OFDMA, etc. UTRA and E-UTRA are part of Universal Mobile Telecommunication System (UMTS). NR is an emerging wireless communications technology under development in conjunction with the 5G Technology Forum (5GTF). 3GPP Long Term Evolution (LTE) and LTE-Advanced (LTE-A) are releases of UMTS that use E-UTRA. UTRA, E-UTRA, UMTS, LTE, LTE-A and GSM are described in documents from an organization named "3rd Generation Partnership Project" (3GPP). cdma2000 and UMB are described in documents from an organization named "3rd Generation Partnership Project 2" (3GPP2). The techniques described herein may be used for the wireless networks and radio technologies mentioned above as well as other wireless networks and radio technologies. For clarity, while aspects may be described herein using terminology commonly associated with 3G and/or 4G wireless technologies, aspects of the present disclosure can be applied in other generation-based communication systems, such as 5G and later, including NR technologies.

EXAMPLE WIRELESS COMMUNICATIONS SYSTEM

[0025] FIG. 1 illustrates an example wireless communication network 100 in which aspects of the present disclosure may be performed. For example, the wireless communication network 100 may be a New Radio (NR) or 5G network.

[0026] As illustrated in FIG. 1, the wireless communication network 100 may include a number of base stations (BSs) 110 and other network entities. A BS may be a station that communicates with user equipments (UEs). Each BS 110 may provide communication coverage for a particular geographic area. In 3GPP, the term "cell" can refer to a coverage area of a Node B (NB) and/or a NB subsystem serving this coverage area, depending on the context in which the term is used. In NR systems, the term "cell" and next generation NodeB (gNB or gNodeB), NR BS, 5G NB, access point (AP), or transmission reception point (TRP) may be interchangeable. In some examples, a cell may not necessarily be stationary, and the geographic area of the cell may move according to the location of a mobile BS. In some examples, the base stations may be interconnected to one another and/or to one or more other base stations or network nodes (not shown) in wireless communication network 100 through various types of backhaul interfaces, such as a direct physical connection, a wireless connection, a virtual network, or the like using any suitable transport network.

[0027] In general, any number of wireless networks may be deployed in a given geographic area. Each wireless network may support a particular radio access technology (RAT) and may operate on one or more frequencies. A RAT may also be referred to as a radio technology, an air interface, etc. A frequency may also be referred to as a carrier, a subcarrier, a frequency channel, a tone, a subband, etc. Each frequency may support a single RAT in a given geographic area in order to avoid interference between wireless networks of different RATs. In some cases, NR or 5G RAT networks may be deployed.

[0028] A BS may provide communication coverage for a macro cell, a pico cell, a femto cell, and/or other types of cells. A macro cell may cover a relatively large geographic area (e.g., several kilometers in radius) and may allow unrestricted access by UEs with service subscription. A pico cell may cover a relatively small geographic area and may allow unrestricted access by UEs with service subscription. A femto cell may cover a relatively small geographic area (e.g., a home) and may allow restricted access by UEs having an association with the femto cell (e.g., UEs in a Closed Subscriber Group (CSG), UEs for users in the home, etc.). A BS for a macro cell may be referred to as a macro BS. A BS for a pico cell may be referred to as a pico BS. A BS for a femto cell may be referred to as a femto BS or a home BS. In the example shown in FIG. 1, the BSs 110a, 110b and 110c may be macro BSs for the macro cells 102a, 102b and 102c, respectively. The BS 110x may be a pico BS for a pico cell 102x. The BSs 110y and 110z may be femto BSs for the femto cells 102y and 102z, respectively. A BS may support one or multiple (e.g., three) cells.

[0029] Wireless communication network 100 may also include relay stations. A relay station is a station that receives a transmission of data and/or other information from an upstream station (e.g., a BS or a UE) and sends a transmission of the data and/or other information to a downstream station (e.g., a UE or a BS). A relay station may also be a UE that relays transmissions for other UEs. In the example shown in FIG. 1, a relay station 110r may communicate with the BS 110a and a UE 120r in order to facilitate communication between the BS 110a and the UE 120r. A relay station may also be referred to as a relay BS, a relay, etc.

[0030] Wireless communication network 100 may be a heterogeneous network that includes BSs of different types, e.g., macro BS, pico BS, femto BS, relays, etc. These different types of BSs may have different transmit power levels, different coverage areas, and different impact on interference in the wireless communication network 100. For example, macro BS may have a high transmit power level (e.g., 20 Watts) whereas pico BS, femto BS, and relays may have a lower transmit power level (e.g., 1 Watt).

[0031] Wireless communication network 100 may support synchronous or asynchronous operation. For synchronous operation, the BSs may have similar frame timing, and transmissions from different BSs may be approximately aligned in time. For asynchronous operation, the BSs may have different frame timing, and transmissions from different BSs may not be aligned in time. The techniques described herein may be used for both synchronous and asynchronous operation.

[0032] A network controller 130 may couple to a set of BSs and provide coordination and control for these BSs. The network controller 130 may communicate with the BSs 110 via a backhaul. The BSs 110 may also communicate with one another (e.g., directly or indirectly) via wireless or wireline backhaul.

[0033] The UEs 120 (e.g., 120x, 120y, etc.) may be dispersed throughout the wireless communication network 100, and each UE may be stationary or mobile. A UE may also be referred to as a mobile station, a terminal, an access terminal, a subscriber unit, a station, a Customer Premises Equipment (CPE), a cellular phone, a smart phone, a personal digital assistant (PDA), a wireless modem, a wireless communication device, a handheld device, a laptop computer, a cordless phone, a wireless local loop (WLL) station, a tablet computer, a camera, a gaming device, a netbook, a smartbook, an ultrabook, an appliance, a medical device or medical equipment, a biometric sensor/device, a wearable device such as a smart watch, smart clothing, smart glasses, a smart wrist band, smart jewelry (e.g., a smart ring, a smart bracelet, etc.), an entertainment device (e.g., a music device, a video device, a satellite radio, etc.), a vehicular component or sensor, a smart meter/sensor, industrial manufacturing equipment, a global positioning system device, or any other suitable device that is configured to communicate via a wireless or wired medium. Some UEs may be considered machine-type communication (MTC) devices or evolved MTC (eMTC) devices. MTC and eMTC UEs include, for example, robots, drones, remote devices, sensors, meters, monitors, location tags, etc., that may communicate with a BS, another device (e.g., remote device), or some other entity. A wireless node may provide, for example, connectivity for or to a network (e.g., a wide area network such as Internet or a cellular network) via a wired or wireless communication link. Some UEs may be considered Internet-of-Things (IoT) devices, which may be narrowband IoT (NB-IoT) devices.

[0034] Certain wireless networks (e.g., LTE) utilize orthogonal frequency division multiplexing (OFDM) on the downlink and single-carrier frequency division multiplexing (SC-FDM) on the uplink. OFDM and SC-FDM partition the system bandwidth into multiple (K) orthogonal subcarriers, which are also commonly referred to as tones, bins, etc. Each subcarrier may be modulated with data. In general, modulation symbols are sent in the frequency domain with OFDM and in the time domain with SC-FDM. The spacing between adjacent subcarriers may be fixed, and the total number of subcarriers (K) may be dependent on the system bandwidth. For example, the spacing of the subcarriers may be 15 kHz and the minimum resource allocation (called a "resource block" (RB)) may be 12 subcarriers (or 180 kHz). Consequently, the nominal Fast Fourier Transfer (FFT) size may be equal to 128, 256, 512, 1024 or 2048 for system bandwidth of 1.25, 2.5, 5, 10, or 20 megahertz (MHz), respectively. The system bandwidth may also be partitioned into subbands. For example, a subband may cover 1.8 MHz (i.e., 6 resource blocks), and there may be 1, 2, 4, 8, or 16 subbands for system bandwidth of 1.25, 2.5, 5, 10 or 20 MHz, respectively.

[0035] While aspects of the examples described herein may be associated with LTE technologies, aspects of the present disclosure may be applicable with other wireless communications systems, such as NR. NR may utilize OFDM with a CP on the uplink and downlink and include support for half-duplex operation using TDD. Beamforming may be supported and beam direction may be dynamically configured. MIMO transmissions with precoding may also be supported. MIMO configurations in the DL may support up to 8 transmit antennas with multi-layer DL transmissions up to 8 streams and up to 2 streams per UE. Multi-layer transmissions with up to 2 streams per UE may be supported. Aggregation of multiple cells may be supported with up to 8 serving cells.

[0036] In some examples, access to the air interface may be scheduled. A scheduling entity (e.g., a BS) allocates resources for communication among some or all devices and equipment within its service area or cell. The scheduling entity may be responsible for scheduling, assigning, reconfiguring, and releasing resources for one or more subordinate entities. That is, for scheduled communication, subordinate entities utilize resources allocated by the scheduling entity. Base stations are not the only entities that may function as a scheduling entity. In some examples, a UE may function as a scheduling entity and may schedule resources for one or more subordinate entities (e.g., one or more other UEs), and the other UEs may utilize the resources scheduled by the UE for wireless communication. In some examples, a UE may function as a scheduling entity in a peer-to-peer (P2P) network, and/or in a mesh network. In a mesh network example, UEs may communicate directly with one another in addition to communicating with a scheduling entity.

[0037] In FIG. 1, a solid line with double arrows indicates desired transmissions between a UE and a serving BS, which is a BS designated to serve the UE on the downlink and/or uplink. A finely dashed line with double arrows indicates interfering transmissions between a UE and a BS.

[0038] FIG. 2 illustrates an example logical architecture of a distributed Radio Access Network (RAN) 200, which may be implemented in the wireless communication network 100 illustrated in FIG. 1. A 5G access node 206 may include an access node controller (ANC) 202. ANC 202 may be a central unit (CU) of the distributed RAN 200. The backhaul interface to the Next Generation Core Network (NG-CN) 204 may terminate at ANC 202. The backhaul interface to neighboring next generation access Nodes (NG-ANs) 210 may terminate at ANC 202. ANC 202 may include one or more TRPs 208 (e.g., cells, BSs, gNBs, etc.).

[0039] The TRPs 208 may be a distributed unit (DU). TRPs 208 may be connected to a single ANC (e.g., ANC 202) or more than one ANC (not illustrated). For example, for RAN sharing, radio as a service (RaaS), and service specific AND deployments, TRPs 208 may be connected to more than one ANC. TRPs 208 may each include one or more antenna ports. TRPs 208 may be configured to individually (e.g., dynamic selection) or jointly (e.g., joint transmission) serve traffic to a UE.

[0040] The logical architecture of distributed RAN 200 may support fronthauling solutions across different deployment types. For example, the logical architecture may be based on transmit network capabilities (e.g., bandwidth, latency, and/or jitter).

[0041] The logical architecture of distributed RAN 200 may share features and/or components with LTE. For example, next generation access node (NG-AN) 210 may support dual connectivity with NR and may share a common fronthaul for LTE and NR.

[0042] The logical architecture of distributed RAN 200 may enable cooperation between and among TRPs 208, for example, within a TRP and/or across TRPs via ANC 202. An inter-TRP interface may not be used.

[0043] Logical functions may be dynamically distributed in the logical architecture of distributed RAN 200. As will be described in more detail with reference to FIG. 5, the Radio Resource Control (RRC) layer, Packet Data Convergence Protocol (PDCP) layer, Radio Link Control (RLC) layer, Medium Access Control (MAC) layer, and a Physical (PHY) layers may be adaptably placed at the DU (e.g., TRP 208) or CU (e.g., ANC 202).

[0044] FIG. 3 illustrates an example physical architecture of a distributed RAN 300, according to aspects of the present disclosure. A centralized core network unit (C-CU) 302 may host core network functions. C-CU 302 may be centrally deployed. C-CU 302 functionality may be offloaded (e.g., to advanced wireless services (AWS)), in an effort to handle peak capacity.

[0045] A centralized RAN unit (C-RU) 304 may host one or more ANC functions. Optionally, the C-RU 304 may host core network functions locally. The C-RU 304 may have distributed deployment. The C-RU 304 may be close to the network edge.

[0046] A DU 306 may host one or more TRPs (Edge Node (EN), an Edge Unit (EU), a Radio Head (RH), a Smart Radio Head (SRH), or the like). The DU may be located at edges of the network with radio frequency (RF) functionality.

[0047] FIG. 4 illustrates example components of BS 110 and UE 120 (as depicted in FIG. 1), which may be used to implement aspects of the present disclosure. For example, antennas 452, processors 466, 458, 464, and/or controller/processor 480 of the UE 120 and/or antennas 434, processors 420, 430, 438, and/or controller/processor 440 of the BS 110 may be used to perform the various techniques and methods described herein.

[0048] At the BS 110, a transmit processor 420 may receive data from a data source 412 and control information from a controller/processor 440. The control information may be for the physical broadcast channel (PBCH), physical control format indicator channel (PCFICH), physical hybrid ARQ indicator channel (PHICH), physical downlink control channel (PDCCH), group common PDCCH (GC PDCCH), etc. The data may be for the physical downlink shared channel (PDSCH), etc. The processor 420 may process (e.g., encode and symbol map) the data and control information to obtain data symbols and control symbols, respectively. The processor 420 may also generate reference symbols, e.g., for the primary synchronization signal (PSS), secondary synchronization signal (SSS), and cell-specific reference signal (CRS). A transmit (TX) multiple-input multiple-output (MIMO) processor 430 may perform spatial processing (e.g., precoding) on the data symbols, the control symbols, and/or the reference symbols, if applicable, and may provide output symbol streams to the modulators (MODs) 432a through 432t. Each modulator 432 may process a respective output symbol stream (e.g., for OFDM, etc.) to obtain an output sample stream. Each modulator may further process (e.g., convert to analog, amplify, filter, and upconvert) the output sample stream to obtain a downlink signal. Downlink signals from modulators 432a through 432t may be transmitted via the antennas 434a through 434t, respectively.

[0049] At the UE 120, the antennas 452a through 452r may receive the downlink signals from the base station 110 and may provide received signals to the demodulators (DEMODs) in transceivers 454a through 454r, respectively. Each demodulator 454 may condition (e.g., filter, amplify, downconvert, and digitize) a respective received signal to obtain input samples. Each demodulator may further process the input samples (e.g., for OFDM, etc.) to obtain received symbols. A MIMO detector 456 may obtain received symbols from all the demodulators 454a through 454r, perform MIMO detection on the received symbols if applicable, and provide detected symbols. A receive processor 458 may process (e.g., demodulate, deinterleave, and decode) the detected symbols, provide decoded data for the UE 120 to a data sink 460, and provide decoded control information to a controller/processor 480.

[0050] On the uplink, at UE 120, a transmit processor 464 may receive and process data (e.g., for the physical uplink shared channel (PUSCH)) from a data source 462 and control information (e.g., for the physical uplink control channel (PUCCH) from the controller/processor 480. The transmit processor 464 may also generate reference symbols for a reference signal (e.g., for the sounding reference signal (SRS)). The symbols from the transmit processor 464 may be precoded by a TX MIMO processor 466 if applicable, further processed by the demodulators in transceivers 454a through 454r (e.g., for SC-FDM, etc.), and transmitted to the base station 110. At the BS 110, the uplink signals from the UE 120 may be received by the antennas 434, processed by the modulators 432, detected by a MIMO detector 436 if applicable, and further processed by a receive processor 438 to obtain decoded data and control information sent by the UE 120. The receive processor 438 may provide the decoded data to a data sink 439 and the decoded control information to the controller/processor 440.

[0051] The controllers/processors 440 and 480 may direct the operation at the BS 110 and the UE 120, respectively. The processor 440 and/or other processors and modules at the BS 110 may perform or direct the execution of processes for the techniques described herein. The memories 442 and 482 may store data and program codes for BS 110 and UE 120, respectively. A scheduler 444 may schedule UEs for data transmission on the downlink and/or uplink.

[0052] FIG. 5 illustrates a diagram 500 showing examples for implementing a communications protocol stack, according to aspects of the present disclosure. The illustrated communications protocol stacks may be implemented by devices operating in a wireless communication system, such as a 5G system (e.g., a system that supports uplink-based mobility). Diagram 500 illustrates a communications protocol stack including a RRC layer 510, a PDCP layer 515, a RLC layer 520, a MAC layer 525, and a PHY layer 530. In various examples, the layers of a protocol stack may be implemented as separate modules of software, portions of a processor or ASIC, portions of non-collocated devices connected by a communications link, or various combinations thereof. Collocated and non-collocated implementations may be used, for example, in a protocol stack for a network access device (e.g., ANs, CUs, and/or DUs) or a UE.

[0053] A first option 505-a shows a split implementation of a protocol stack, in which implementation of the protocol stack is split between a centralized network access device (e.g., an ANC 202 in FIG. 2) and distributed network access device (e.g., DU 208 in FIG. 2). In the first option 505-a, an RRC layer 510 and a PDCP layer 515 may be implemented by the central unit, and an RLC layer 520, a MAC layer 525, and a PHY layer 530 may be implemented by the DU. In various examples the CU and the DU may be collocated or non-collocated. The first option 505-a may be useful in a macro cell, micro cell, or pico cell deployment.

[0054] A second option 505-b shows a unified implementation of a protocol stack, in which the protocol stack is implemented in a single network access device. In the second option, RRC layer 510, PDCP layer 515, RLC layer 520, MAC layer 525, and PHY layer 530 may each be implemented by the AN. The second option 505-b may be useful in, for example, a femto cell deployment.

[0055] Regardless of whether a network access device implements part or all of a protocol stack, a UE may implement an entire protocol stack as shown in 505-c (e.g., the RRC layer 510, the PDCP layer 515, the RLC layer 520, the MAC layer 525, and the PHY layer 530).

[0056] In LTE, the basic transmission time interval (TTI) or packet duration is the 1 ms subframe. In NR, a subframe is still 1 ms, but the basic TTI is referred to as a slot.

A subframe contains a variable number of slots (e.g., 1, 2, 4, 8, 16, … slots) depending on the subcarrier spacing. The NR RB is 12 consecutive frequency subcarriers. NR may support a base subcarrier spacing of 15 KHz and other subcarrier spacing may be defined with respect to the base subcarrier spacing, for example, 30 kHz, 60 kHz, 120 kHz, 240 kHz, etc. The symbol and slot lengths scale with the subcarrier spacing. The CP length also depends on the subcarrier spacing.

[0057] FIG. 6 is a diagram showing an example of a frame format 600 for NR. The transmission timeline for each of the downlink and uplink may be partitioned into units of radio frames. Each radio frame may have a predetermined duration (e.g., 10 ms) and may be partitioned into 10 subframes, each of 1 ms, with indices of 0 through 9. Each subframe may include a variable number of slots depending on the subcarrier spacing. Each slot may include a variable number of symbol periods (e.g., 7 or 14 symbols) depending on the subcarrier spacing. The symbol periods in each slot may be assigned indices. A mini-slot, which may be referred to as a sub-slot structure, refers to a transmit time interval having a duration less than a slot (e.g., 2, 3, or 4 symbols).

[0058] Each symbol in a slot may indicate a link direction (e.g., DL, UL, or flexible) for data transmission and the link direction for each subframe may be dynamically switched. The link directions may be based on the slot format. Each slot may include DL/UL data as well as DL/UL control information.

[0059] In NR, a synchronization signal (SS) block is transmitted. The SS block includes a PSS, a SSS, and a two symbol PBCH. The SS block can be transmitted in a fixed slot location, such as the symbols 0-3 as shown in FIG. 6. The PSS and SSS may be used by UEs for cell search and acquisition. The PSS may provide half-frame timing, the SS may provide the CP length and frame timing. The PSS and SSS may provide the cell identity. The PBCH carries some basic system information, such as downlink system bandwidth, timing information within radio frame, SS burst set periodicity, system frame number, etc. The SS blocks may be organized into SS bursts to support beam sweeping. Further system information such as, remaining minimum system information (RMSI), system information blocks (SIBs), other system information (OSI) can be transmitted on a physical downlink shared channel (PDSCH) in certain subframes. The SS block can be transmitted up to sixty-four times, for example, with up to sixty-four different beam directions for mmW. The up to sixty-four transmissions of the SS block are referred to as the SS burst set. SS blocks in an SS burst set are transmitted in the same frequency region, while SS blocks in different SS bursts sets can be transmitted at different frequency locations.

[0060] In some circumstances, two or more subordinate entities (e.g., UEs) may communicate with each other using sidelink signals. Real-world applications of such sidelink communications may include public safety, proximity services, UE-to-network relaying, vehicle-to-vehicle (V2V) communications, Internet of Everything (IoE) communications, IoT communications, mission-critical mesh, and/or various other suitable applications. Generally, a sidelink signal may refer to a signal communicated from one subordinate entity (e.g., UE1) to another subordinate entity (e.g., UE2) without relaying that communication through the scheduling entity (e.g., UE or BS), even though the scheduling entity may be utilized for scheduling and/or control purposes. In some examples, the sidelink signals may be communicated using a licensed spectrum (unlike wireless local area networks, which typically use an unlicensed spectrum).

[0061] A UE may operate in various radio resource configurations, including a configuration associated with transmitting pilots using a dedicated set of resources (e.g., a radio resource control (RRC) dedicated state, etc.) or a configuration associated with transmitting pilots using a common set of resources (e.g., an RRC common state, etc.). When operating in the RRC dedicated state, the UE may select a dedicated set of resources for transmitting a pilot signal to a network. When operating in the RRC common state, the UE may select a common set of resources for transmitting a pilot signal to the network. In either case, a pilot signal transmitted by the UE may be received by one or more network access devices, such as an AN, or a DU, or portions thereof. Each receiving network access device may be configured to receive and measure pilot signals transmitted on the common set of resources, and also receive and measure pilot signals transmitted on dedicated sets of resources allocated to the UEs for which the network access device is a member of a monitoring set of network access devices for the UE. One or more of the receiving network access devices, or a CU to which receiving network access device(s) transmit the measurements of the pilot signals, may use the measurements to identify serving cells for the UEs, or to initiate a change of serving cell for one or more of the UEs.

EXAMPLE TECHNIQUES FOR CODEBOOK SUBSET RESTRICTION FOR FREQUENCY DOMAIN COMPRESSION

[0062] Channel state information (CSI) may refer to known channel properties of a communication link. The CSI may represent the combined effects of, for example, scattering, fading, and power decay with distance between a transmitter and receiver. Channel estimation using the pilots, such as CSI reference signals (CSI-RS), may be performed to determine these effects on the channel. CSI may be used to adapt transmissions based on the current channel conditions, which is useful for achieving reliable communication, in particular, with high data rates in multi-antenna systems. CSI is typically estimated at the receiver, quantized, and fed back to the transmitter.

[0063] A network (e.g., a base station 110), may configure UEs for CSI reporting. For example, the BS 110 may configure the UE 120 with a CSI report configuration (sometimes referred to as a 'CSI report setting') or with multiple CSI report configurations. The CSI report configuration may be provided to the UE via higher layer signaling, such as radio resource control (RRC) signaling.

[0064] The CSI report configuration may configure the CSI parameters (sometimes referred to as quantities) to be reported using codebooks. Three example types of codebooks include Type I single panel, Type I multi-panel, and Type II single panel. Regardless of which codebook is used, the CSI report may include a channel quality indicator (CQI), a precoding matrix indicator (PMI), a CSI-RS resource indicator (CRI), and/or a rank indicator (RI). The structure of the PMI may vary based on the codebook. For the Type I single panel codebook, the PMI may include a W1 matrix (e.g., subset of beams) and a W2 matrix (e.g., phase for cross polarization combination and beam selection). For the Type I multi-panel codebook, compared to type I single panel codebook, the PMI further comprises a phase for cross panel combination. For the Type II single panel codebook, the PMI is a linear combination of beams; it has a subset of orthogonal beams to be used for linear combination and has per layer, per polarization, amplitude and phase for each beam. For the PMI of any type, there may be wideband (WB) PMI and/or subband (SB) PMI as configured.

[0065] Type-II CSI may involve spatial compression, where the CSI may be described with a codebook $W = W_1 W_2$, W_1 representing the spatial domain compression matrix (orthogonal DFT beams) and W_2 representing short-term and narrowband properties which may be reported per subband. A codebook subset restriction (CBSR) may be implemented to restrict the PMI that may be fed back to the BS. CBSR may be defined on wideband amplitude of linear combination coefficients.

[0066] CBSR implemented for CSI with spatial compression may support rank indicator (RI) restriction and DFT beam restriction based on DFT beam groups. For example, CBSR for CSI with spatial compression may be implemented by partitioning $N_1 N_2 O_1 O_2$ DFT beams into $O_1 O_2$ beam groups $G(r_1, r_2)$ comprising (N_1, N_2) adjacent beams. N1 and N2 represent first and second quantities of antenna ports in first and second dimensions of an antenna array, and O1 and O2 represent first and second oversampling factors for DFT beams in the first and second dimensions. (r_1, r_2) represents the bottom-left DFT beam of the group G, where $r_1 \in \{0, N_1, \ldots, (O_1 - 1)N_1\}$, $r_2 \in \{0, N_2, \ldots, (O_2 - 1)N_2\}$. The group may be defined as $G(r_1, r_2) = \{(r_1 + x_1, r_2 + x_2), \text{where } x_1 = 0,1, \ldots, N_1 - 1 \text{ and } x_2 = 0,1, \ldots, N_2 - 1\}$.

[0067] CBSR may be configured via B_1 and B_2, where B_1 is a length-$\left\lceil \log_2 \binom{O_1 O_2}{P} \right\rceil$ indicator which selects P beam groups $G(r_1, r_2)$ for further restriction. For example, $P = 4$ beam groups may be selected for restriction. The indicator $B_2 = B^{(1)} B^{(2)} \ldots B^{(P)}$, where $B^{(i)}$ is a length-$2N_1 N_2$ bitmap and restricts DFT beams and associated maximum WB amplitude coefficients in $G(r_1, r_2)$ for the i^{th} restricted (r_1, r_2) value in B_1. For each of the $N_1 N_2$ beams, a 2-bit indicator may be used for amplitude restriction. For example, a bit pair value of "00" may indicate a maximum WB beam power P_{MAX} of 0, a bit pair value of "01" may indicate a maximum WB beam power P_{MAX} of $\sqrt{0.25}$, a bit pair value of "10" may indicate a maximum WB beam power P_{MAX} of $\sqrt{0.5}$, a bit pair value of "11" may indicate a maximum WB beam power P_{MAX} of 1. Accordingly, the associated WB amplitude coefficients for each layer and polarization of a beam may be at most the indicated p_{MAX} value. Total length of B_1 and B_2 may be represented by the following equation:

$$\left\lceil \log_2 \binom{O_1 O_2}{P} \right\rceil + 2PN_1 N_2.$$

[0068] Certain CSI enhancements may be implemented such as CSI compression via frequency domain compression. For example, a CSI codebook structure with frequency compression may be generalized as $W = W_1 \tilde{W}_2 W_f^H$, where W_f^H represents frequency domain compression basis, and $\tilde{W}_2$ contains coefficients for spatial/frequency domain combination.

[0069] Certain aspects of the present disclosure provide techniques for CBSR implemented for CSI frequency domain compression. For example, a new definition of wideband amplitude per beam may be provided based on the feedback design of $\tilde{W}_2$ for frequency domain compression.

[0070] Each row (beam) of the $\tilde{W}_2$ matrix may have the same or different number of elements, and the amplitude and phase of $\tilde{W}_2$ may be quantized and fed back to the eNB by the UE. For example, for beam index i (e.g., i[th] row of $\tilde{W}_2$), a set of amplitudes M_i may be fed back to the BS, which may be denoted as $A_{i,j}$, where M_i represents the number of frequency domain basis j.

[0071] Different amplitude quantization alternatives may construct different forms of $A_{i,j}$. For example, for element independent reporting, $A_{i,j}$ may be fed back individually, and for multi-level feedback, $A_{i,j} = A_i * A_j$ may be fed back in the linear domain (or $A_{i,j} = A_i + A_j$ for dB domain multi-level feedback). Generally, the amplitude for frequency compression may be categorized into three alternatives. For per beam/frequency domain (FD) basis reporting, for all $2L$ beams and M_i FD basis to feedback for the i[th] beam, the UE may feedback $\sum_{i=0}^{2L-1} M_i$ amplitudes, where M_i may be the same or different for different beams, and L is the number of spatial domain basis vectors, which may be mapped to two polarizations, resulting in $2L$ total beams.

[0072] For wideband amplitude per beam and per FD basis differential amplitude reporting, for all $2L$ beams and M_i FD basis to feedback, the UE may feedback $2L$ beam amplitude and $\sum_{i=0}^{2L-1} M_i$ differential amplitudes, where $M_i$may be the same or different for different beams. For wideband amplitude per beam plus M FD basis plus per beam/FD basis differential amplitudes, for all $2L$ beams and M FD basis, the UE may feedback $2L + M$ wideband amplitudes and $2LM$ differential amplitudes.

[0073] FIG. 7 is a flow diagram illustrating example operations 700 for wireless communication, in accordance with certain aspects of the present disclosure. The operations 700 may be performed by a UE such as the UE 120.

[0074] The operations 700, begin at block 702, by receiving at least one pilot signal from a base station, and at block 704, identifying spatial compression beams based on the at least one pilot signal received from the base station. At block 706, the UE identifies a codebook subset restriction indicating, for each of the spatial compression beams, one or more amplitude restrictions for a plurality of frequency domain basis. At block 708, the UE may generate a CSI report (e.g., including PMI) with frequency compression and with the spatial compression beams in accordance with the codebook subset restriction, and at block 710, transmit the CSI report.

[0075] In certain aspects, the codebook subset restriction restricts, for each of the spatial compression beams, a maximum wideband amplitude across the plurality of frequency domain basis for the generation of the CSI report. In other words, the wideband amplitude across the plurality of frequency domain basis may be restricted to a value below a threshold amplitude Thr_i for each beam i. The amplitude restriction for the maximum amplitude per beam may be defined per the following equation:

$$\max A_{i,j} < Thr_i,\ 0 \leq j < M_i$$

[0076] In certain aspects, the codebook subset restriction restricts, for each of the spatial compression beams, a sum of wideband amplitudes across the plurality of frequency domain basis for the generation of the CSI report to be below a threshold amplitude Thr_i. For example, the CBSR may restrict the summation or weighted amplitude per beam for all the FD basis. The restriction may be defined as the summation of amplitudes per beam across the FD basis from j=0 to M_i, as defined in the following equation:

$$\sum_{j=0}^{M_i-1} A_{i,j} < Thr_i$$

[0077] In certain aspects, the codebook subset restriction restricts, for each of the spatial compression beams, an average of wideband amplitudes across the plurality of frequency domain basis for the generation of the CSI report to be below a threshold amplitude Thr_i. The restriction may be defined as the average amplitude per beam, as defined in the following equation:

$$\sqrt{\sum_{j=0}^{M_i-1} A_{i,j}^2} < Thr_i$$

[0078] In certain aspects, the CBSR may restrict the maximum re-constructed per subband level amplitude per beam. In other words, the precoding matrix W2 may be reconstructed by multiplying the matrices $\widetilde{W}_2$ and W_f^H, per the following equation:

$$W_2 = \widetilde{W}_2 W_f^H$$

Each row of the recovered precoding matrix W_2 may refer to a per beam coefficient, and the maximum amplitude per beam may be restricted for each row of W2. For example, the maximum amplitude per beam i, as defined in the following equation:

$$max_j\, abs(W_2(i,j))$$

may be restricted to be below a threshold amplitude Thr_i (e.g., a per beam maximum amplitude). In certain aspects, the CBSR as described herein may be identified and transmitted to the UE by a base station, as described in more detail with respect to FIG. 8.

[0079] FIG. 8 is a flow diagram illustrating example operations 800 for wireless communication, in accordance with certain aspects of the present disclosure. The operations 800 may be performed by a base station such as the base station 110.

[0080] The operations 800, begin at block 802, by identifying, for each of spatial domain compression beams, a codebook subset restriction indicating one or more amplitude restrictions for a plurality of frequency domain bases, and at block 804, transmitting the codebook subset restriction. At block 806, at least one pilot signal is transmitted for the identification of the spatial domain compression beams at a UE, and at block 808, a CSI report is received after the transmission of the at least one pilot signal, the CSI report being in accordance with the codebook subset restriction.

[0081] The methods disclosed herein comprise one or more steps or actions for achieving the described method. The method steps and/or actions may be interchanged with one another without departing from the scope of the claims. In other words, unless a specific order of steps or actions is specified, the order and/or use of specific steps and/or actions may be modified without departing from the scope of the claims.

[0082] As used herein, a phrase referring to "at least one of" a list of items refers to any combination of those items, including single members. As an example, "at least one of: a, b, or c" is intended to cover a, b, c, a-b, a-c, b-c, and a-b-c, as well as any combination with multiples of the same element (e.g., a-a, a-a-a, a-a-b, a-a-c, a-b-b, a-c-c, b-b, b-b-b, b-b-c, c-c, and c-c-c or any other ordering of a, b, and c).

[0083] As used herein, the term "determining" encompasses a wide variety of actions. For example, "determining" may include calculating, computing, processing, deriving, investigating, looking up (e.g., looking up in a table, a database or another data structure), ascertaining and the like. Also, "determining" may include receiving (e.g., receiving information), accessing (e.g., accessing data in a memory) and the like. Also, "determining" may include resolving, selecting, choosing, establishing and the like.

[0084] The previous description is provided to enable any person skilled in the art to practice the various aspects described herein. Various modifications to these aspects will be readily apparent to those skilled in the art, and the generic principles defined herein may be applied to other aspects. Thus, the claims are not intended to be limited to the aspects shown herein, but is to be accorded the full scope consistent with the language claims, wherein reference to an element in the singular is not intended to mean "one and only one" unless specifically so stated, but rather "one or more." Unless specifically stated otherwise, the term "some" refers to one or more. All structural and functional equivalents to the elements of the various aspects described throughout this disclosure that are known or later come to be known to those of ordinary skill in the art are expressly incorporated herein by reference and are intended to be encompassed by the claims. Moreover, nothing disclosed herein is intended to be dedicated to the public regardless of whether such disclosure is explicitly recited in the claims. No claim element is to be construed under the provisions of 35 U.S.C. §112, sixth paragraph, unless the element is expressly recited using the phrase "means for" or, in the case of a method claim, the element is recited using the phrase "step for."

[0085] The various operations of methods described above may be performed by any suitable means capable of performing the corresponding functions. The means may include various hardware and/or software component(s) and/or module(s), including, but not limited to a circuit, an application specific integrated circuit (ASIC), or processor. Generally, where there are operations illustrated in figures, those operations may have corresponding counterpart means-plus-function components with similar numbering.

[0086] The various illustrative logical blocks, modules and circuits described in connection with the present disclosure may be implemented or performed with a general purpose processor, a digital signal processor (DSP), an application specific integrated circuit (ASIC), a field programmable gate array (FPGA) or other programmable logic device (PLD), discrete gate or transistor logic, discrete hardware components, or any combination thereof designed to perform the functions described herein. A general-purpose processor may be a microprocessor, but in the alternative, the processor may be any commercially available processor, controller, microcontroller, or state machine. A processor may also be implemented as a combination of computing devices, e.g., a combination of a DSP and a microprocessor, a plurality of microprocessors, one or more microprocessors in conjunction with a DSP core, or any other such configuration.

[0087] If implemented in hardware, an example hardware configuration may comprise a processing system in a wireless node. The processing system may be implemented with a bus architecture. The bus may include any number of interconnecting buses and bridges depending on the specific application of the processing system and the overall design constraints. The bus may link together various circuits including a processor, machine-readable media, and a bus interface. The bus interface may be used to connect a network adapter, among other things, to the processing system via the bus. The network adapter may be used to implement the signal processing functions of the PHY layer. In the case of a user terminal 120 (see FIG. 1), a user interface (e.g., keypad, display, mouse, joystick, etc.) may also be connected to the bus. The bus may also link various other circuits such as timing sources, peripherals, voltage regulators, power management circuits, and the like, which are well known in the art, and therefore, will not be described any further. The processor may be implemented with one or more general-purpose and/or special-purpose processors. Examples include microprocessors, microcontrollers, DSP processors, and other circuitry that can execute software. Those skilled in the art will recognize how best to implement the described functionality for the processing system depending on the particular application and the overall design constraints imposed on the overall system.

[0088] If implemented in software, the functions may be stored or transmitted over as one or more instructions or code on a computer readable medium. Software shall be construed broadly to mean instructions, data, or any combination thereof, whether referred to as software, firmware, middleware, microcode, hardware description language, or otherwise. Computer-readable media include both computer storage media and communication media including any medium that facilitates transfer of a computer program from one place to another. The processor may be responsible for managing the bus and general processing, including the execution of software modules stored on the machine-readable storage media. A computer-readable storage medium may be coupled to a processor such that the processor can read information from, and write information to, the storage medium. In the alternative, the storage medium may be integral to the processor. By way of example, the machine-readable media may include a transmission line, a carrier wave modulated by data, and/or a computer readable storage medium with instructions stored thereon separate from the wireless node, all of which may be accessed by the processor through the bus interface. Alternatively, or in addition, the machine-readable media, or any portion thereof, may be integrated into the processor, such as the case may be with cache and/or general register files. Examples of machine-readable storage media may include, by way of example, RAM (Random Access Memory), flash memory, ROM (Read Only Memory), PROM (Programmable Read-Only Memory), EPROM (Erasable Programmable Read-Only Memory), EEPROM (Electrically Erasable Programmable Read-Only Memory), registers, magnetic disks, optical disks, hard drives, or any other suitable storage medium, or any combination thereof. The machine-readable media may be embodied in a computer-program product.

[0089] A software module may comprise a single instruction, or many instructions, and may be distributed over several different code segments, among different programs, and across multiple storage media. The computer-readable media may comprise a number of software modules. The software modules include instructions that, when executed by an apparatus such as a processor, cause the processing system to perform various functions. The software modules may include a transmission module and a receiving module. Each software module may reside in a single storage device or be distributed across multiple storage devices. By way of example, a software module may be loaded into RAM from a hard drive when a triggering event occurs. During execution of the software module, the processor may load some of the instructions into cache to increase access speed. One or more cache lines may then be loaded into a general register file for execution by the processor. When referring to the functionality of a software module below, it will be understood that such functionality is implemented by the processor when executing instructions from that software module.

[0090] Also, any connection is properly termed a computer-readable medium. For example, if the software is transmitted from a website, server, or other remote source using a coaxial cable, fiber optic cable, twisted pair, digital subscriber line (DSL), or wireless technologies such as infrared (IR), radio, and microwave, then the coaxial cable, fiber optic cable, twisted pair, DSL, or wireless technologies such as infrared, radio, and microwave are included in the definition of medium. Disk and disc, as used herein, include compact disc (CD), laser disc, optical disc, digital versatile disc (DVD), floppy disk, and Blu-ray® disc where disks usually reproduce data magnetically, while discs reproduce data optically with lasers. Thus, in some aspects computer-readable media may comprise non-transitory computer-readable media (e.g., tangible media). In addition, for other aspects computer-readable media may comprise transitory computer-readable media (e.g., a signal). Combinations of the above should also be included within the scope of computer-readable media.

[0091] Thus, certain aspects may comprise a computer program product for performing the operations presented herein. For example, such a computer program product may comprise a computer-readable medium having instructions stored (and/or encoded) thereon, the instructions being executable by one or more processors to perform the operations described herein. For example, instructions for perform the operations described herein.

[0092] Further, it should be appreciated that modules and/or other appropriate means for performing the methods and techniques described herein can be downloaded and/or otherwise obtained by a user terminal and/or base station as applicable. For example, such a device can be coupled to a server to facilitate the transfer of means for performing the methods described herein. Alternatively, various methods described herein can be provided via storage means (e.g., RAM, ROM, a physical storage medium such as a compact disc (CD) or floppy disk, etc.), such that a user terminal and/or base station can obtain the various methods upon coupling or providing the storage means to the device. Moreover, any other suitable technique for providing the methods and techniques described herein to a device can be utilized.

[0093] It is to be understood that the claims are not limited to the precise configuration and components illustrated above. Various modifications, changes and variations may be made in the arrangement, operation and details of the methods and apparatus described above without departing from the scope of the claims.

WHAT IS CLAIMED IS:

CLAIMS

1. A method for wireless communication, comprising:

receiving at least one pilot signal from a base station;

identifying spatial domain compression beams based on the at least one pilot signal received from the base station;

identifying, for each of the spatial domain compression beams, a codebook subset restriction indicating one or more amplitude restrictions for a plurality of frequency domain basis;

generating channel state information (CSI) report with frequency compression and with the spatial domain compression beams in accordance with the codebook subset restriction; and

transmitting the CSI report.

2. The method of claim 1, wherein the codebook subset restriction restricts, for each of the spatial domain compression beams, a maximum wideband amplitude across the plurality of frequency domain basis for the generation of the CSI report.

3. The method of claim 1, wherein the codebook subset restriction restricts, for each of the spatial domain compression beams, a sum of wideband amplitudes across the plurality of frequency domain basis for the generation of the CSI report to be below a threshold amplitude.

4. The method of claim 1, wherein the codebook subset restriction restricts, for each of the spatial domain compression beams, an average of wideband amplitudes across the plurality of frequency domain basis for the generation of the CSI report to be below a threshold amplitude.

5. The method of claim 1, wherein the CSI report comprises a codebook generated using a multiplication of a first precoding matrix representing a spatial domain compression matrix and a second precoding matrix, the second precoding matrix being generated using a multiplication of a matrix representing frequency domain compression basis and a matrix having coefficients for spatial and frequency domain combination.

6. The method of claim 5, wherein the codebook subset restriction restricts, for each of the spatial domain compression beams, a maximum amplitude for each subband corresponding to the second precoding matrix.

7. The method of claim 1, wherein the codebook subset restriction restricts, for each of the spatial domain compression beams, a maximum amplitude across the plurality of frequency domain basis for each of a plurality of subbands.

8. The method of claim 1, wherein identifying the codebook subset restriction comprises receiving the codebook subset restriction from a base station.

9. The method of claim 1, wherein the CSI report comprises precoding matrix information.

10. A method for wireless communication, comprising:

identifying, for each of spatial domain compression beams, a codebook subset restriction indicating one or more amplitude restrictions for a plurality of frequency domain basis;

transmitting the codebook subset restriction;

transmitting at least one pilot signal for identification of the spatial domain compression beams at a user-equipment (UE); and

receiving a channel station information (CSI) report after the transmission of at least one pilot signal, the CSI report being in accordance with the codebook subset restriction.

11. The method of claim 10, wherein the codebook subset restriction restricts, for each of the spatial domain compression beams, a maximum wideband amplitude across the plurality of frequency domain basis.

12. The method of claim 10, wherein the codebook subset restriction restricts, for each of the spatial domain compression beams, a sum of wideband amplitudes across the plurality of frequency domain basis to be below a threshold amplitude.

13. The method of claim 10, wherein the codebook subset restriction restricts, for each of the spatial domain compression beams, an average of wideband amplitudes across the plurality of frequency domain basis to be below a threshold amplitude.

14. The method of claim 10, wherein the CSI report comprises a codebook generated using a multiplication of a first precoding matrix representing a spatial domain compression matrix and a second precoding matrix, the second precoding matrix being generated using a

multiplication of a matrix representing frequency domain compression basis and a matrix having coefficients for spatial and frequency domain combination.

15. The method of claim 14, wherein the codebook subset restriction restricts, for each of the spatial domain compression beams, a maximum amplitude for each subband corresponding to the second precoding matrix.

16. The method of claim 10, wherein the codebook subset restriction restricts, for each of the spatial domain compression beams, a maximum amplitude across the plurality of frequency domain basis for each of a plurality of subbands.

17. The method of claim 10, wherein the CSI report comprises precoding matrix information.

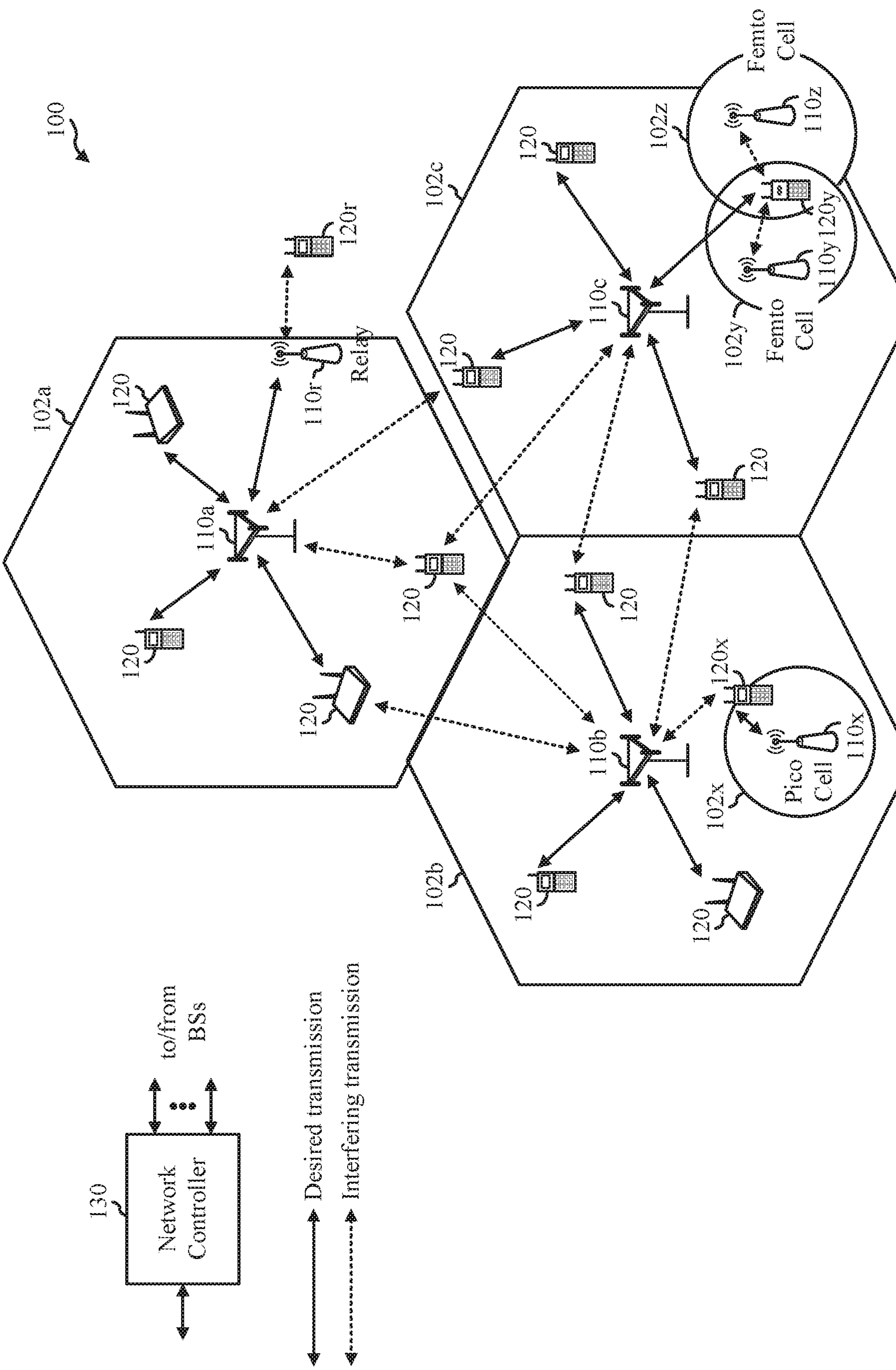
100
102a
102b
102c
102x
102y
102z
110a
110b
110c
110r
110x
110y
110z
120
120r
120x
120y
Relay
Pico Cell
Femto Cell
Femto Cell
130
Network Controller
to/from BSs
Desired transmission
Interfering transmission

FIG. 1

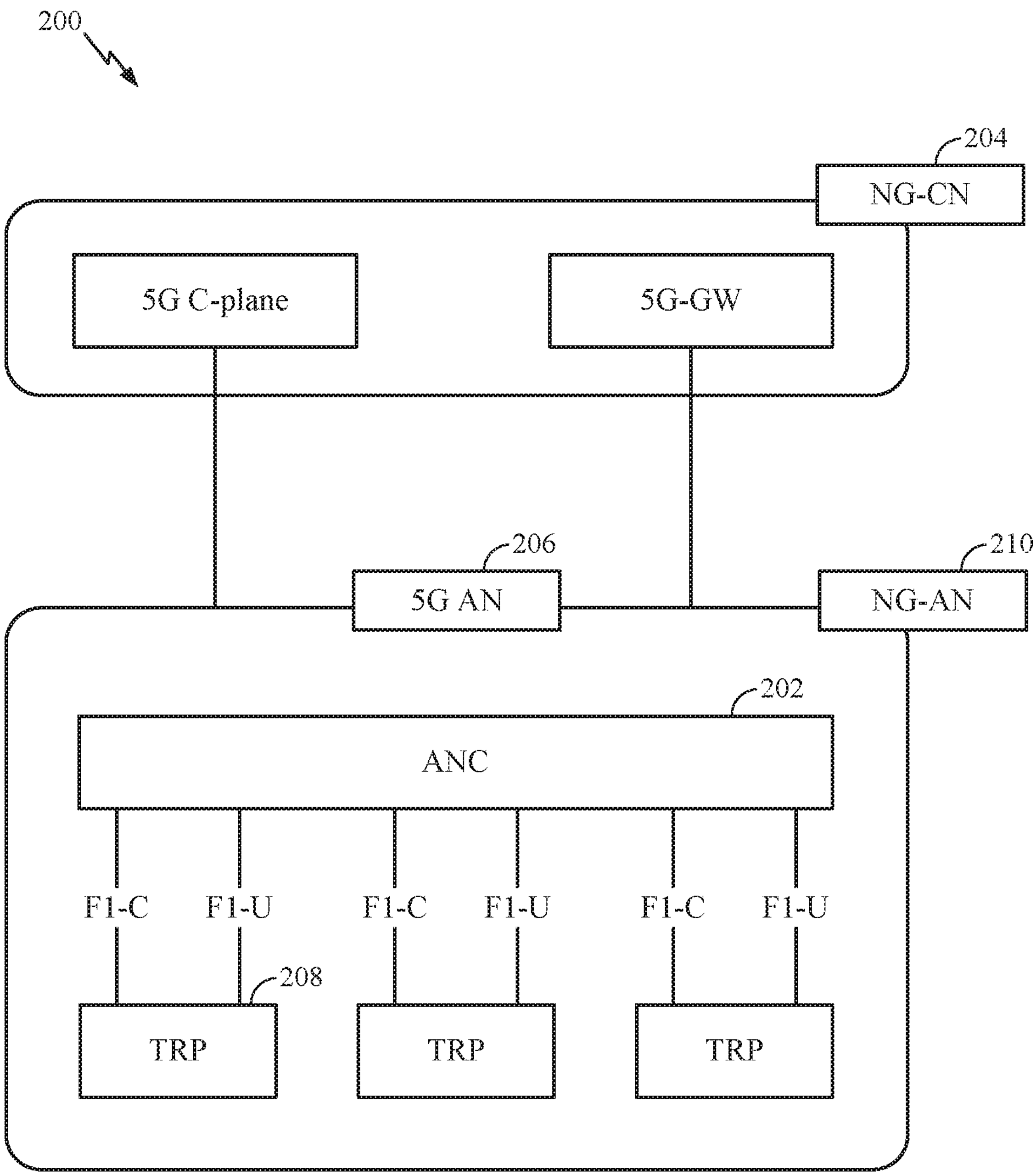
200
204
NG-CN
5G C-plane
5G-GW
206
5G AN
210
NG-AN
202
ANC
F1-C
F1-U
F1-C
F1-U
F1-C
F1-U
208
TRP
TRP
TRP

FIG. 2

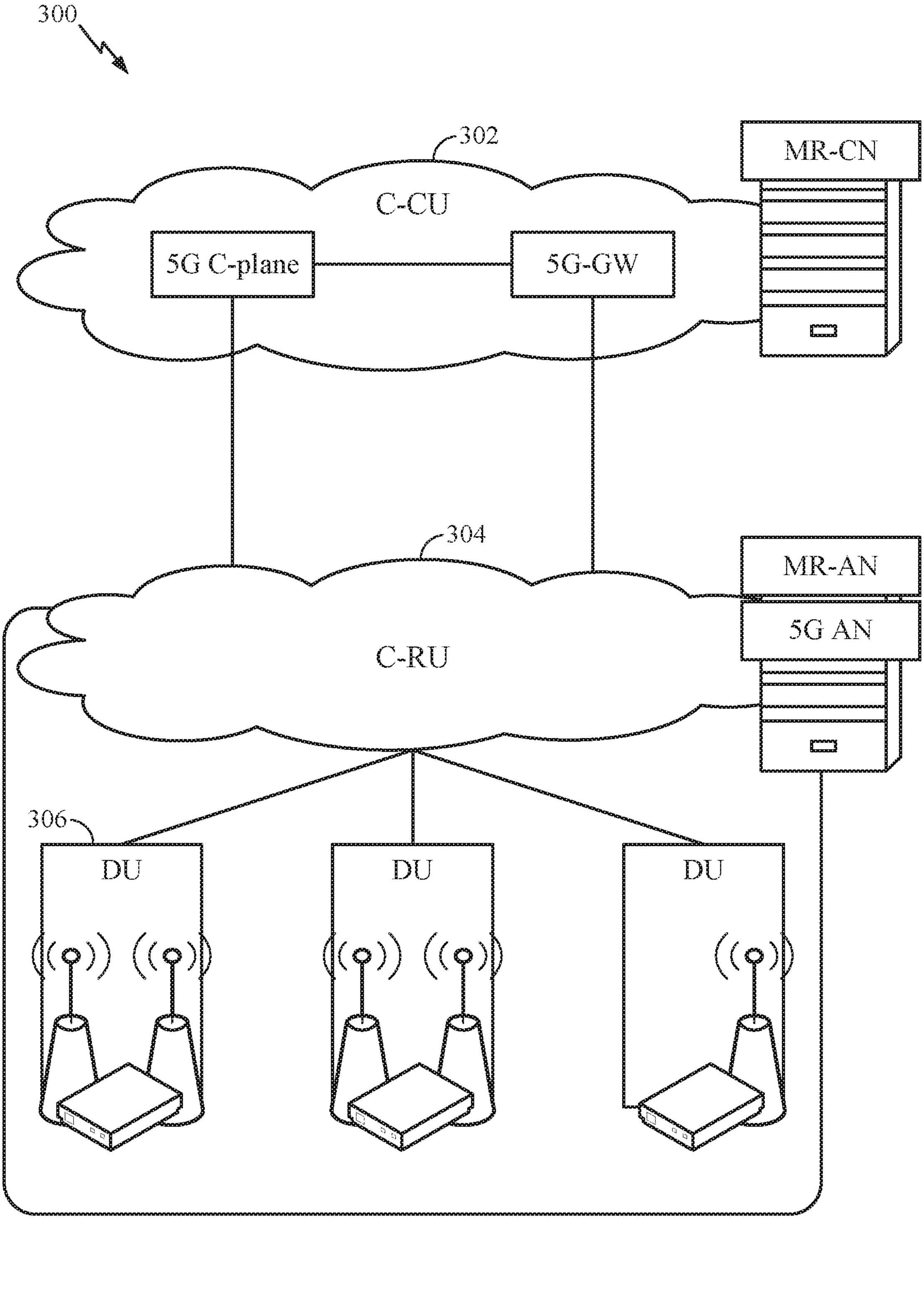

FIG. 3

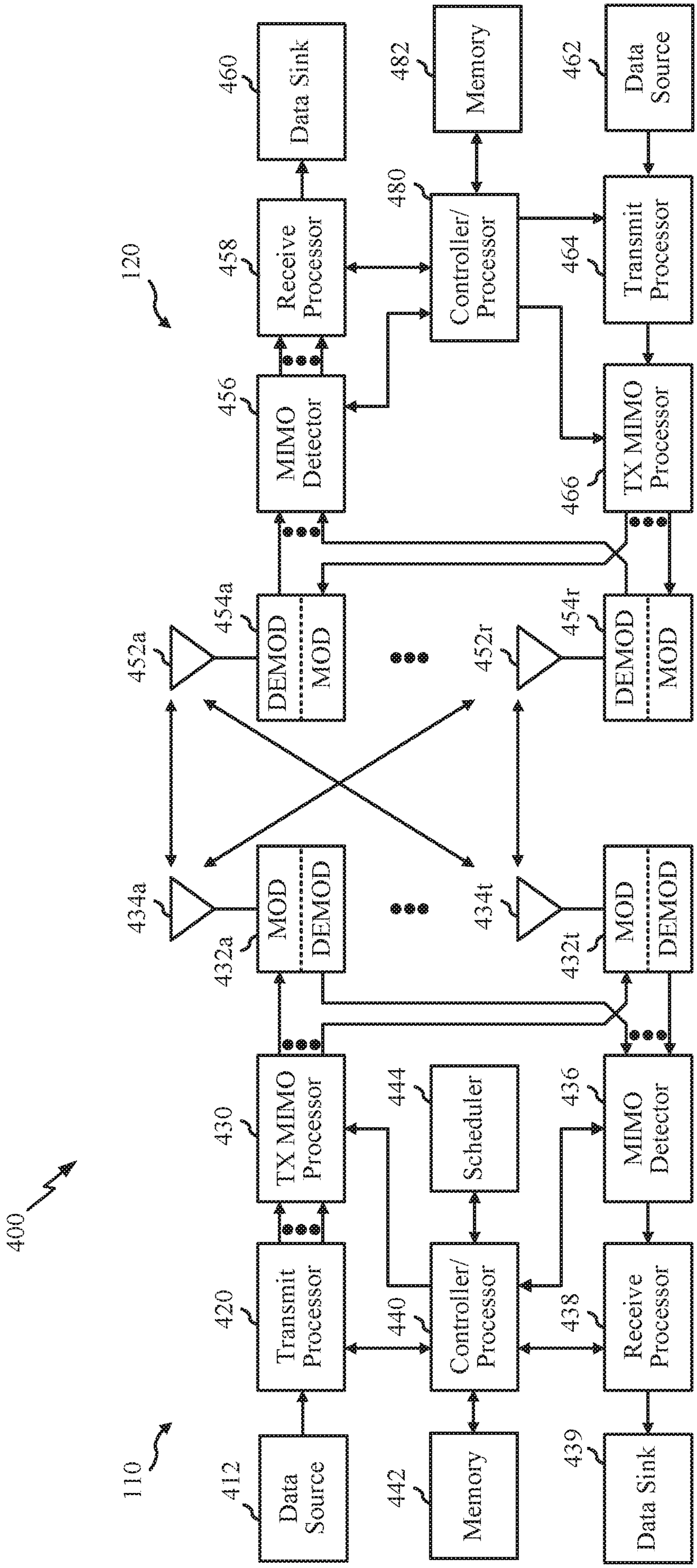
400
110
120
412 Data Source
420 Transmit Processor
430 TX MIMO Processor
432a MOD DEMOD
434a
432t MOD DEMOD
434t
440 Controller/ Processor
442 Memory
444 Scheduler
436 MIMO Detector
438 Receive Processor
439 Data Sink
452a
454a DEMOD MOD
452r
454r DEMOD MOD
456 MIMO Detector
458 Receive Processor
460 Data Sink
480 Controller/ Processor
482 Memory
462 Data Source
464 Transmit Processor
466 TX MIMO Processor

FIG. 4

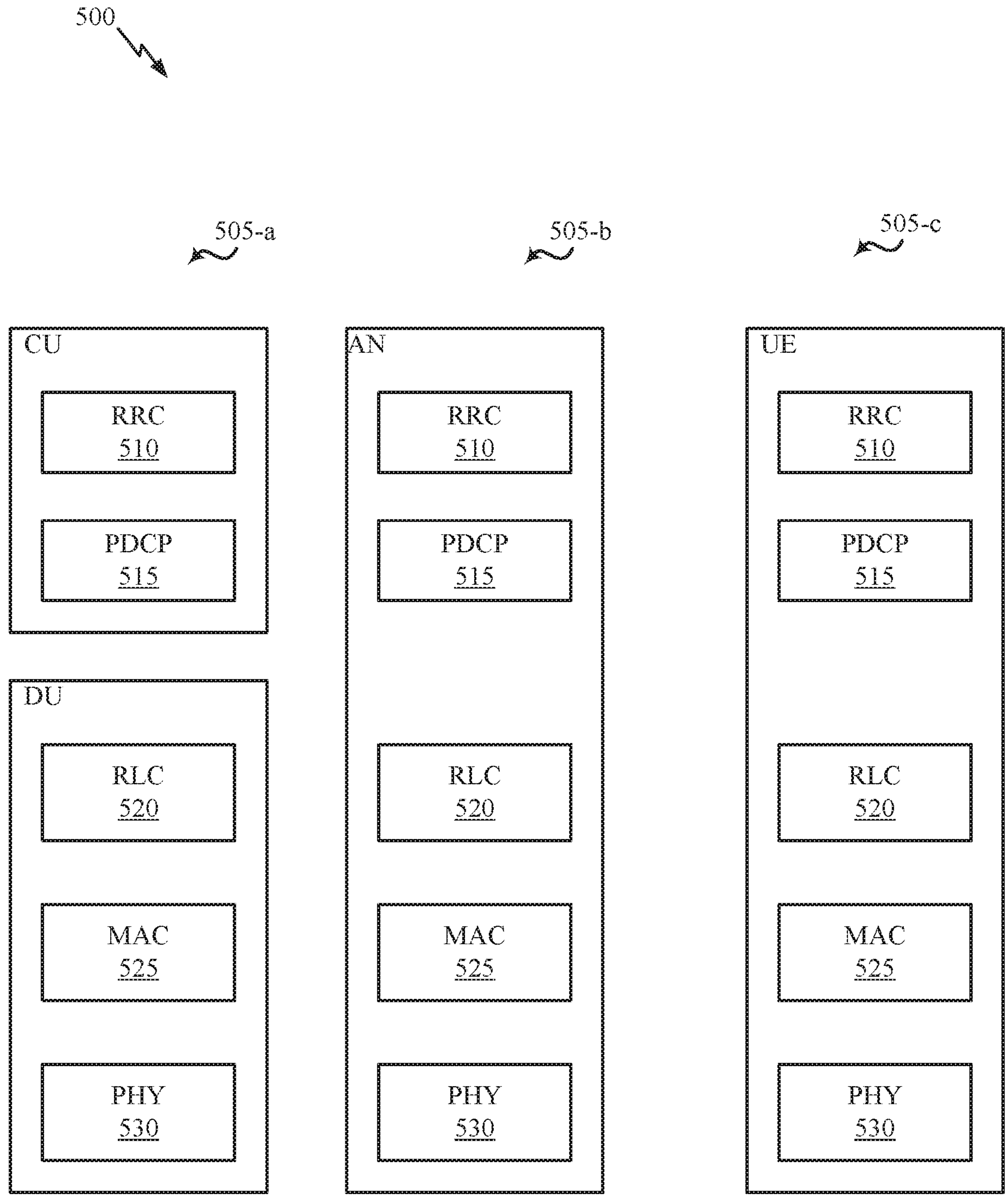
500
505-a
505-b
505-c
CU
RRC
510
PDCP
515
DU
RLC
520
MAC
525
PHY
530
AN
RRC
510
PDCP
515
RLC
520
MAC
525
PHY
530
UE
RRC
510
PDCP
515
RLC
520
MAC
525
PHY
530

FIG. 5

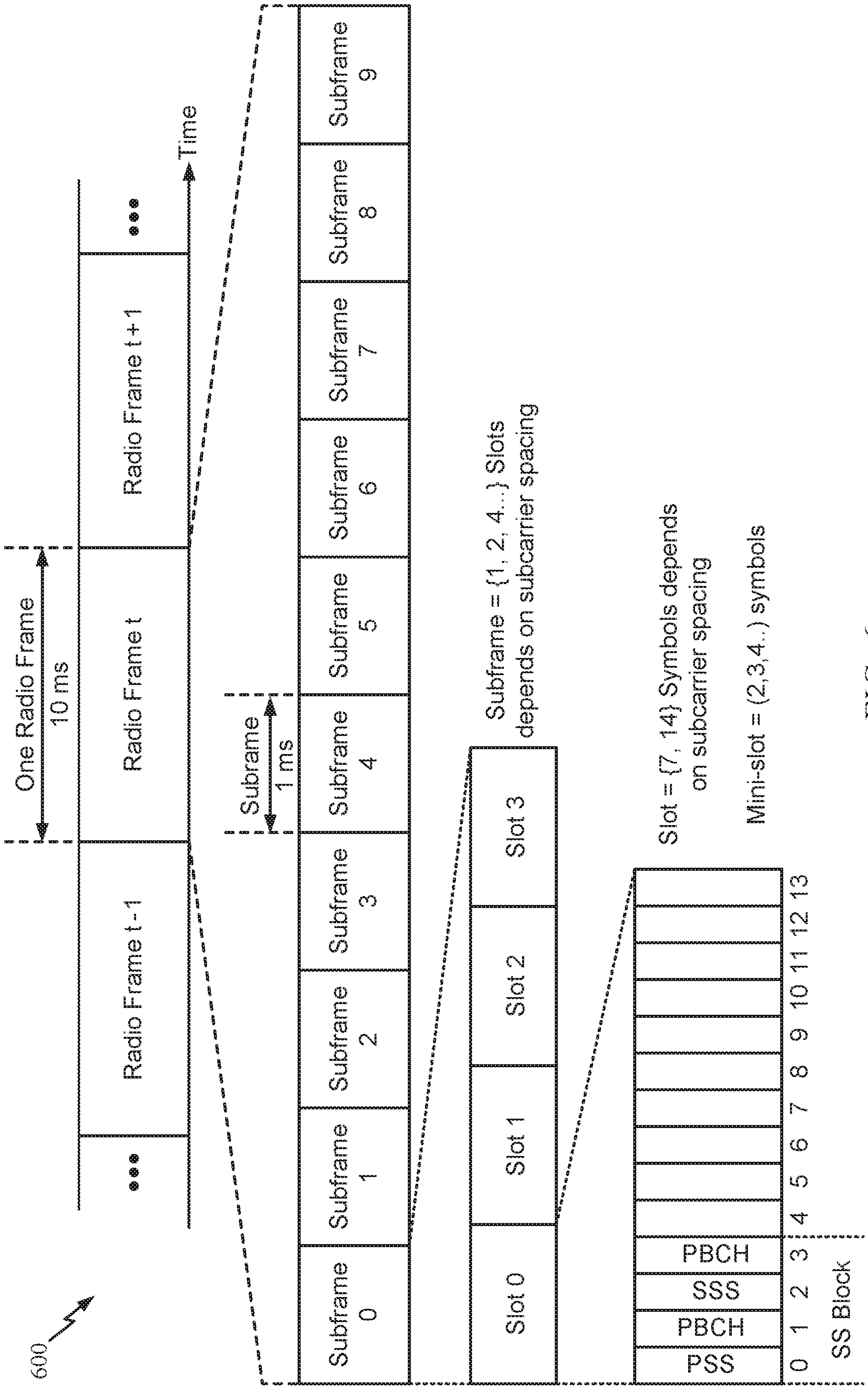
600
One Radio Frame
10 ms
Radio Frame t - 1
Radio Frame t
Radio Frame t + 1
Time
Subrame
1 ms
Subframe 0
Subframe 1
Subframe 2
Subframe 3
Subframe 4
Subframe 5
Subframe 6
Subframe 7
Subframe 8
Subframe 9
Subframe = {1, 2, 4...} Slots depends on subcarrier spacing
Slot 0
Slot 1
Slot 2
Slot 3
Slot = {7, 14} Symbols depends on subcarrier spacing
Mini-slot = (2,3,4..) symbols
PSS
PBCH
SSS
PBCH
0 1 2 3 4 5 6 7 8 9 10 11 12 13
SS Block

FIG. 6

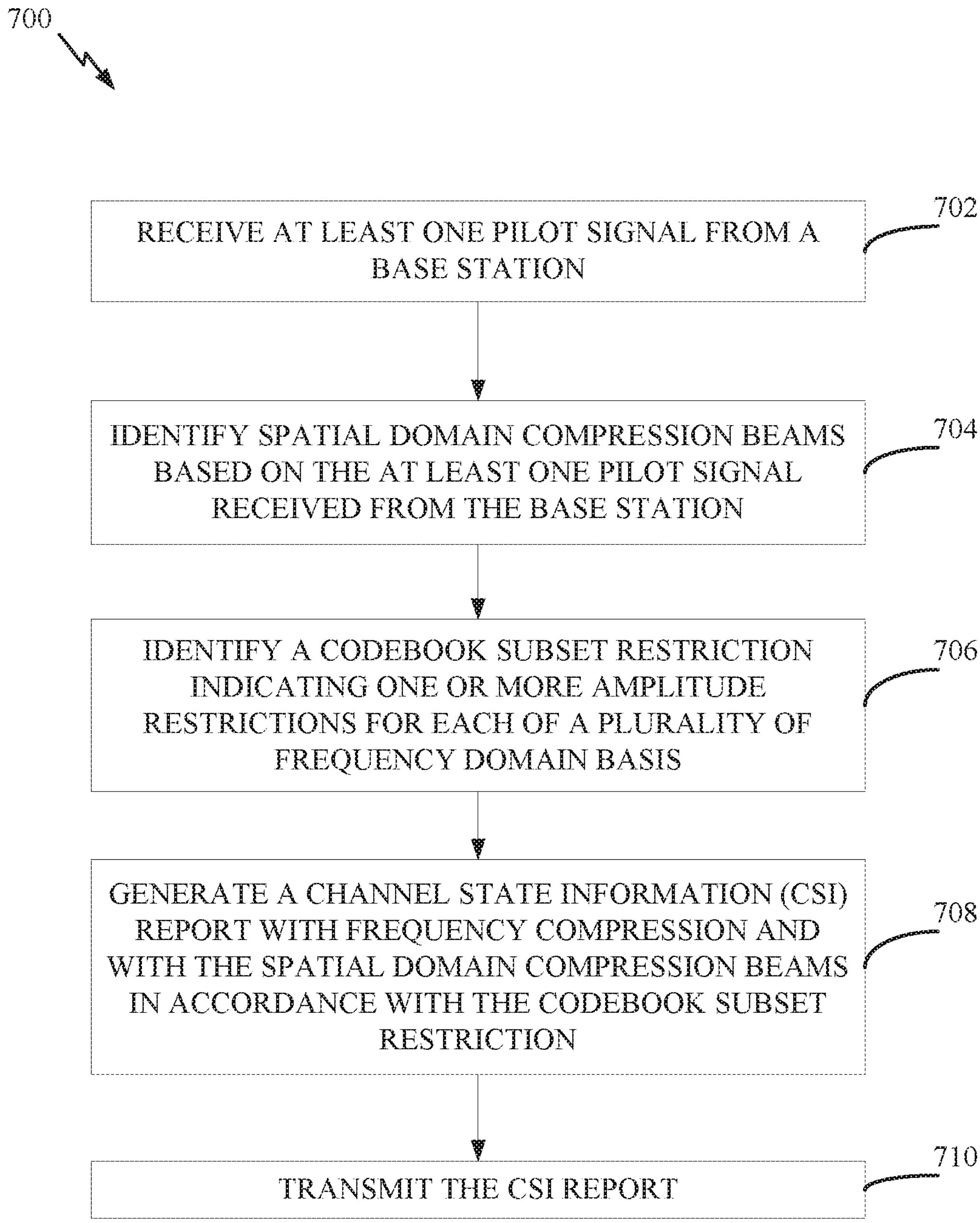
700
RECEIVE AT LEAST ONE PILOT SIGNAL FROM A BASE STATION
702
IDENTIFY SPATIAL DOMAIN COMPRESSION BEAMS BASED ON THE AT LEAST ONE PILOT SIGNAL RECEIVED FROM THE BASE STATION
704
IDENTIFY A CODEBOOK SUBSET RESTRICTION INDICATING ONE OR MORE AMPLITUDE RESTRICTIONS FOR EACH OF A PLURALITY OF FREQUENCY DOMAIN BASIS
706
GENERATE A CHANNEL STATE INFORMATION (CSI) REPORT WITH FREQUENCY COMPRESSION AND WITH THE SPATIAL DOMAIN COMPRESSION BEAMS IN ACCORDANCE WITH THE CODEBOOK SUBSET RESTRICTION
708
TRANSMIT THE CSI REPORT
710

FIG. 7

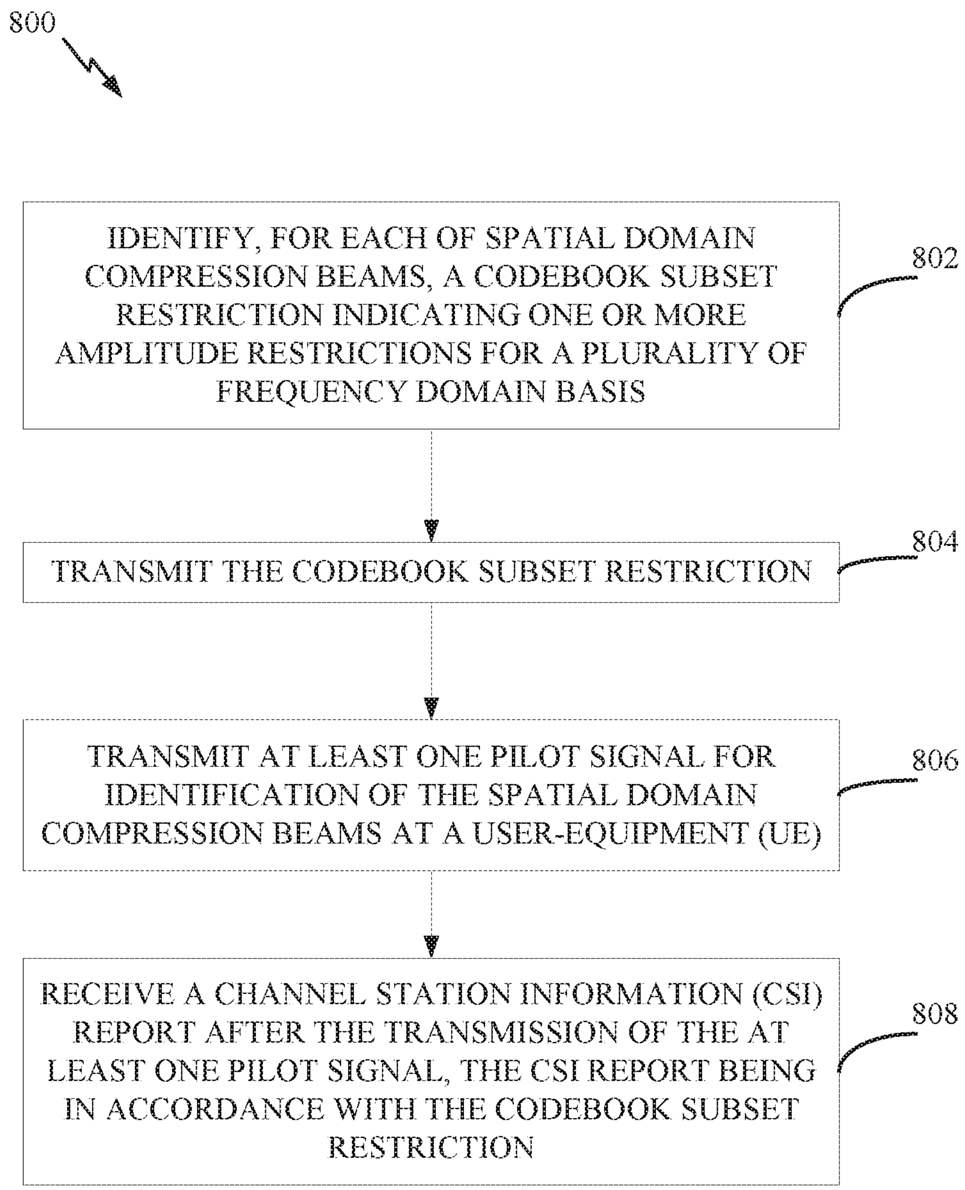
800
IDENTIFY, FOR EACH OF SPATIAL DOMAIN COMPRESSION BEAMS, A CODEBOOK SUBSET RESTRICTION INDICATING ONE OR MORE AMPLITUDE RESTRICTIONS FOR A PLURALITY OF FREQUENCY DOMAIN BASIS
802
TRANSMIT THE CODEBOOK SUBSET RESTRICTION
804
TRANSMIT AT LEAST ONE PILOT SIGNAL FOR IDENTIFICATION OF THE SPATIAL DOMAIN COMPRESSION BEAMS AT A USER-EQUIPMENT (UE)
806
RECEIVE A CHANNEL STATION INFORMATION (CSI) REPORT AFTER THE TRANSMISSION OF THE AT LEAST ONE PILOT SIGNAL, THE CSI REPORT BEING IN ACCORDANCE WITH THE CODEBOOK SUBSET RESTRICTION
808

FIG. 8

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2018/119726

A. CLASSIFICATION OF SUBJECT MATTER

H04B 7/0456(2017.01)i; H04B 17/373(2015.01)i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

H04B; H04Q; H04W

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

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

CNPAT, CNKI, 3GPP, WPI, EPODOC:pilot, spatial, compression, beam, codebook, subset, restriction, amplitude, channel, state, information, CSI, report

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2017279513 A1 (QUALCOMM INCORPORATED) 28 September 2017 (2017-09-28) abstract and description, paragraphs [0027]-[0119]	1-17
A	WO 2016164073 A1 (INTEL CORPORATION) 13 October 2016 (2016-10-13) the whole document	1-17
A	TW 201817187 A (MEDIATEK INC. ET AL.) 01 May 2018 (2018-05-01) the whole document	1-17
A	NTT DOCOMO, INC. "Status Report to TSG" *3GPP TSG RAN meeting #75 RP-170376,* 09 March 2017 (2017-03-09), the whole document	1-17

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

* Special categories of cited documents:
- "A" document defining the general state of the art which is not considered to be of particular relevance
- "E" earlier application or patent but published on or after the international filing date
- "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- "O" document referring to an oral disclosure, use, exhibition or other means
- "P" document published prior to the international filing date but later than the priority date claimed
- "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
- "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
- "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
- "&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
13 August 2019	**09 September 2019**

Name and mailing address of the ISA/CN	Authorized officer
National Intellectual Property Administration, PRC **6, Xitucheng Rd., Jimen Bridge, Haidian District, Beijing 100088** **China**	**CHANG,Jiaofa**
Facsimile No. **(86-10)62019451**	Telephone No. **86-(10)-53961735**

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CN2018/119726

Patent document cited in search report			Publication date (day/month/year)	Patent family member(s)			Publication date (day/month/year)
US	2017279513	A1	28 September 2017	EP	2965445	A1	13 January 2016
				JP	2016514429	A	19 May 2016
				CN	105027463	A	04 November 2015
				WO	2014138625	A1	12 September 2014
				KR	20150128844	A	18 November 2015
				US	2014254701	A1	11 September 2014
				BR	112015021698	A2	18 July 2017
				IN	201502064	P3	27 May 2016
WO	2016164073	A1	13 October 2016		None		
TW	201817187	A	01 May 2018	TW	I624159	B	11 May 2018