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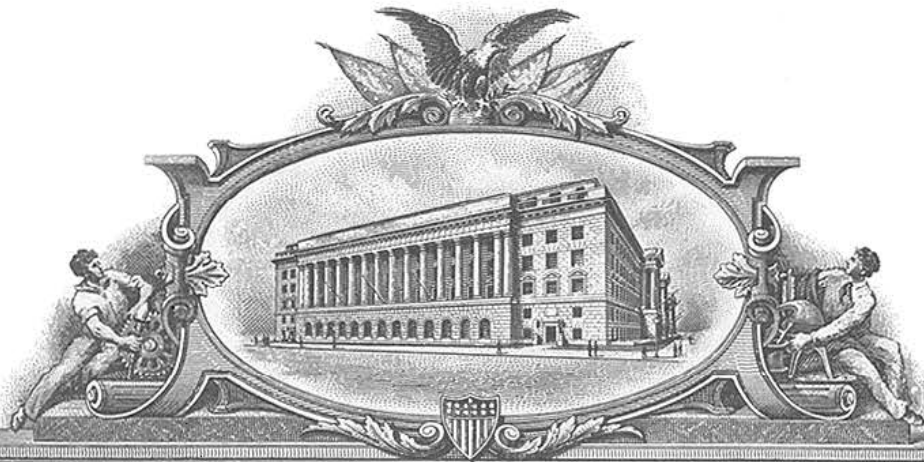
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December 30, 2024

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APPLICATION NUMBER: 63/605,258
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Provisional Application for Patent Cover Sheet

This is a request for filing a PROVISIONAL APPLICATION FOR PATENT under 37 CFR 1.53(c)

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All Inventors Must Be Listed – Additional Inventor Information blocks may be generated within this form by selecting the **Add** button.

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Title of Invention

Neighbor Cell Radio Resource Management Reduction for Carrier Aggregation or Dual Connectivity

Attorney Docket Number (if applicable)

P63609USP1

Correspondence Address

Direct all correspondence to (select one):

☒ The address corresponding to Customer Number☐ Firm or Individual Name

Customer Number

62579

The invention was made by an agency of the United States Government or under a contract with an agency of the United States Government.

☒ No.☐ Yes, the invention was made by an agency of the United States Government. The U.S. Government agency name is:☐ Yes, the invention was under a contract with an agency of the United States Government. The name of the U.S. Government agency and Government contract number are:

Entity Status**Applicant asserts small entity status under 37 CFR 1.27 or applicant certifies micro entity status under 37 CFR 1.29**

- ☐ Applicant asserts small entity status under 37 CFR 1.27
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Signature	/Gregory W. Osterloth/			Date (YYYY-MM-DD)	2023-12-01
First Name	Gregory W.	Last Name	Osterloth	Registration Number (If appropriate)	36232

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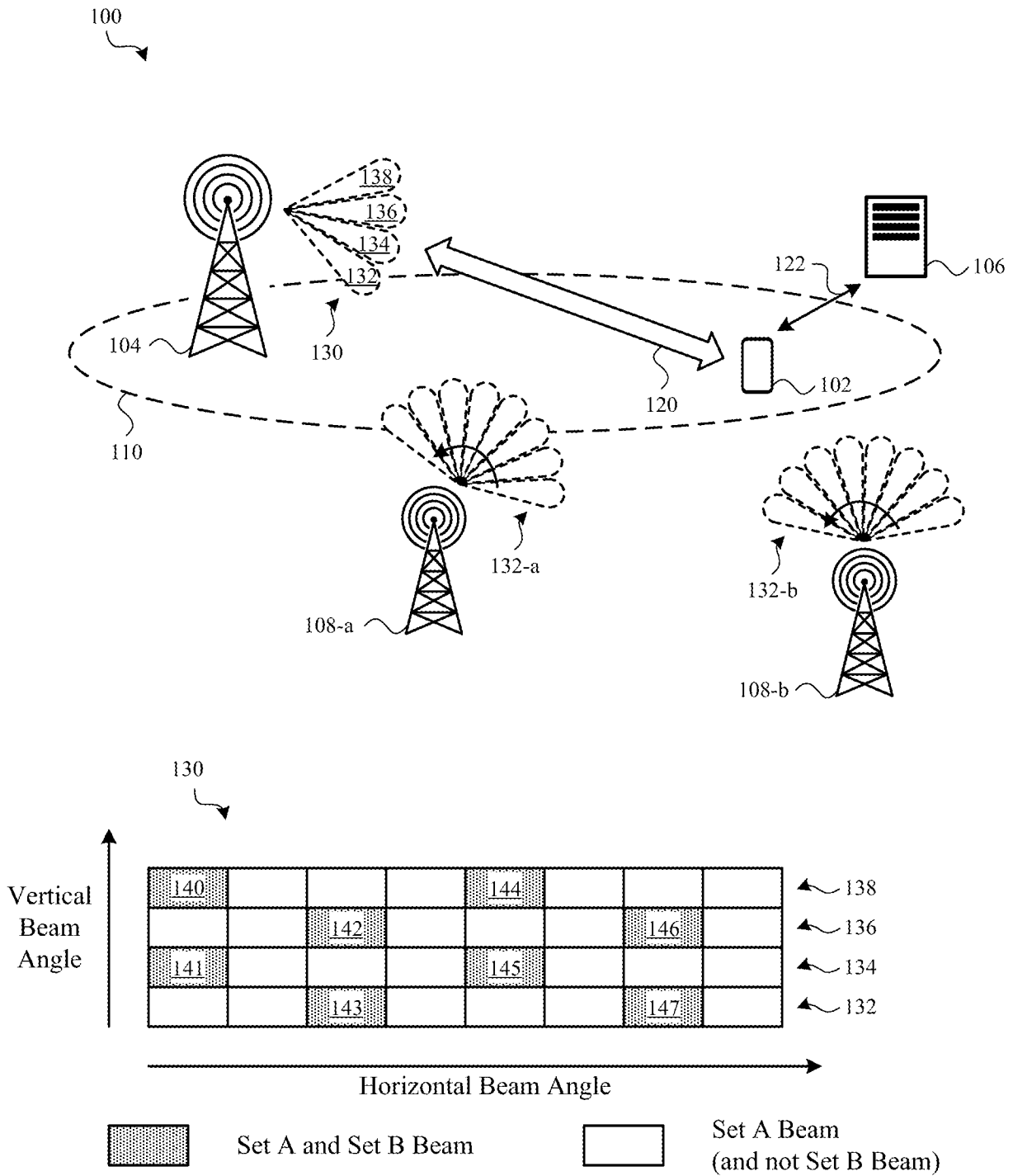


FIG. 1

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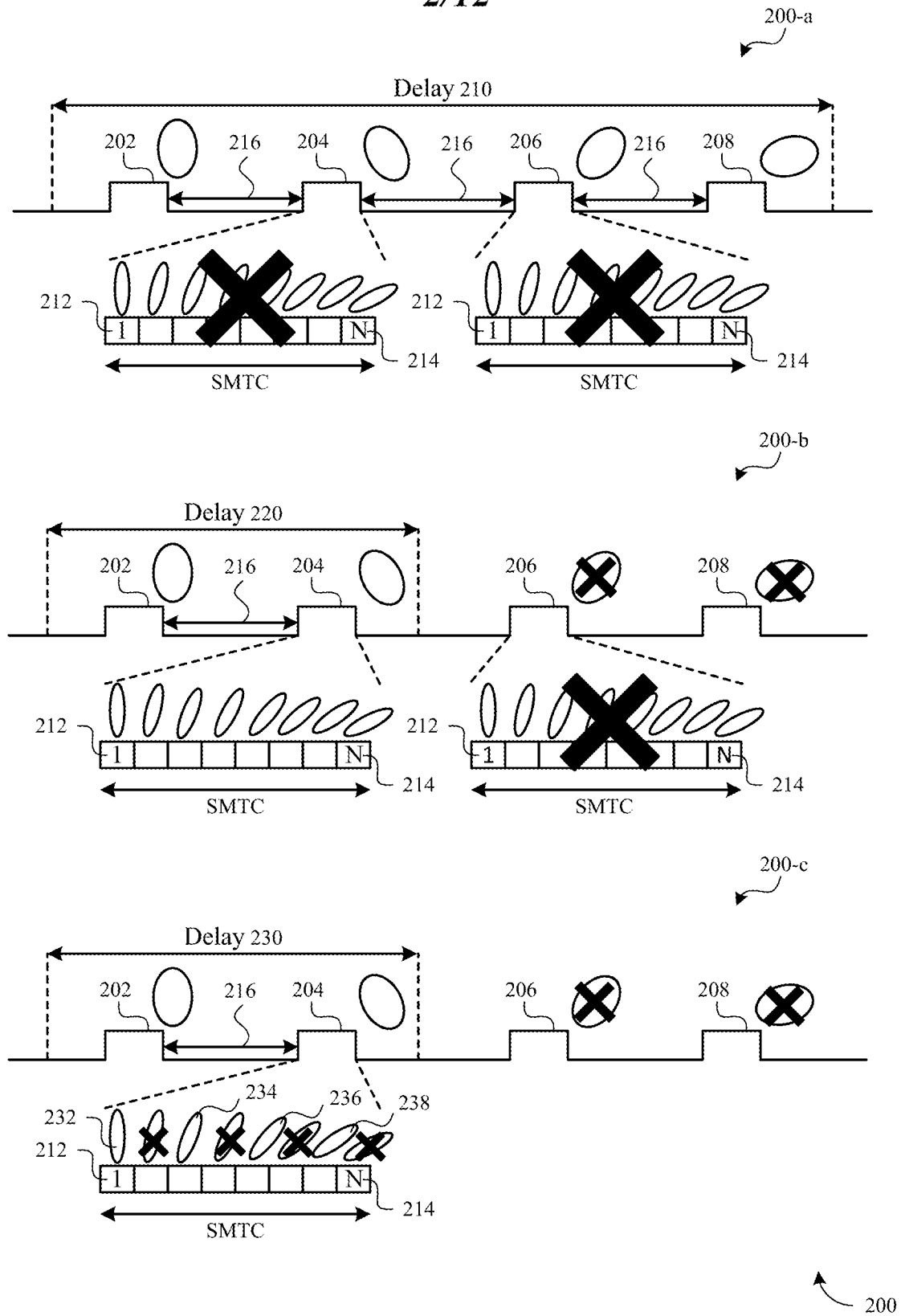


FIG. 2

300 ↗

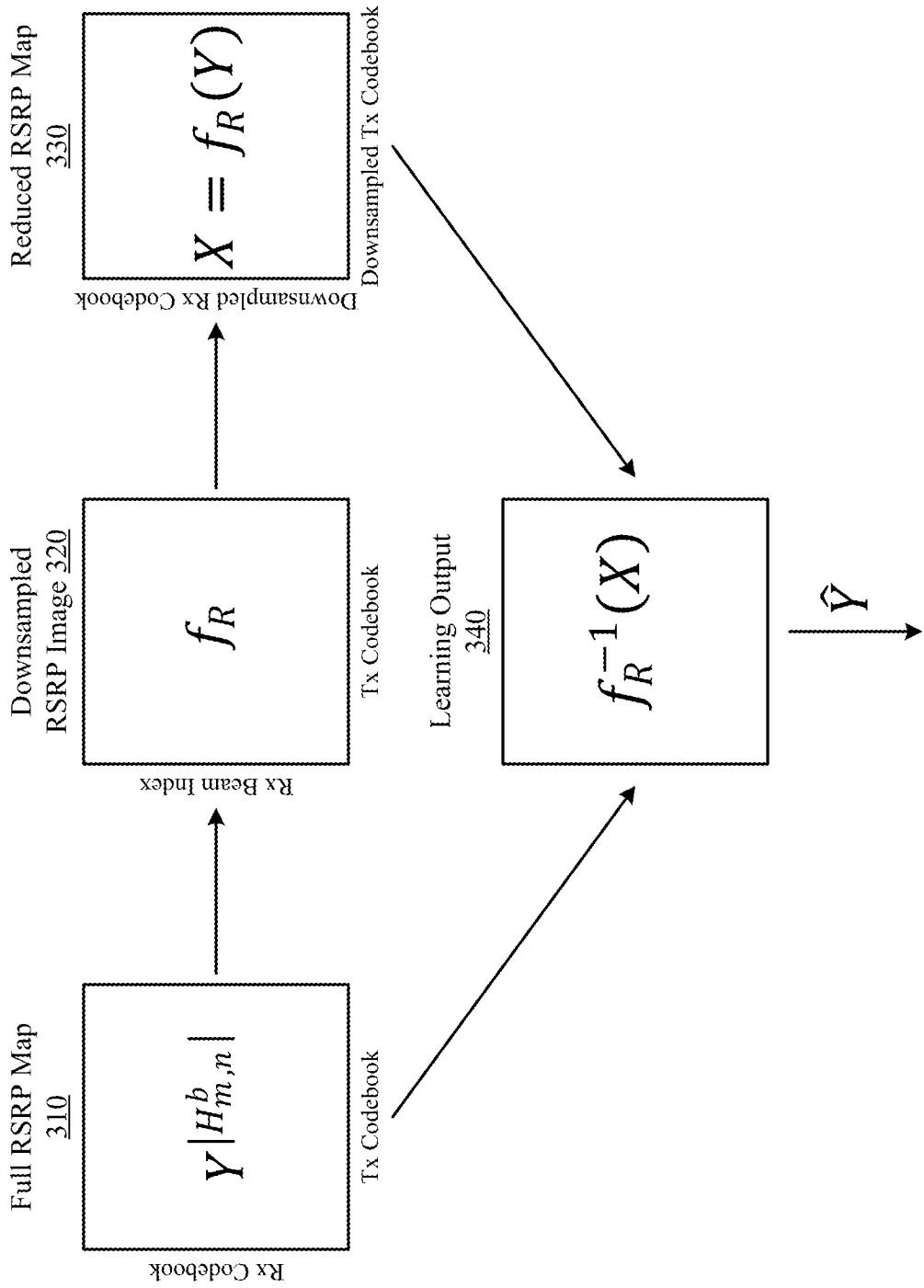


FIG. 3

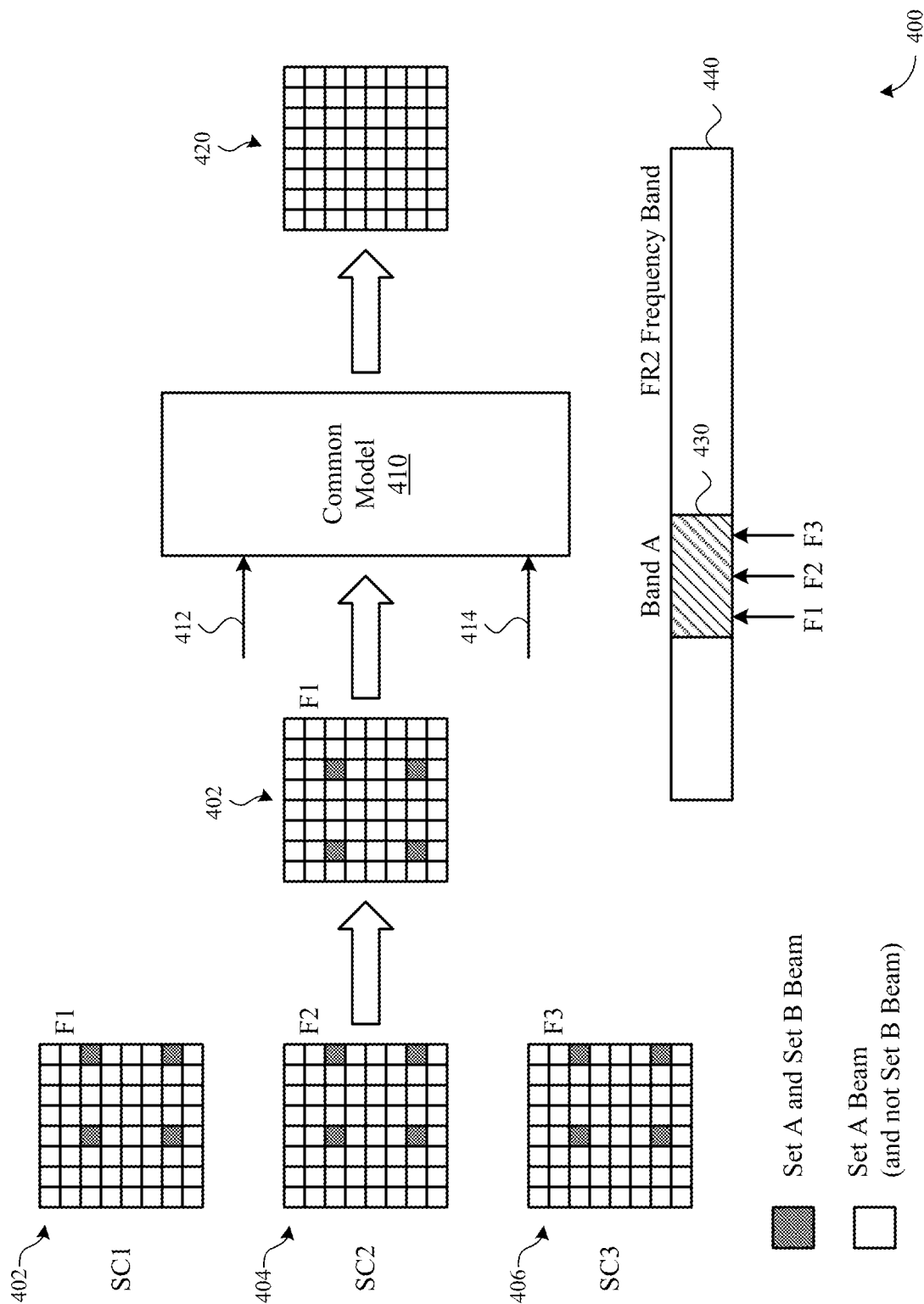


FIG. 4

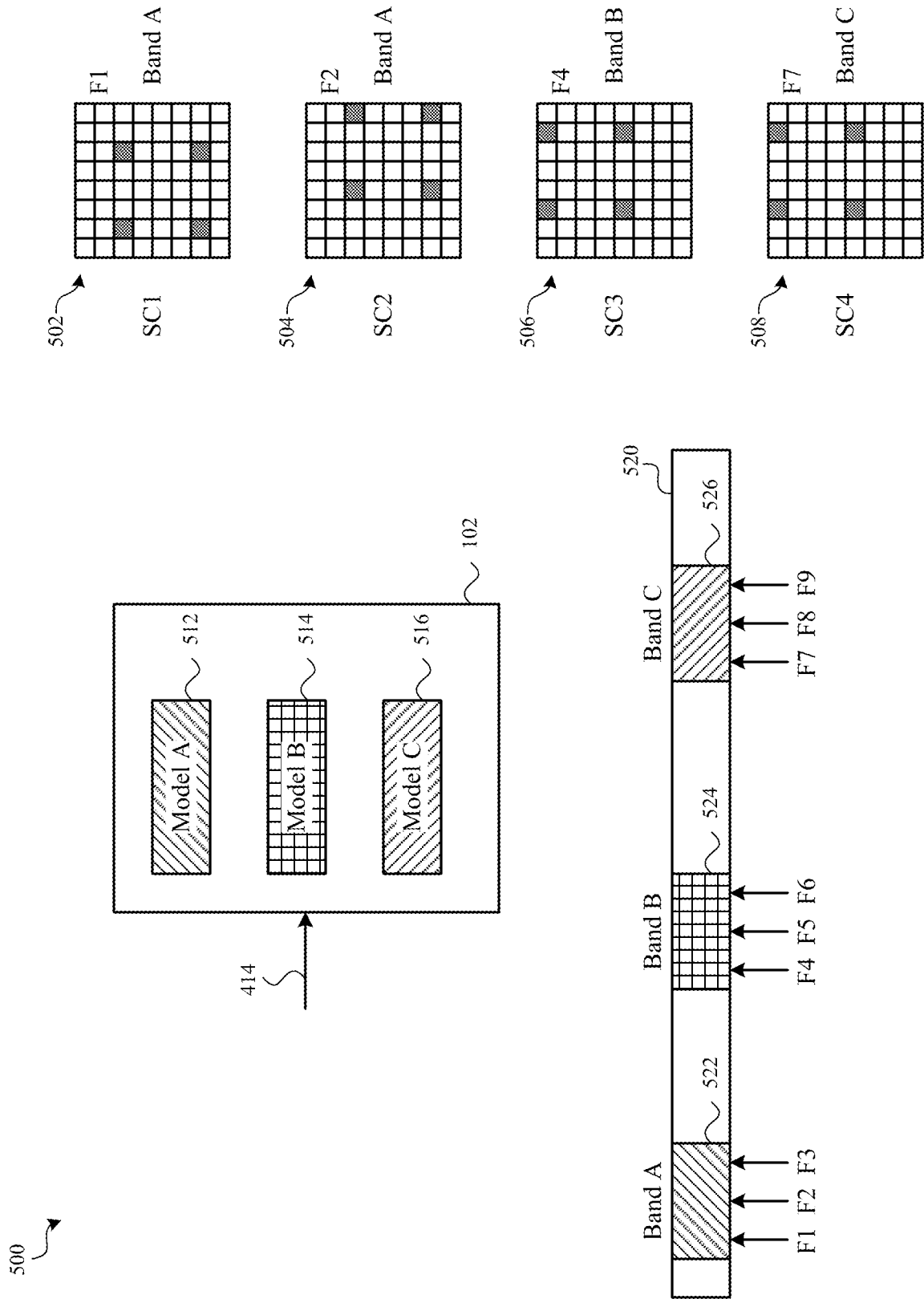


FIG. 5

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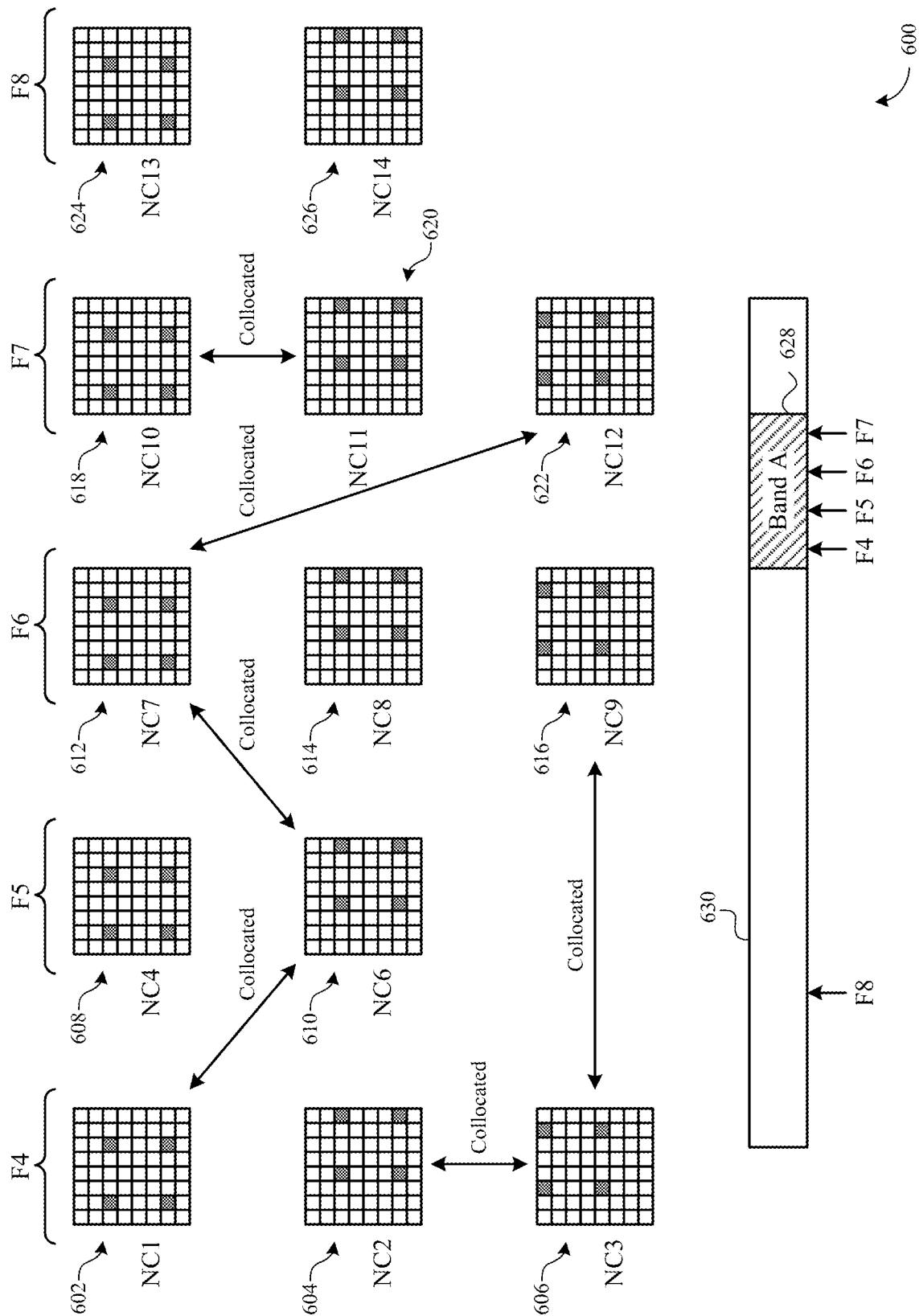


FIG. 6

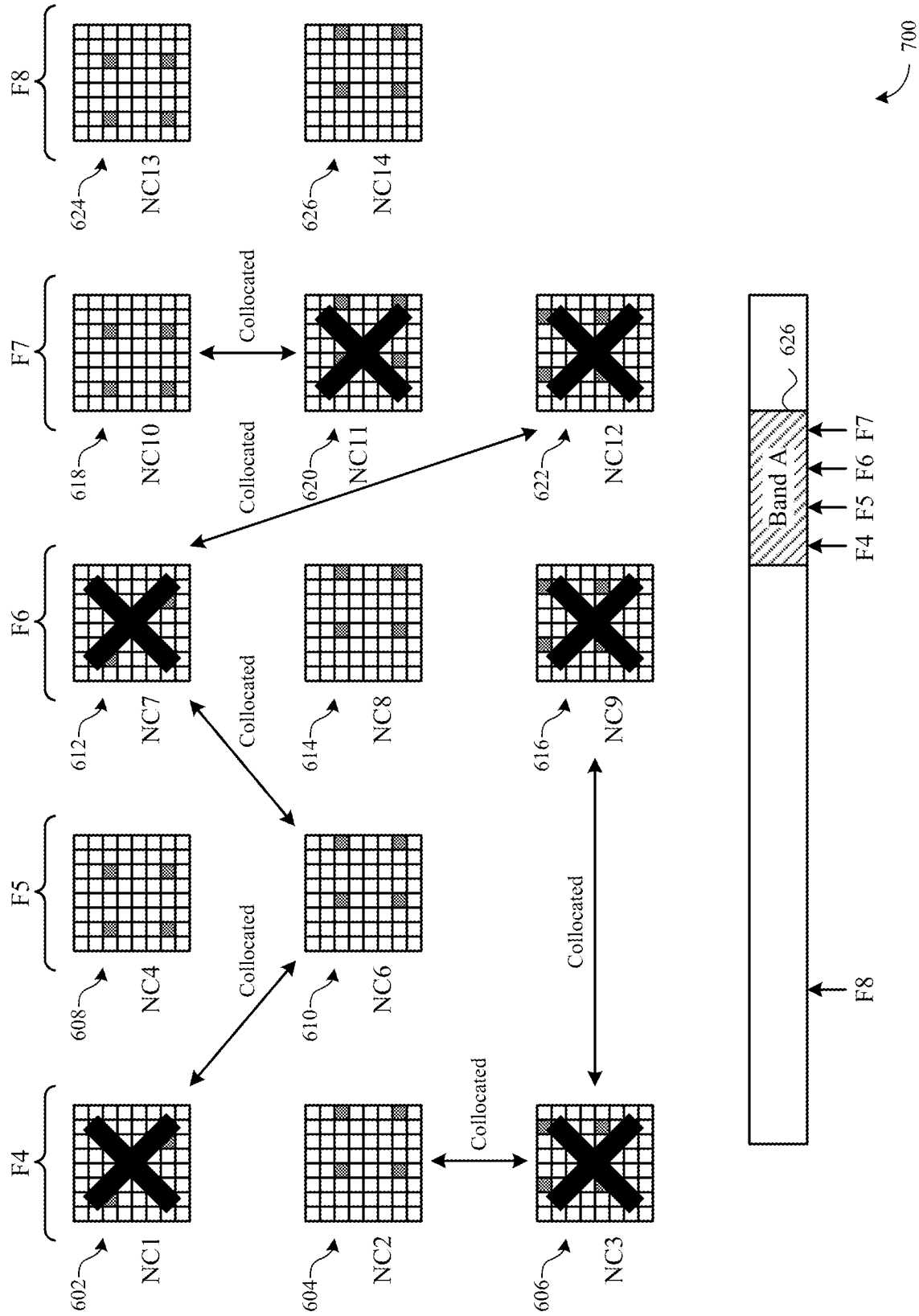


FIG. 7

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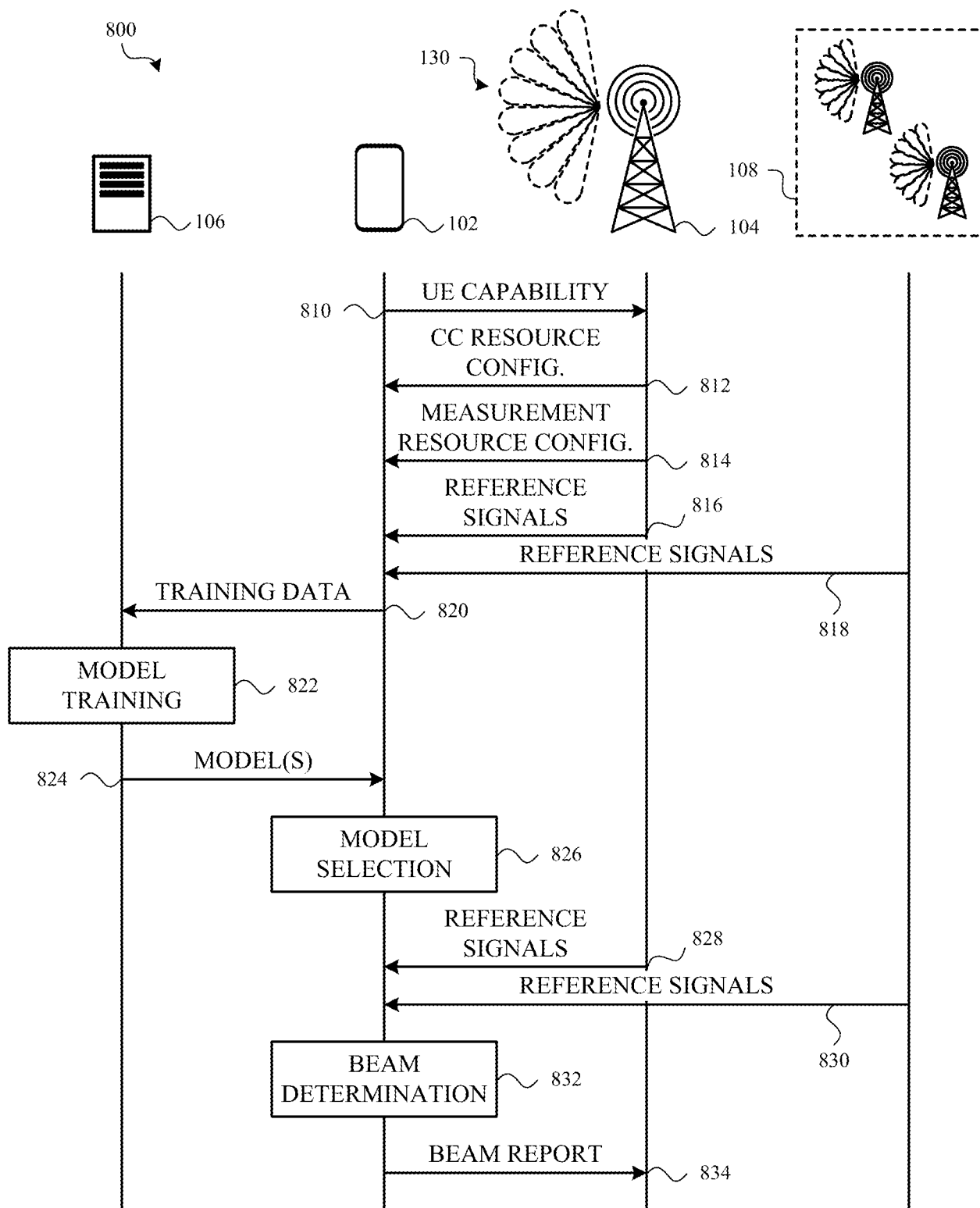


FIG. 8

900

9/12

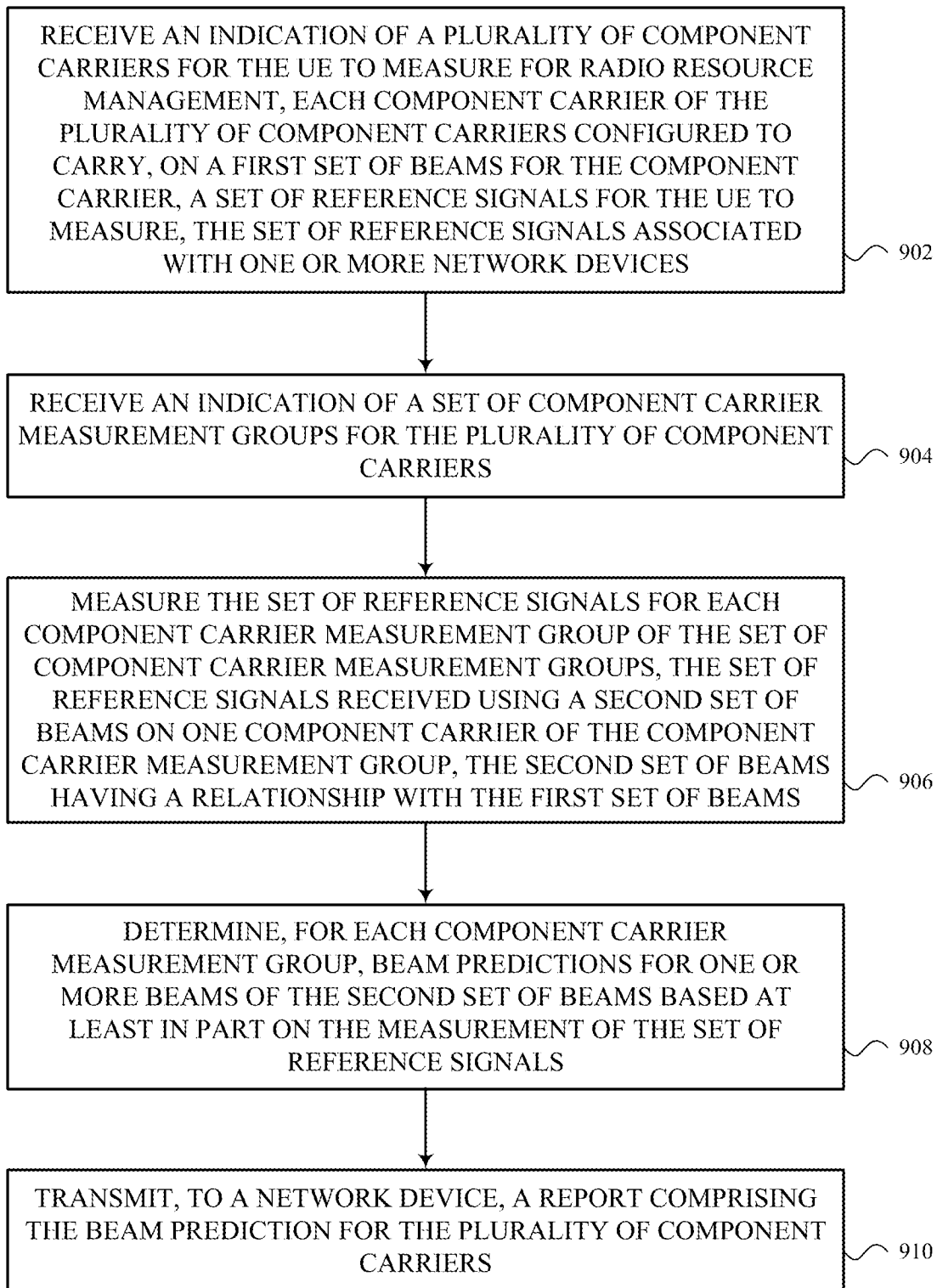


FIG. 9

1000
↘

10/12

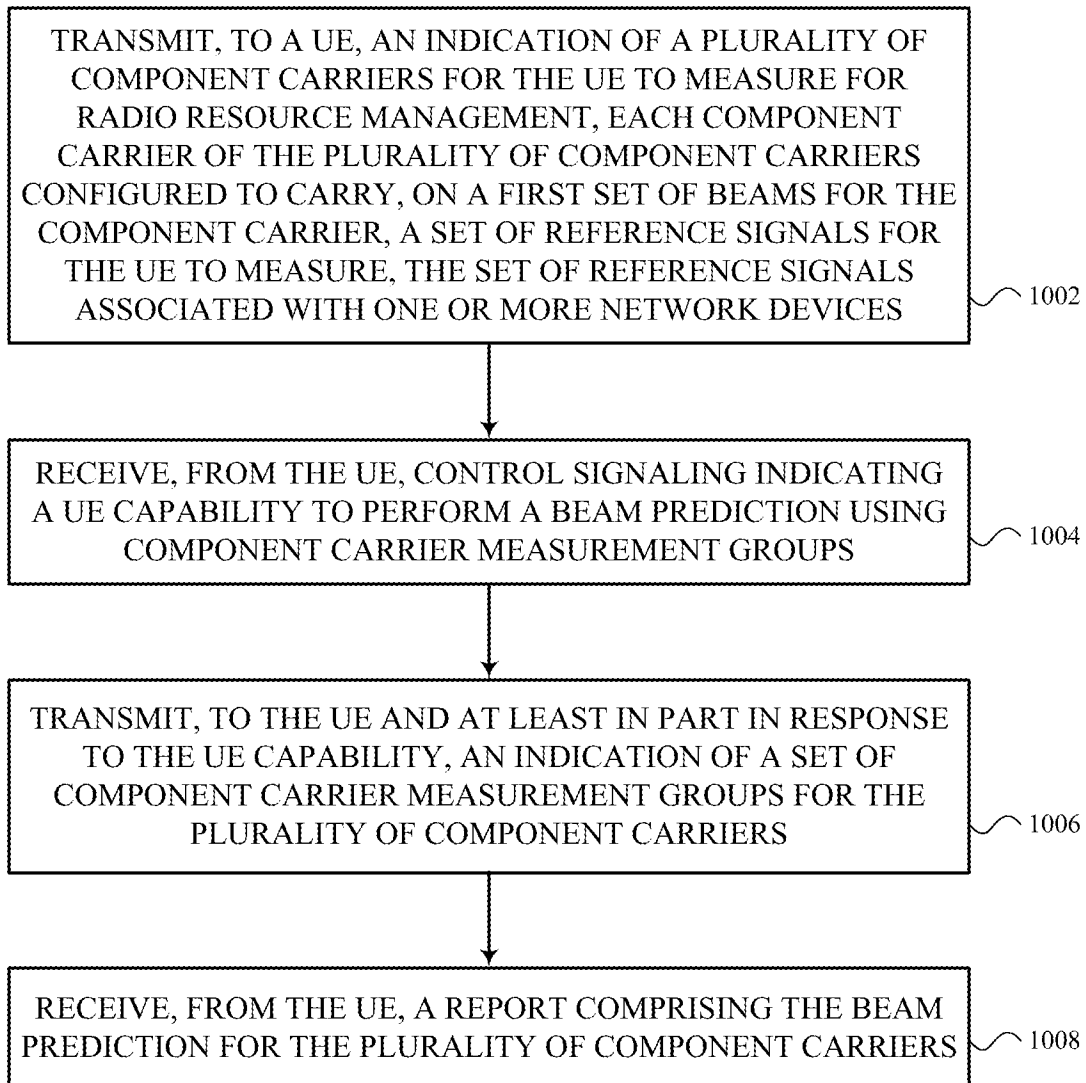


FIG. 10

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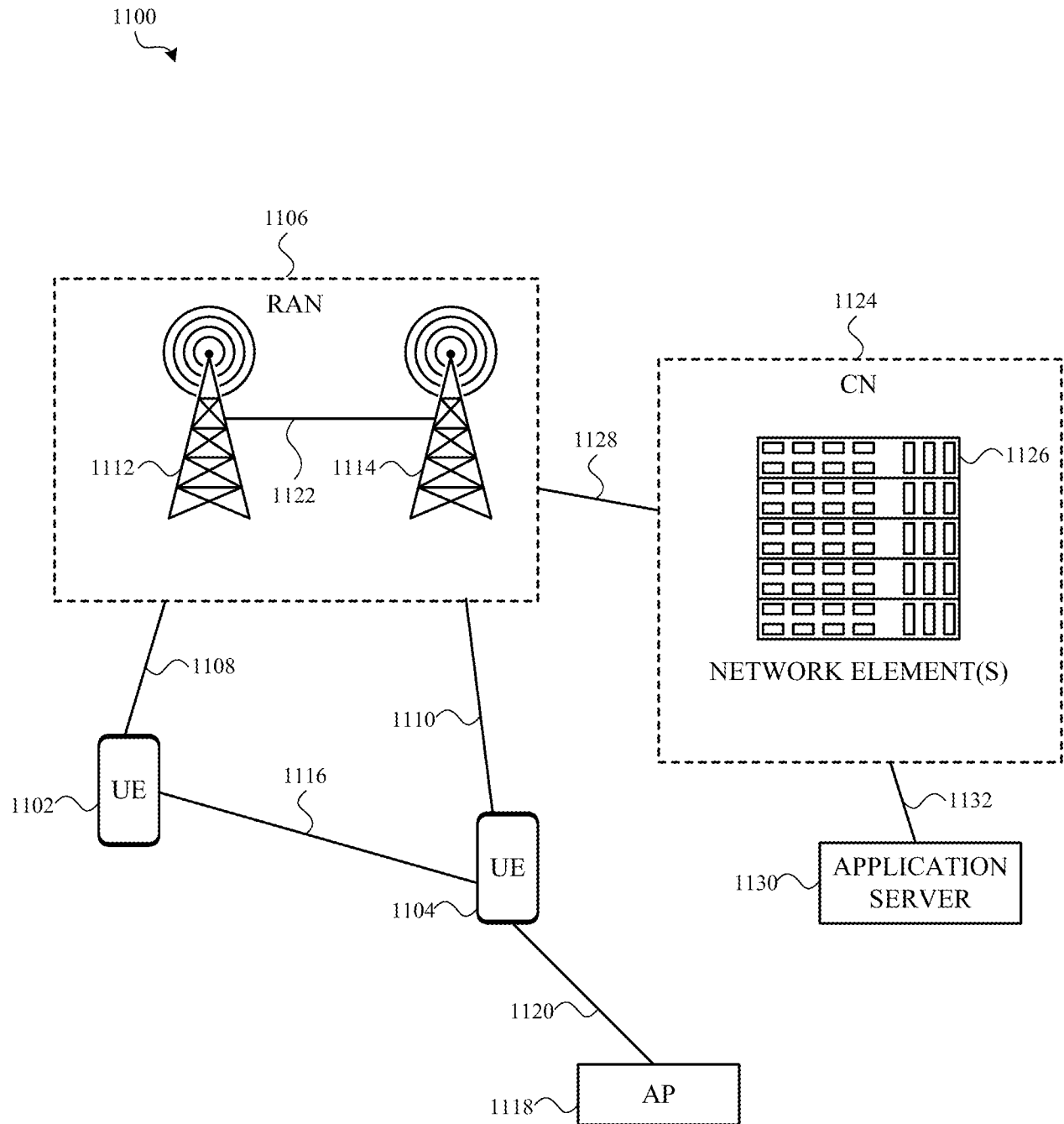


FIG. 11

1200

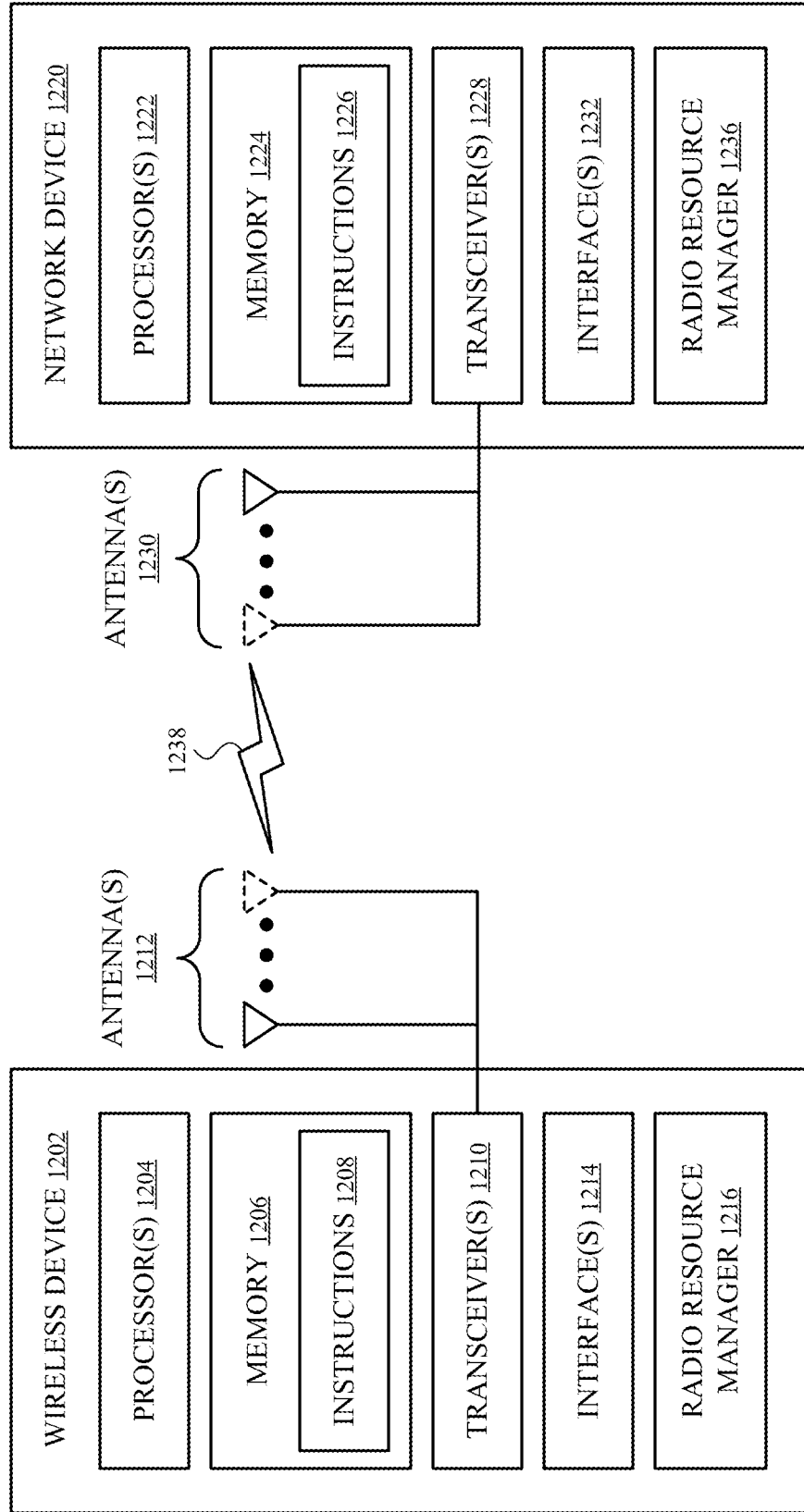


FIG. 12



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Title of Invention

Neighbor Cell Radio Resource Management Reduction for Carrier Aggregation or Dual Connectivity

Application Information

APPLICATION TYPE Utility - Provisional Application under
35 USC 111(b)

PATENT # -

CONFIRMATION # 6362

FILED BY Valerie Brown

PATENT CENTER # 63461985

FILING DATE -

CUSTOMER # 62579

FIRST NAMED INVENTOR Konstantinos Sarrigeorgidis

CORRESPONDENCE ADDRESS -

AUTHORIZED BY Gregory Osterloth

Documents

TOTAL DOCUMENTS: 3

DOCUMENT	PAGES	DESCRIPTION	SIZE (KB)
P63609USP1-Specification.pdf	38	Specification	200 KB
P63609USP1-Drawings.pdf	12	Drawings-only black and white line drawings	1709 KB
P63609USP1-ApplicationTransmittal.pdf	3	Provisional Cover Sheet (SB16)	753 KB

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NEIGHBOR CELL RADIO RESOURCE MANAGEMENT REDUCTION FOR CARRIER AGGREGATION OR DUAL CONNECTIVITY

TECHNICAL FIELD

[0001] This application relates generally to wireless communication systems, including systems, apparatuses, and methods for neighbor cell radio resource management (RRM) reduction for carrier aggregation (CA) or dual connectivity (DC).

BACKGROUND

[0002] Wireless mobile communication technology uses various standards and protocols to transmit data between a network device (e.g., a base station, a radio head, etc.) and a wireless communication device. Wireless communication system standards and protocols can include, for example, 3rd Generation Partnership Project (3GPP) long term evolution (LTE) (e.g., 4G), 3GPP new radio (NR) (e.g., 5G), and IEEE 802.11 standard for wireless local area networks (WLAN) (commonly known to industry groups as Wi-Fi®).

[0003] As contemplated by the 3GPP, different wireless communication systems standards and protocols can use various radio access networks (RANs) for communicating between a network device of the RAN (which may also sometimes be referred to generally as a RAN node, a network node, or simply a node) and a wireless communication device known as a UE. 3GPP RANs can include, for example, global system for mobile communications (GSM), enhanced data rates for GSM evolution (EDGE) RAN (GERAN), Universal Terrestrial Radio Access Network (UTRAN), Evolved Universal Terrestrial Radio Access Network (E-UTRAN), and/or Next-Generation Radio Access Network (NG-RAN).

[0004] Each RAN may use one or more radio access technologies (RATs) to perform communication between the network device and the UE. For example, the GERAN implements GSM and/or EDGE RAT, the UTRAN implements universal mobile telecommunication system (UMTS) RAT or other 3GPP RAT, the E-UTRAN implements LTE RAT (sometimes simply referred to as LTE), and NG-RAN implements NR RAT (sometimes referred to herein as 5G RAT, 5G NR RAT, or simply NR). In certain deployments, the E-UTRAN may also implement NR RAT. In certain deployments, NG-RAN may also implement LTE RAT.

[0005] A network device used by a RAN may correspond to that RAN. One example of an E-UTRAN network device is an Evolved Universal Terrestrial Radio Access Network (E-UTRAN) Node B (also commonly denoted as evolved Node B, enhanced Node B, eNodeB, or eNB). One example of an NG-RAN network device is a next generation Node B (also sometimes referred to as a g Node B or gNB).

[0006] A RAN provides its communication services with external entities through its connection to a core network (CN). For example, E-UTRAN may utilize an Evolved Packet Core (EPC), while NG-RAN may utilize a 5G Core Network (5GC).

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] To easily identify the discussion of any particular element or act, the most significant digit or digits in a reference number refer to the figure number in which that element is first introduced.

[0008] FIG. 1 shows an example wireless communication system, according to embodiments described herein.

[0009] FIG. 2 shows an example signaling diagram, according to one or more aspects described herein.

[0010] FIG. 3 shows an example learning diagram, according to one or more aspects described herein.

[0011] FIG. 4 shows an example signaling diagram, according to one or more aspects described herein.

[0012] FIG. 5 shows an example signaling diagram, according to one or more aspects described herein.

[0013] FIG. 6 shows an example signaling diagram, according to one or more aspects described herein.

[0014] FIG. 7 shows an example signaling diagram, according to one or more aspects described herein.

[0015] FIG. 8 shows an example signal flow, according to one or more aspects described herein.

[0016] FIG. 9 shows an example method of wireless communication by a UE, according to one or more aspects described herein.

[0017] FIG. 10 shows an example method of wireless communication by a network device, according to one or more aspects described herein.

[0018] FIG. 11 illustrates an example architecture of a wireless communication system, according to embodiments described herein.

[0019] FIG. 12 illustrates an example system for performing signaling between a wireless device and a network device, according to embodiments described herein.

DETAILED DESCRIPTION

[0020] Various embodiments are described with regard to a user equipment (UE). However, reference to a UE is merely provided for illustrative purposes. The example embodiments may be utilized with any electronic component that may establish a connection to a network and is configured with the hardware, software, and/or firmware to exchange information and data with a network. Therefore, the UE as described herein is used to represent any appropriate electronic device.

[0021] Beamforming may be used in a wireless communications system in an effort to optimize wireless communications with a UE by focusing signals at the UE, enhancing efficiency and reliability. Beamforming by a network device may employ multiple antennas and advanced algorithms to create precise, concentrated communication links. This targeted approach boosts signal strength, quality, and data rates, supporting multiple-input multiple-output (MIMO) configurations. By adapting signal direction based on UE location and surroundings, beamforming overcomes obstacles to enable faster speeds and lower latency for users in diverse scenarios and applications. A network device (e.g., a base station or gNB) serving UEs in a coverage area may use a set of beams, each beam of which is associated with a particular set of antenna parameters for transmission and/or reception using one or more sets of antenna arrays at the network device. Different beams may generally be associated with communications in a particular vertical and horizontal direction. For example, a base station may be deployed and configured such that a beam is horizontally associated with some number of radial degrees (e.g., radial angles of five, ten, or twenty degrees), while one or more beams may be present in the vertical direction and associated with different vertical angles (e.g., two, three, or four beams in the vertical direction). In some cases, the distribution of beams may be uniform (e.g., vertically and/or horizontally uniform or evenly distribution). In other cases, however, beams may be irregularly sized and/or distributed in the spatial domain.

[0022] In some wireless communication networks, radio resource management (RRM) involves a set of functionalities and procedures to efficiently manage and optimize radio resources in the network. Measurements are used to provide the network with information about the radio environment, allowing the network to make informed decisions for resource allocation, handovers, and other optimization strategies. In the network, both UEs and network devices transmit reference

signals that network devices or UEs measure. For example, a UE may measure reference signals transmitted by a network device to determine reference signal received power (RSRP) and reference signal received quality (RSRQ) for a downlink, and report such measurements to the network device. In the case of a serving cell, the UE may determine channel state information (CSI), including channel quality indicator, rank indicator, and precoding matrix indicator based on measuring CSI reference signals transmitted by the network device. Other exemplary measurements for RRM may include interference measurements from neighboring cells, event-trigger measurements, mobility and handover-related measurements, determination of cell identity and cell identity groups for neighboring network devices, beam management measurements, UE positioning measurement, and network synchronization measurements.

[0023] In some cases, the overhead required for reference signal measurements for RRM purposes can be high. In many cases these reference signal measurements are of synchronization signal blocks (SSBs) and CSI reference signals (CSI-RS). A UE may be configured to measure reference signals for RRM during a particular time, such as an SSB-based RRM measurement timing configuration (SMTC) window, which is a periodic time window that can be used for measurement SSBs. As an example, for an SMTC periodicity of 20 ms, the SMTC overhead in a Frequency Range 2 (FR2) may be about 25%, especially for FR2 using a 5 ms SSB burst length. As such, reducing overhead for RRM measurements is desirable to increase available resources for communication.

[0024] Additionally, a UE may communicate with a network device using multiple component carriers using a carrier aggregation (CA) configuration, or with multiple network devices in a dual connectivity (DC) configuration. Such multiple component carrier configurations may require further resources for RRM measurements, for example due to performing measurements on each of the component carriers. Moreover, where beamforming is used by the network devices and/or UEs, multiple beams need to be measured, including multiple beams for each component carrier.

[0025] In light of these challenges, according to the disclosure herein, reducing the number of beams to be measured is desirable, including both transmit beams and receive beams. Layer 3 (L3) measurements may be performed inside the SMTC window, in one or more embodiments described herein. L3 measurement delay is reduced at least in part by reducing or minimizing the receive beam sweeping set, which may be used for spatial beam prediction in some examples. L3

measurement overhead is reduced by skipping, at least in part or entirely transmit beam and/or receive beam sweeping. L3 measurement overhead is further reduced at least in part by skipping measurement of one or more transmit-receive beam pairs, for example achieving a reduction in scheduling restrictions, which may increase throughput in some cases. I

[0026] At least in part to help reduce the burden of RRM, a UE may use or rely on machine learning with reference to various management and control tasks, such as CSI, beam management, or positioning. In one or more embodiments, the UE uses machine learning to determine parameters for one or more beams of the Set A beams based on the Set B beam measurements. Machine learning may also include artificial intelligence in some cases. Processors, systems, servers, or other devices or components, or groups of any of these, that implement or perform machine learning may be referred to as a machine learning engine.

[0027] A machine learning engine may include and/or generate a machine learning model to find patterns or make decisions from a previously unseen dataset. In some examples, a machine learning model may refer to a program (algorithm, code, process). Additionally, or alternatively, a machine learning model may refer to parameters, values, data, or other inputs provided to a machine learning engine (e.g., a program) that define or otherwise control the operation of the machine learning engine. The machine learning model may be trained using a dataset, where the program is optimized to find certain patterns or outputs from the dataset. The output of the training is the machine learning model.

[0028] As further discussed herein, techniques to reduce RRM overhead for neighbor cells, including in the case of multiple component carrier communications such as CA or DC configurations. A beam estimation/prediction (BEP) model (e.g., a machine learning model for beam estimation) may be used by a UE to determine a beam prediction using a subset of the transmit beams used by a network device for transmission of reference signals (e.g., SSB or CSI-RS) for RRM measurements. For the component carriers that the UE is to measure on different frequencies than the serving frequency, the UE may group certain component carriers and/or frequencies together for purposes of the RRM measurements. The UE may effectively treat certain component carriers and/or frequencies as collocated for purposes of the RRM measurements, such that measurements for one component carrier and/or frequency can be considered as valid for other component carriers and/or frequencies.

[0029] In one or more embodiments, as further described herein, the network configures the multiple component carriers for the RRM for the UE, and also configures one or more component carrier measurement groups. As used herein a component carrier measurement group is a set of one or more component carriers and/or frequencies that the UE treats as collocated for purposes of RRM. The UE then measures reference signals for RRM on a second set of beams. Here, the second set of beams are the beams that the UE measures and the BEP model uses to predict (e.g., calculate, determine, identify) a beam prediction for the beams of the first set of beams. The UE can then report the beam prediction for the component carrier measurement group. In the event that there are multiple component carrier measurement groups, multiple beam predictions (one or more per component carrier measurement group) can be sent to the network, via the network device (e.g., the network device serving the UE). For the other, non-measured component carriers of the same component carrier measurement group, the network may consider the beam prediction as applying to these component carriers as well.

[0030] FIG. 1 shows an example wireless communication system 100, according to one or more aspects described herein. In one or more embodiments, wireless communication system 100, supports one or more aspects of neighbor cell RRM reduction for CA or DC, as further described herein.

[0031] Wireless communication system 100 includes a UE 102, network device 104, network device 108-a, network device 108-b and a machine learning engine 106. One or more UEs including the UE 102 may be being served by (e.g., has an established radio resource control (RRC) connection with) the network device 104 via communication link 120. Coverage area 110 (e.g., a cell or serving cell) is the service area for the RF spectrum band utilized by network device 104. Network devices 108 (e.g., network device 108-a and network device 108-b) are neighboring network devices for UE 102. In one or more embodiments, communication link 120 may include a downlink connection and/or uplink connection.

[0032] In one or more embodiments, network device 104 and network devices 108 utilize beam steering, which may also be, include, or be referred to as electronic beam steering. Additionally, in one or more embodiments, UE 102 utilizes beam steering to receive signals, transmit signals, or both. As used herein, electronic beam steering refers, without limitation, to the ability of a device (e.g., network device 104, network devices 108) to perform beamforming, beam shaping, or other

multiple antenna or multiple antenna-element techniques that control, direct, or otherwise shape electromagnetic energy radiated from the network device 104 or network devices 108 in different directions and with different magnitudes or amplitudes. Electronic beam steering also refers to the network device 104 or network devices 108 adjusting antennas or antenna elements to increase or decrease the ability to receive electromagnetic radiation from a particular direction. Such reception beamforming may be referred to as a “receive beams,” as opposed to transmit beamforming using “transmit beams.” A network device 104 uses beam steering for the transmission of signals to UEs (e.g., UE 102) served by the network device 104. Such signals can include data signals, control signals, or both. Control signal may include reference signals, synchronization signals, or control channels, or combinations of these.

[0033] In one or more embodiments, network device 104 and network devices 108 utilize beam steering to transmit reference signals on a set of beams 130. In some embodiments, the reference signals include a channel state information reference signal (CSI-RS) or a synchronization signal block (SSB) (e.g., including a primary synchronization signal (PSS), secondary synchronization signal (SSS), physical broadcast channel (PBCH) carrying control information, and a demodulation reference signal (DMRS) for the PBCH). As an example configuration, a network device 104 may transmit reference signals (e.g., CSI-RS, SSB, or both) on a set of 32 transmit beams that are spatially distributed in both vertical and horizontal directions. For example, the set of beams 130 may include 8 of transmit beams 132 at a first vertical beam angle, 8 of transmit beams 134 at a second vertical beam angle, 8 of transmit beams 136 at a third vertical beam angle, and 8 of transmit beams 138 at a fourth vertical beam angle. The beams of the set of beams 130 may be spread horizontally as well. Although described with reference to the set of beams 130 for the network device 104, one or more of network devices 108 may also transmit reference signals (e.g., CSI-RS, SSB, or both) on a set of transmit beams 132 (e.g., set of transmit beams 132-a from network device 108-a, and set of transmit beams 132-b from network device 108-b), which may include 32, 64, or any other number of beams.

[0034] In the example of wireless communication system 100, the set of beams 130 (and/or the set of beams 132) illustrates an example of a Set A beams, and may also be referred to as operational beams. A subset of the set of beams 130 includes 8 beams (beam 140, beam 141, beam 142, beam 143, beam 144, beam 145, beam 146, and beam 147) that collectively may be an example of a Set B beams. As illustrated with reference to the set of beams 130, Set B is a subset

of Set A in the illustration. In one or more embodiments, the set of beams 130 may each correspond to a beam used for the transmission of SSBs by the network device 104. In some embodiments, each beam of the set of beams 130 may be transmitted on a different set of time and frequency resources, in addition to being transmitted on different spatial resources as illustrated with reference to the set of beams 130. In one or more embodiments, one or more features of the set of beams 130 similarly apply to the set of beams 132.

[0035] In one or more embodiments, machine learning engine 106 may be a UE-side server in communication with UE 102. Machine learning engine 106 may implement or otherwise perform one or more machine learning tasks, such as training a BEP model for UE 102 based on a set of measurements taken by UE 102 of reference signals received from network device 104 on one or more beams of the set of beams 130 (e.g., Set A beams, Set B beams). Following training, machine learning engine 106 may then provide the BEP model back to UE 102 via communication link 122, which may be a wired or wireless connection.

[0036] Machine learning engine 106 may be or include one or more computing components, such as a processor and memory. In one or more embodiments, the machine learning engine 106 is a device external to UE 102, but in communication with UE 102 (e.g., directly, or via a network device such as network device 104, such as a server). In other embodiments, the machine learning engine 106 is a server (e.g., a software-based server) for a machine learning engine that is internal to UE 102 or otherwise collocated with UE 102, for example within a same mobile device, vehicle, and so on.

[0037] In some examples, the design (e.g., configuration, parameter values, analog beam selection such as SSB or narrow beam resources) for a network operator controlling and/or configuring network device 104 are part of a core implementation and proprietary (e.g., to the network operator, network entity manufacturer, etc.). Such design may consider various network conditions, such as UE mobility (e.g., how frequently the best transmission beam for a UE changes), UE distribution (e.g., where the targeted UEs are physically), a hierarchy among SSB beams and/or narrow beams, and so on. A network operator may wish to provide high quality of service (QoS) for UEs and also reduce power consumption by the network, including by network entities. As such, a network operator may desire to utilize different beam designs at different times. As an example, a key performance indicator for the network may be system capacity during rush

hour, but in the middle of the night a key performance indicator may be power consumption. In other examples, additional or different key performance indicators may be desired.

[0038] FIG. 2 shows an example signaling diagram 200, according to one or more aspects described herein. In one or more embodiments, signaling diagram 200 supports one or more aspects of neighbor cell RRM reduction for CA or DC, as further described herein.

[0039] Signaling diagram 200 shows RRM measurements performed by a UE 102. A set of measurements 200-a, a set of measurements 200-b, and a set of measurements 200-c, for the UE are illustrated in various scenarios according to aspects described herein. In each scenario, a UE 102 may perform, using receive beams of the UE 102, measurements of reference signals that are transmitted by the network devices 108 (e.g., neighboring network devices for UE 102) using a transmit beam sweep at the network device.

[0040] UE 102 may perform such measurements during a measurement gap, whose length (duration) is greater than the SMTC window length. As such, the network (e.g., via a configuration of the UE 102 by one of the network devices, such as network device 104), may set the SMTC window and measurement gap length based on the periodicity of SSB bursts (e.g., a set of periodic occurring SSB transmissions by network devices, such as network devices 108).

[0041] In some examples, the SMTC window periodicity can be set in the same range of SSBs, e.g., 5, 10, 20, 40, 80 or 160 ms, and the window duration can be set to 1, 2, 3, 4, or 5 ms, according to the number of SSBs transmitted on the cell being measured (e.g., a cell of the network devices 108). As such, a different network device and/or different cell of the network devices 108 may be measured with different window periodicity and different window duration.

[0042] During each SMTC window (e.g., SMTC window 202, SMTC window 204, SMTC window 206, and SMTC window 208), network devices 108 transmit on a set of transmit beams (e.g., set of beams 132). In the example of signaling diagram 200, N number of reference signals (e.g., SSB, CSI-RS) are transmitted during the SMTC window. A first reference signal 212 is transmitted on a first transmit beam in a first direction (e.g., have a generally horizontal and vertical direction as further discussed herein). Each reference signal transmission may include a reference signal transmitted in a different direction for different reference signals, up to an Nth reference signal 214.

[0043] From the perspective of UE 102, the UE measures the reference signals transmitted by the network device 108 using a receive beam during an SMTC window, switching the receive beam during different SMTC windows. As such, UE 102 uses a first receive beam during SMTC window 202, a second receive beam during SMTC window 204, a third receive beam during SMTC window 206, and a fourth receive beam during SMTC window 208. The SMTC windows may be separated in time according to an SMTC periodicity 216.

[0044] As further discussed herein, including for multiple component carrier configurations for UE 102, the delay due to RRM measurements may be significant. The set of measurements 200-a, set of measurements 200-b, and set of measurement 200-c illustrate techniques to reduce the overhead and/or delay for RRM measurements.

[0045] A delay 210 due to RRM measurements are illustrated for the set of measurements 200-a. For the set of measurements 200-a, a reduced number of RRM measurements are made by UE 102. For example, measurements during one or more SMTC windows are eliminated, such as SMTC window 204 and SMTC window 206, as illustrated. In this example, overhead is reduced, while delay 210 may remain the same.

[0046] A delay 220 due to RRM measurements are illustrated for the set of measurements 200-b. For the set of measurements 200-b, a reduced number of RRM measurements are made by UE 102, but during a latter portion of the measurement period. For example, measurements during one or more SMTC windows are eliminated, such as SMTC window 206 and SMTC window 208, as illustrated. In this example, overhead is reduced similar to the set of measurements 200-b, but the delay 220 may be reduced relative to delay 210. Thus, both overhead and delay reduction may be achieved.

[0047] A delay 230 due to RRM measurements are illustrated for the set of measurements 200-c. For the set of measurements 200-c, a reduced number of RRM measurements are made by UE 102 during a latter portion of the measurement period, similar to the set of measurement 200-b. For example, measurements during one or more SMTC windows are eliminated, such as SMTC window 206 and SMTC window 208, as illustrated. Additionally, the UE 102 may eliminate measurements on one or more receive beams during one or more of the SMTC windows. For example, UE 102 may measure reference signals for RRM measurements using receive beam 232, receive beam 234, receive beam 236, and receive beam 238, but not on other reference signal

measurement occasions of the SMTC window 204. In this example, both delay and overhead are reduced relative to the set of measurements 200-a. Thus, both delay and further overhead reduction may be achieved.

[0048] FIG. 3 shows an example learning diagram 300 for a model, according to one or more aspects described herein. In one or more embodiments, learning diagram 300, supports one or more aspects of neighbor cell RRM reduction for CA or DC, as further described herein.

[0049] As further discussed herein, a BEP model may be used to determine a beam prediction for a set of transmit beams of network devices 108, based on measurements by UE 102 on a reduced set of transmit beams. In some examples, a BEP model may be or use aspects of learning diagram 300.

[0050] Learning diagram 300 includes a full reference signal received power (RSRP) map 310, a downsampled RSRP image 320, a reduced RSRP map 330, and learning output 340. In training the model, the UE 102 may take RSRP measurements across each transmit beam (m) and receive beam (n) of the codebook to generate the full RSRP map 310 ($Y^{|H_{m,n}^b|}$), where H is the channel matrix for the full training signal. The full RSRP map 310 is a high resolution map. The downsampled RSRP image 320 (f_R) is based on downsampled measurements from the full RSRP map 310, and a reduced RSRP map is used to generate (via f_R) the reduced RSRP map 330, represented by $X = f_R(Y)$. The output of the learning process is learning output 340 ($\hat{Y} = f_R^{-1}(X)$), which can be used to determine an interpolation of the full map ($\hat{Y}$), and is based on the generated data of the full RSRP map 310 as true labels and generated data as inputs to the learning model (e.g., a BEP model).

[0051] In some aspects, learning diagram 300 includes finding the best $N\{\text{Tx,Rx}\}$ beam pairs from the interpolated image map $[\hat{r}, \hat{t}]_{1:N} = g(\hat{Y})$. The optimum $\{\text{Tx,Rx}\}$ beam may be denoted by $[r^*, t^*] = g(Y)$, from the genie labels Y . In some aspects, simulations for computing the probability of $[r^*, t^*] \in [\hat{r}, \hat{t}]_{1:N}$ may be performed as part of learning diagram 300.

[0052] As further discussed herein a BEP model—which may be an example of a machine learning model in some aspects—can be used to predict a beam for a full (or merely larger) set of transmit beams of a network device based on UE measurements of a reduced set of transmit beams (e.g., a subset of the full set) or a different set of beams (e.g., a set of transmit beams for reference

signals, such as SSBs, that are relatively wider than the communication transmit beams, such as transmit beams for CSI-RS). In one or more embodiments, a UE 102 may be configured to communicate with at least one network device 104 using multiple component carriers (e.g., in a CA configuration, or a DC configuration with multiple serving network devices, including network device 104). Using one or more BEP models, the UE 102 can predict multiple component carriers (e.g., CA or DC serving cells), including for neighboring serving cells (e.g., serving cells of one or more network devices 108).

[0053] In some embodiments, the component carriers may be in FR2 (e.g., about 24.25 GHz to 52.6 GHz), though the embodiments described herein may be applied to other frequency ranges (or radio frequency spectrum bands). In some embodiments different BEP models are different for different frequencies (e.g., frequency bands) with a frequency range, for example the model may have a different interpolation function. According to one example, a BEP model for a first frequency in FR2 that is closer to 24.25 GHz is different than a BEP model for a second frequency in FR2 that is closer to 52.6 GHz. Additionally, different spatial domain prediction BEP models may be needed to cover a whole frequency range, an increased number of deployment scenarios, or both. However, it may be desirable to reduce the total number of BEP models that are tried and needed to support the frequency ranges and deployment scenarios.

[0054] Examples of deployment scenarios that may be covered consistent with the disclosure and embodiments discussed herein, include collocated and non-collocated neighbor cells (neighbor component carriers), as well as collocated and non-collocated serving cells (serving component carriers) for multiple component carriers (e.g., CA or DC). In many scenarios, neighbor cells are generally not collocated, even if they are in the same frequency band or frequency. In some scenarios, neighbor cells could be collocated, even if they are not in the same carrier. In many scenarios, serving cells are collocated if they are in the same frequency band. In some scenarios, however, the serving cells may not be collocated for CA if intra-band non-collocated CA is used (e.g., configured). In some scenarios, serving cells for CA are inter-band, and may be collocated for CA or DC, or are non-collocated CA.

[0055] FIG. 4 shows an example signaling diagram 400, according to one or more aspects described herein. In one or more embodiments, signaling diagram 400 supports one or more aspects of neighbor cell RRM reduction for CA or DC, as further described herein.

[0056] Signaling diagram 400 illustrates an in intra-band, collocated multiple component carrier (e.g., CA) scenario with three serving cells at frequencies F1, F2, and F3, according to one or more embodiments. Each of frequencies F1, F2, and F3 are within a same frequency band 430 (Band A) and are thus intra-band serving cells. In one or more embodiments, frequency band 430 may be in the FR2 frequency band 440, which is FR2. Serving cell 402 is at F1, serving cell 404 is at F2, and serving cell 406 is at F3. In one or more embodiments, Set A beams for the serving cell 402, serving cell 404, and serving cell 406 include transmit beams on which a serving network device transmits reference signal for measurement (e.g., RRM measurements) by a UE, and the Set B beams are the reduced set of beams that the UE measures in conjunction with using a BEP model (e.g., probing beams used for training the BEP model).

[0057] In one or more embodiments, at least in part because the deployment illustrated in signaling diagram 400 is intra-band and collocated, a same dataset and BEP model can be and is used for each of the serving cells, the serving cell 402, serving cell 404, and serving cell 406. The BEP model, common model 410, obtains (e.g., receives) RSRP measurement information 412 from a UE 102, and may determine a full RSRP map 420 for each serving cell, including the serving cell 402, serving cell 404, and serving cell 406. From the full RSRP map 420, the UE 102 may determine a beam prediction. At least in part because the serving cell 402, serving cell 404, and serving cell 406, a same transmit beam may be a best beam for the transmit beam. In some embodiments, the UE 102 may measure reference signals for serving cell 402 (e.g., but not serving cell 404 nor the serving cell 406), to determine RSRP measurements, and use the common model 410 to determine a beam prediction (e.g., a best transmit beam) for the UE 102. By measuring one of the three collocated serving cells, the UE may reduce RRM overhead. Additionally, by measuring a reduced number of transmit beams (e.g., not all Set A beams, but only Set A and Set B beams), the UE may further reduce RRM overhead while still obtaining a beam prediction.

[0058] In some embodiments, UE 102 may obtain association information from one or more of the network devices (e.g., network device 104, or one or more of network device 108) related to collocation information for one or more of the serving cells. In one or more embodiments, the assistance information may be transmitted to UE 102 as control signaling (e.g., a downlink control information (DCI) message, media access control (MAC) control element, or radio resource control (RRC) signaling), and indicate collocation information (e.g., quasi collocation (QCL)) information associated with one or more of serving cell 402, serving cell 404 or serving cell 406.

[0059] FIG. 5 shows an example signaling diagram 500, according to one or more aspects described herein. In one or more embodiments, signaling diagram 500 supports one or more aspects of neighbor cell RRM reduction for CA or DC, as further described herein. As shown for signaling diagram, an inter-band scenario may include frequencies, some of which are with a same frequency band and some of which are in different frequency bands.

[0060] Frequency band 522 (Band A) includes frequencies F1, F2, and F3; frequency band 524 (Band B) includes frequencies F4, F5, and F6; and frequency band 526 (Band C) includes frequencies F7, F8, and F9. In some embodiments, each for frequency band 522, frequency band 524, and frequency band 526 are non-adjacent to each other in frequency. Thus, frequencies in different frequency bands (e.g., F1 and F4, F5 and F8, and so on) are thus inter-band serving cells. In some embodiments, each of frequency band 522, frequency band 524, and frequency band 526 are in a same frequency range 520 (e.g., FR2).

[0061] In some examples, and as illustrated for signaling diagram 500, a UE 102 is configured with four component carriers as serving cells: F1 (serving cell 502), F2 (serving cell 504), F4 (serving cell 506), and F7 (serving cell 508). In one or more embodiments, each different frequency band is associated with a different BEP model. According to the example of signaling diagram 500, the BEP models of the UE 102 include BEP model 512 (Model A) that is for F1 and F2, BEP model 514 (Model B) that is for F4, and BEP model 516 (Model C) that is for F7. In some embodiments, UE 102 assumes (or is configured to assume) that frequencies within a same frequency band are collocated. As such, as illustrated for signaling diagram 500, a same BEP model (e.g., BEP model 512) may be used for F1 and F2.

[0062] Additionally, UE assistance information 414 may provide further collocation information for the UE 102. In one or more embodiments, the UE assistance information 414 includes selection or merging information for the BEP models. In some examples the selection or merging information includes a selection criterion for the UE to use to merge BEP models according to a frequency separation of the frequency band. For example, in some embodiments, the UE 102 groups the component carriers into component carrier measurement groups based on the frequency distance for the component carriers satisfying a frequency separation threshold (e.g., control signaling may indicate $\text{Model ID} = f(\text{Freq})$). In some embodiments, the network device 104 may provide an explicit indication of a mapping between each serving cell and a BEP model.

(e.g., a model identifier (ID) may be signaled for each frequency band), either of the configured frequency bands (e.g., F1, F2, F4, and F7) or for all frequency bands (e.g., F1-F9)). As such, in some embodiments, the UE 102 can receive, for each component carrier of the plurality of component carriers, an indication of a component carrier measurement group for the component carrier.

[0063] FIG. 6 shows an example signaling diagram 600, according to one or more aspects described herein. In one or more embodiments, signaling diagram 600 supports one or more aspects of neighbor cell RRM reduction for CA or DC, as further described herein. As shown for signaling diagram, an inter-band scenario may include frequencies, some of which are with a same frequency band and some of which are in different frequency bands.

[0064] Frequency band 628 (Band A) includes frequencies F4, F5, F6, and F7. Frequency F8 is also within a same frequency range 630 (e.g., FR2) as frequency band 628, but may be non-adjacent in frequency. In one or more embodiments, frequencies F4, F5, F6, and F7 of frequency band 628 use a first BEP model, and frequency F8 uses a second BEP model.

[0065] In one or more embodiments, overhead for beam measurement are reduced for inter-frequency neighbor cell measurement. UE 102 may be scheduled to make measurement on frequency F4, F5, F6, F7, and F8. UE 102 may detect neighbor cell 602 through neighbor cell 626 (corresponding to neighbor cells NC1 to NC14, respectively). According to previous techniques, the UE 102 would measure all 13 sets of measurements, including performing BEP model prediction. According to one or more embodiments, frequencies F4, F5, F6, and F7 are close enough in frequency such that the UE 102 would consider a same BEP model to be valid and thus used for frequencies F4, F5, F6, and F7, for example if the neighbor cells are collocated. Frequency 8, in some embodiments is far enough away from frequencies F4, F5, F6, and F7 (e.g., the difference in frequency exceeds a threshold frequency difference value). As such neighbor cell 624 and neighbor cell 626 use a different BEP model than for frequencies F4, F5, F6, and F7.

[0066] In one or more embodiments, for each inter-frequency measurement (e.g., for frequency F8 within frequency range 630), a UE 102 checks if the neighbor cell carrier is close to the serving cell's band of frequencies (e.g., within a threshold frequency value) where a first BEP model was trained. In the case that the neighbor cell carrier is too far away (e.g., the frequency of the neighbor cell carrier is more than a threshold frequency away), then the RRM measurements are processed

according to a legacy mode (e.g., without a BEP model according to current techniques, or when the use of BEP models is not configured at the UE 102), or using a different, second BEP model than the first BEP model.

[0067] In some embodiments, the network (e.g., via a network device 104 serving the UE 102) provides control signaling (e.g., UE assistance information) indicating a group of component carrier measurement groups (e.g., pairs, sets, or groupings of neighbor cells that are considered collocated, which may include for purposes of RRM measurement, and which may include using BEP models for RRM measurements, reducing RRM measurement overhead.

[0068] In the example illustrated in the signaling diagram 600, the control signaling received at UE 102 indicates that neighbor cell 602, neighbor cell 610, neighbor cell 612, and neighbor cell 622 are collocated; indicates that that neighbor cell 604, neighbor cell 606, and neighbor cell 616 are collocated; and indicates that that neighbor cell 618 and neighbor cell 620 are collocated. Collocated neighbor cells use a same BEP model for training and for inference (e.g., to predict a beam during an RRM procedure). As such, neighbor cell 602, neighbor cell 610, neighbor cell 612, and neighbor cell 622 use a first BEP model for training and inference. Neighbor cell 604, neighbor cell 606, and neighbor cell 616 use a second BEP model for training and inference. Neighbor cell 618 and neighbor cell 620 use a third BEP model for training and inference.

[0069] In the example illustrated in the signaling diagram 600, no collocation information may have been provided for neighbor cell 608 and neighbor cell 614. Alternatively, the control signaling received by the UE 102 have provided an indication that neighbor cell 608 is not collocated with any other neighbor cells, and neighbor cell 614 is not collocated with any other neighbor cells.

[0070] FIG. 7 shows an example signaling diagram 700, according to one or more aspects described herein. In one or more embodiments, signaling diagram 700 supports one or more aspects of neighbor cell RRM reduction for CA or DC, as further described herein.

[0071] In one or more embodiments, based at least in part on the UE assistance signaling discussed herein for signaling diagram 600, UE 102 may perform RRM measurements for neighbor cell 604, neighbor cell 608, neighbor cell 610, neighbor cell 614, and neighbor cell 618. UE 102 then uses, based on such measurements, the first BEP model, the second BEP model, the third BEP model, the fourth BEP model, and the fifth BEP model, as further discussed with

reference to signaling diagram 700 to perform beam prediction for neighbor cell 602 through neighbor cell 622. RRM measurements and BEP model-based beam prediction is performed for neighbor cell 624 and neighbor cell 626 as discussed above with reference to signaling diagram 600.

[0072] As shown and discussed with reference to signaling diagram 600 and signaling diagram 700, the number of different BEP models used for RRM measurements can be reduced from thirteen to seven. As such, in one or more embodiments, RRM measurement overhead is reduced.

[0073] FIG. 8 shows an example signal flow 800, according to one or more aspects described herein. In one or more embodiments, signal flow 800, supports one or more aspects of neighbor cell RRM reduction for CA or DC, as further described herein. In some cases, the UE may be the UE 102, wireless device 1202, or one of the other UEs described herein.

[0074] Signal flow 800 includes communications by and between a UE 102, the network device 104, the machine learning engine 106, and one or more network devices 108, which may be, be included in, or include aspects of the corresponding devices discussed herein.

[0075] UE 102 transmits UE capability signaling 810 to the network device 104, where the UE capability signaling 810 indicates or otherwise identifies a UE capability to perform beam prediction using component carrier measurement groups. In some embodiments, such UE capability signaling 810 is RRC signaling, for example when the UE establishes an RRC connection with the network device 104. In other embodiments the UE capability signaling 810 is any type of control signaling, for example a MAC control element or uplink control information (UCI) signaling.

[0076] Network device 104 transmits and UE 102 receives a resource configuration 812 for communication with the network device 104, including a CA or DC configuration that includes multiple component carriers. In some embodiments, resource configuration 812 is RRC signaling.

[0077] Network device 104 transmits and UE 102 receives a measurement resource configuration 814 indicating a set of component carriers that the UE 102 is to measure for RRM. In one for more embodiments, the measurement resource configuration 814 may be received prior to resource configuration 812, or together with resource configuration 812, for example in RRC signaling. As further discussed herein, measurement resource configuration 814 may identify

RRM measurement resources for the network device 104 serving the UE 102, or for the network devices 108 that serve neighbor cells to UE 102.

[0078] In one or more embodiments, measurement resource configuration 814 further includes an indication of a set of component carrier measurement groups for the component carriers indicated to the UE 102 for measurement, where the component carrier measurement groups are groups of component carriers (e.g., serving cells or neighbor cells, as further discussed herein) that are grouped for RRM measurements and use of a common BEP model between the component carriers (cells) of a group.

[0079] UE 102 may receive reference signals 816 from network device 104 for serving cell measurements, or may receive reference signals 818 from one or more network devices 108 for neighbor cell measurements. In one or more embodiments, one or both of the reference signals 816 and reference signals 818 are SSBs. In some embodiments, one or both of the reference signals 816 and reference signals 818 are CSI-RSs. In some embodiments, reference signals 816 are CSI-RSs. In some embodiments, reference signals 818 are SSBs. In some embodiments, the reference signals 816 and the reference signals 818 are some combination of SSBs and CSI-RSs.

[0080] UE 102 may measure one or both of the reference signals 816 and the reference signals 818, and transmits or otherwise provides training data 820 to the machine learning engine 106. In some embodiments, the machine learning engine 106 is external to UE 102. In some embodiments, the machine learning engine 106 is internal to or a component of the UE 102. In one or more embodiments, training data 820 includes RSRP, received signal strength indicator (RSSI), reference signal received quality (RSRQ), signal-to-interference noise ratio (SINR), or other signal information based on measurements of the reference signals 816 and the reference signals 818.

[0081] Model training 822 occurs, as further discussed herein (including with reference to learning diagram 300), and one or more BEP models 824 are transmitted or otherwise provided to and obtained by the UE 102.

[0082] At model selection 826, UE 102 may determine which BEP models 824 to utilize according to the set of component carriers indicated by the measurement resource configuration 814 and detection or identification of neighbor cells of one or more network devices 108. For example, UE 102 may detect some quantity of neighbor cells, and determine whether frequencies

for such neighbor cells are within some frequency threshold value (as further discussed herein) to determine which neighbor cells to measure.

[0083] UE 102 may receive reference signals 828 from network device 104 for serving cell measurements, or may receive reference signals 830 from one or more network devices 108 for neighbor cell measurements. In one or more embodiments, one or both of the reference signals 828 and reference signals 830 are SSBs. In some embodiments, one or both of the reference signals 828 and reference signals 830 are CSI-RSs. In some embodiments, reference signals 828 are CSI-RSs. In some embodiments, reference signals 830 are SSBs. In some embodiments, the reference signals 828 and the reference signals 830 are some combination of SSBs and CSI-RSs.

[0084] As further described herein, UE 102 uses the RRM measurements taken for reference signals 828 and/or reference signals 830 to make one or more beam predictions to transmit to network device 104 in a beam report. In one or more embodiments, the beam report 834 is a CSI report.

[0085] FIG. 9 shows an example method 900 of wireless communication by a UE. In one or more embodiments, method 900, supports one or more aspects of neighbor cell RRM reduction for CA or DC, as further described herein. In some cases, the UE may be the UE 102, wireless device 1202, or one of the other UEs described herein. The method 900 may be performed using a processor, a transceiver (*e.g.*, a main radio), or other components of the UE.

[0086] At 902, the method 900 includes receiving an indication of a plurality of component carriers for the UE to measure for radio resource management, each component carrier of the plurality of component carriers configured to carry, on a first set of beams for the component carrier, a set of reference signals for the UE to measure, the set of reference signals associated with one or more network devices.

[0087] At 904, the method 900 includes receiving an indication of a set of component carrier measurement groups for the plurality of component carriers.

[0088] At 906, the method 900 includes measuring the set of reference signals for each component carrier measurement group of the set of component carrier measurement groups, the set of reference signals received using a second set of beams on one component carrier of the

component carrier measurement group, the second set of beams having a relationship with the first set of beams.

[0089] At 908, the method 900 includes determining, for each component carrier measurement group, a beam prediction for one or more beams of the second set of beams based at least in part on the measurement of the set of reference signals. In some embodiments, the beam predictions for the one or more beams are determined using a BEP model.

[0090] At 910, the method 900 includes transmitting, to a network device, a report comprising the beam predictions for the plurality of component carriers.

[0091] In one or more embodiments, the indication of the set of component carrier measurement groups comprises an indication of a selection criteria for grouping component carriers into component carrier measurement groups. The method 900 may further include selecting, from the plurality of component carriers and according to the indication of the selection criteria, a set of component carriers for each component carrier measurement group of the set of component carrier measurement groups.

[0092] In one or more embodiments, the selection criteria comprises a frequency separation threshold, and the method 900 further includes identifying a frequency distance between component carriers of the plurality of component carriers, and grouping the component carriers into the component carrier measurement groups based at least in part on the frequency distance for the component carriers satisfying the frequency separation threshold.

[0093] In one or more embodiments, the method 900 further includes receiving, for each component carrier of the plurality of component carriers, an indication of a component carrier measurement group for the component carrier.

[0094] In one or more embodiments, the method 900 further includes receiving, for each component carrier of the plurality of component carriers, an indication of the BEP model for the component carrier.

[0095] In one or more embodiments, the set of component carrier measurement groups includes at least a first component carrier measurement group for component carriers of a first radio frequency spectrum band, and a second component carrier measurement group for component carriers of a second radio frequency spectrum band. In some embodiments, the beam predictions

for the one or more beams are determined using a BEP model. In some embodiments, the BEP model for each component carrier measurement group comprises a first BEP model for the first component carrier measurement group, and a second BEP model for the second component carrier measurement group, and the beam prediction is determined using the first BEP model and the second BEP model.

[0096] In one or more embodiments, the method 900 further includes transmitting control signaling indicating a UE capability to perform the beam prediction using component carrier measurement groups, the indication of the set of component carrier measurement groups received at least in part in response to transmitted control signaling.

[0097] In one or more embodiments, the set of reference signals comprise one or more of a set of SSB or a set of CSI-RS.

[0098] The method 900 may be variously embodied, extended, or adapted, as described in the following paragraphs and elsewhere in this description.

[0099] FIG. 10 shows an example method 1000 of wireless communication by a network device. In one or more embodiments, method 1000, supports one or more aspects of neighbor cell RRM reduction for CA or DC, as further described herein. In some cases, the network device may be the network device 104, one of the network devices 108, network device 1220, or one of the other network devices described herein. The method 1000 may be performed using a processor, a transceiver (*e.g.*, main radio), or other components of the network device.

[0100] At 1002, the method 1000 includes transmitting, to a UE, an indication of a plurality of component carriers for the UE to measure for radio resource management, each component carrier of the plurality of component carriers configured to carry, on a first set of beams for the component carrier, a set of reference signals for the UE to measure, the set of reference signals associated with one or more network devices.

[0101] At 1004, the method 1000 includes receiving, from the UE, control signaling indicating a UE capability to perform a beam prediction using component carrier measurement groups.

[0102] At 1006, the method 1000 includes transmitting, to the UE and at least in part in response to the UE capability, an indication of a set of component carrier measurement groups for the

plurality of component carriers, each component measurement group of the set of component carrier measurement groups corresponding to a BEP model.

[0103] At 1008, the method 1000 includes receiving, from the UE, a report indicating the beam prediction for one or more beams of a second set of beams, the beam prediction for the plurality of component carriers.

[0104] In one or more embodiments, the indication of the set of component carrier measurement groups comprises an indication of a selection criteria for grouping component carriers into the component carrier measurement groups. In some embodiments, the selection criteria comprises a frequency separation threshold for the UE to use to group component carriers of the plurality of component carriers into the component carrier measurement groups.

[0105] In one or more embodiments, the method 1000 further includes transmitting, to the UE and for each component carrier of the plurality of component carriers, one or more of an indication of a component carrier measurement group for the component carrier or an indication of BEP model for the component carrier.

[0106] The method 1000 may be variously embodied, extended, or adapted, as described in the following paragraphs and elsewhere in this description.

[0107] Embodiments contemplated herein include one or more non-transitory computer-readable media storing instructions to cause an electronic device, upon execution of the instructions by one or more processors of the electronic device, to perform one or more elements of the method 900 or 1000. In the context of method 900, this non-transitory computer-readable media may be, for example, a memory of a UE (such as a memory 1206 of a wireless device 1202 that is a UE, as described herein). In the context of method 1000, this non-transitory computer-readable media may be, for example, a memory of a network device (such as a memory 1224 of a network device 1220, as described herein).

[0108] Embodiments contemplated herein include an apparatus having logic, modules, or circuitry to perform one or more elements of the method 900 or 1000. In the context of method 900, this apparatus may be, for example, an apparatus of a UE (such as a wireless device 1202 that is a UE). In the context of method 1000, this apparatus may be, for example, an apparatus of a network device (such as a network device 1220, as described herein).

[0109] Embodiments contemplated herein include an apparatus having one or more processors and one or more computer-readable media, using or storing instructions that, when executed by the one or more processors, cause the one or more processors to perform one or more elements of the method 900 or 1000. In the context of method 900, this apparatus may be, for example, an apparatus of a UE (such as a wireless device 1202 that is a UE, as described herein). In the context of the method 1000, this apparatus may be, for example, an apparatus of a network device (such as a network device 1220, as described herein).

[0110] Embodiments contemplated herein include a signal as described in or related to one or more elements of the method 900 or 1000.

[0111] Embodiments contemplated herein include a computer program or computer program product having instructions, wherein execution of the program by a processor causes the processor to carry out one or more elements of the method 900 or 1000. In the context of method 900, the processor may be a processor of a UE (such as a processor(s) 1204 of a wireless device 1202 that is a UE, as described herein), and the instructions may be, for example, located in the processor and/or on a memory of the UE (such as a memory 1206 of a wireless device 1202 that is a UE, as described herein). In the context of method 1000, the processor may be a processor of a network device (such as a processor(s) 1222 of a network device 1220, as described herein), and the instructions may be, for example, located in the processor and/or on a memory of the network device (such as a memory 1224 of a network device 1220, as described herein).

[0112] FIG. 11 illustrates an example architecture of a wireless communication system, according to embodiments described herein. The following description is provided for an example wireless communication system 1100 that operates in conjunction with the LTE system standards or specifications and/or 5G or NR system standards or specifications, as provided by 3GPP technical specifications.

[0113] As shown, the wireless communication system 1100 includes UE 1102 and UE 1104 (although any number of UEs may be used). In this example, the UE 1102 and the UE 1104 are illustrated as smartphones (e.g., handheld touchscreen mobile computing devices connectable to one or more cellular networks) but may also comprise any mobile or non-mobile computing device configured for wireless communication.

[0114] The UE 1102 and UE 1104 may be configured to communicatively couple with a RAN 1106. In embodiments, the RAN 1106 may be NG-RAN, E-UTRAN, etc. The UE 1102 and UE 1104 utilize connections (or channels) (shown as connection 1108 and connection 1110, respectively) with the RAN 1106, each of which comprises a physical communications interface. The RAN 1106 can include one or more network devices, such as base station 1112 and base station 1114, that enable the connection 1108 and connection 1110.

[0115] In this example, the connection 1108 and connection 1110 are air interfaces to enable such communicative coupling and may be consistent with RAT(s) used by the RAN 1106, such as, for example, an LTE and/or NR.

[0116] In some embodiments, the UE 1102 and UE 1104 may also directly exchange communication data via a sidelink interface 1116. The UE 1104 is shown to be configured to access an access point (shown as AP 1118) via connection 1120. By way of example, the connection 1120 can comprise a local wireless connection, such as a connection consistent with any IEEE 802.11 protocol, wherein the AP 1118 may comprise a Wi-Fi® router. In this example, the AP 1118 may be connected to another network (for example, the Internet) without going through a CN 1124.

[0117] In embodiments, the UE 1102 and UE 1104 can be configured to communicate using orthogonal frequency division multiplexing (OFDM) communication signals with each other or with the base station 1112 and/or the base station 1114 over a multicarrier communication channel in accordance with various communication techniques, such as, but not limited to, an orthogonal frequency division multiple access (OFDMA) communication technique (e.g., for downlink communications) or a single carrier frequency division multiple access (SC-FDMA) communication technique (e.g., for uplink and ProSe or sidelink communications), although the scope of the embodiments is not limited in this respect. The OFDM signals can comprise a plurality of orthogonal subcarriers.

[0118] In some embodiments, all or parts of the base station 1112 or base station 1114 may be implemented as one or more software entities running on server computers as part of a virtual network. In addition, or in other embodiments, the base station 1112 or base station 1114 may be configured to communicate with one another via interface 1122. In embodiments where the wireless communication system 1100 is an LTE system (e.g., when the CN 1124 is an EPC), the

interface 1122 may be an X2 interface. The X2 interface may be defined between two or more network devices of a RAN (e.g., two or more eNBs and the like) that connect to an EPC, and/or between two eNBs connecting to the EPC. In embodiments where the wireless communication system 1100 is an NR system (e.g., when CN 1124 is a 5GC), the interface 1122 may be an Xn interface. The Xn interface is defined between two or more network devices of a RAN (e.g., two or more gNBs and the like) that connect to the 5GC, between a base station 1112 (e.g., a gNB) connecting to the 5GC and an eNB, and/or between two eNBs connecting to the 5GC (e.g., CN 1124).

[0119] The RAN 1106 is shown to be communicatively coupled to the CN 1124. The CN 1124 may comprise one or more network elements 1126, which are configured to offer various data and telecommunications services to customers/subscribers (e.g., users of UE 1102 and UE 1104) who are connected to the CN 1124 via the RAN 1106. The components of the CN 1124 may be implemented in one physical device or separate physical devices including components to read and execute instructions from a machine-readable or computer-readable medium (e.g., a non-transitory machine-readable storage medium).

[0120] In embodiments, the CN 1124 may be an EPC, and the RAN 1106 may be connected with the CN 1124 via an S1 interface 1128. In embodiments, the S1 interface 1128 may be split into two parts, an S1 user plane (S1-U) interface, which carries traffic data between the base station 1112 or base station 1114 and a serving gateway (S-GW), and the S1-MME interface, which is a signaling interface between the base station 1112 or base station 1114 and mobility management entities (MMEs).

[0121] In embodiments, the CN 1124 may be a 5GC, and the RAN 1106 may be connected with the CN 1124 via an NG interface 1128. In embodiments, the NG interface 1128 may be split into two parts, an NG user plane (NG-U) interface, which carries traffic data between the base station 1112 or base station 1114 and a user plane function (UPF), and the S1 control plane (NG-C) interface, which is a signaling interface between the base station 1112 or base station 1114 and access and mobility management functions (AMFs).

[0122] Generally, an application server 1130 may be an element offering applications that use internet protocol (IP) bearer resources with the CN 1124 (e.g., packet switched data services). The application server 1130 can also be configured to support one or more communication services

(e.g., VoIP sessions, group communication sessions, etc.) for the UE 1102 and UE 1104 via the CN 1124. The application server 1130 may communicate with the CN 1124 through an IP communications interface 1132.

[0123] FIG. 12 illustrates an example system 1200 for performing signaling 1238 between a wireless device 1202 and a network device 1220, according to embodiments described herein. The system 1200 may be a portion of a wireless communication system as herein described. The wireless device 1202 may be, for example, a UE of a wireless communication system. The network device 1220 may be, for example, a base station (e.g., an eNB or a gNB) or a radio head of a wireless communication system.

[0124] The wireless device 1202 may include one or more processor(s) 1204. The processor(s) 1204 may execute instructions such that various operations of the wireless device 1202 are performed, as described herein. The processor(s) 1204 may include one or more baseband processors implemented using, for example, a central processing unit (CPU), a digital signal processor (DSP), an application specific integrated circuit (ASIC), a controller, a field programmable gate array (FPGA) device, another hardware device, a firmware device, or any combination thereof configured to perform the operations described herein.

[0125] The wireless device 1202 may include a memory 1206. The memory 1206 may be a non-transitory computer-readable storage medium that stores instructions 1208 (which may include, for example, the instructions being executed by the processor(s) 1204). The instructions 1208 may also be referred to as program code or a computer program. The memory 1206 may also store data used by, and results computed by, the processor(s) 1204.

[0126] The wireless device 1202 may include one or more transceiver(s) 1210 (also collectively referred to as a transceiver 1210) that may include radio frequency (RF) transmitter and/or receiver circuitry that use the antenna(s) 1212 of the wireless device 1202 to facilitate signaling (e.g., the signaling 1238) to and/or from the wireless device 1202 with other devices (e.g., the network device 1220) according to corresponding RATs.

[0127] The wireless device 1202 may include one or more antenna(s) 1212 (e.g., one, two, four, eight, or more). For embodiments with multiple antenna(s) 1212, the wireless device 1202 may leverage the spatial diversity of such multiple antenna(s) 1212 to send and/or receive multiple different data streams on the same time and frequency resources. This behavior may be referred to

as, for example, MIMO behavior (referring to the multiple antennas used at each of a transmitting device and a receiving device that enable this aspect). MIMO transmissions by the wireless device 1202 may be accomplished according to precoding (or digital beamforming) that is applied at the wireless device 1202 that multiplexes the data streams across the antenna(s) 1212 according to known or assumed channel characteristics such that each data stream is received with an appropriate signal strength relative to other streams and at a desired location in the spatial domain (e.g., the location of a receiver associated with that data stream). Some embodiments may use single user MIMO (SU-MIMO) methods (where the data streams are all directed to a single receiver) and/or multi-user MIMO (MU-MIMO) methods (where individual data streams may be directed to individual (different) receivers in different locations in the spatial domain).

[0128] In some embodiments having multiple antennas, the wireless device 1202 may implement analog beamforming techniques, whereby phases of the signals sent by the antenna(s) 1212 are relatively adjusted such that the (joint) transmission of the antenna(s) 1212 can be directed (this is sometimes referred to as beam steering).

[0129] The wireless device 1202 may include one or more interface(s) 1216. The interface(s) 1216 may be used to provide input to or output from the wireless device 1202. For example, a wireless device 1202 that is a UE may include interface(s) 1216 such as microphones, speakers, a touchscreen, buttons, and the like in order to allow for input and/or output to the UE by a user of the UE. Other interfaces of such a UE may be made up of transmitters, receivers, and other circuitry (e.g., other than the transceiver(s) 1210/antenna(s) 1212 already described) that allow for communication between the UE and other devices and may operate according to known protocols (e.g., Wi-Fi®, Bluetooth®, and the like).

[0130] The wireless device 1202 may include radio resource manager 1218. The radio resource manager 1218 may be implemented via hardware, software, or combinations thereof. For example, the radio resource manager 1218 may be implemented as a processor, circuit, and/or instructions 1208 stored in the memory 1206 and executed by the processor(s) 1204. In some examples, the radio resource manager 1218 may be integrated within the processor(s) 1204 and/or the transceiver(s) 1210. For example, the radio resource manager 1218 may be implemented by a combination of software components (e.g., executed by a DSP or a general processor) and

hardware components (e.g., logic gates and circuitry) within the processor(s) 1204 or the transceiver(s) 1210.

[0131] The radio resource manager 1218 may be used for various aspects of the present disclosure, for example, aspects of FIGs. 1-12, from a wireless device or UE perspective. The radio resource manager 1218 may be configured to, for example, receive, via the transceiver(s) 1210, an indication of a plurality of component carriers for the UE to measure for radio resource management, each component carrier of the plurality of component carriers configured to carry, on a first set of beams for the component carrier, a set of reference signals for the UE to measure, the set of reference signals associated with one or more network devices; receive, via the transceiver(s) 1210, an indication of a set of component carrier measurement groups for the plurality of component carriers; measure, for each component carrier measurement group of the set of component carrier measurement groups, the set of reference signals received using a second set of beams on one component carrier of the component carrier measurement group, the second set of beams having a relationship with the first set of beams; determine, for each component carrier measurement group, beam predictions for one or more beams of the second set of beams based at least in part on the measurement of the set of reference signals; and transmit, to a network device via the transceiver(s) 1210, a report comprising the beam predictions for the plurality of component carriers.

[0132] The network device 1220 may include one or more processor(s) 1222. The processor(s) 1222 may execute instructions such that various operations of the network device 1220 are performed, as described herein. The processor(s) 1222 may include one or more baseband processors implemented using, for example, a CPU, a DSP, an ASIC, a controller, an FPGA device, another hardware device, a firmware device, or any combination thereof configured to perform the operations described herein.

[0133] The network device 1220 may include a memory 1224. The memory 1224 may be a non-transitory computer-readable storage medium that stores instructions 1226 (which may include, for example, the instructions being executed by the processor(s) 1222). The instructions 1226 may also be referred to as program code or a computer program. The memory 1224 may also store data used by, and results computed by, the processor(s) 1222.

[0134] The network device 1220 may include one or more transceiver(s) 1228 (also collectively referred to as a transceiver 1228) that may include RF transmitter and/or receiver circuitry that use the antenna(s) 1230 of the network device 1220 to facilitate signaling (e.g., the signaling 1238) to and/or from the network device 1220 with other devices (e.g., the wireless device 1202) according to corresponding RATs.

[0135] The network device 1220 may include one or more antenna(s) 1230 (e.g., one, two, four, or more). In embodiments having multiple antenna(s) 1230, the network device 1220 may perform MIMO, digital beamforming, analog beamforming, beam steering, etc., as has been described.

[0136] The network device 1220 may include one or more interface(s) 1232. The interface(s) 1232 may be used to provide input to or output from the network device 1220. For example, a network device 1220 of a RAN (e.g., a base station, a radio head, etc.) may include interface(s) 1232 made up of transmitters, receivers, and other circuitry (e.g., other than the transceiver(s) 1228/antenna(s) 1230 already described) that enables the network device 1220 to communicate with other equipment in a network, and/or that enables the network device 1220 to communicate with external networks, computers, databases, and the like for purposes of operations, administration, and maintenance of the network device 1220 or other equipment operably connected thereto.

[0137] The network device 1220 may include at least one radio resource manager 1234. The radio resource manager 1234 may be implemented via hardware, software, or combinations thereof. For example, the radio resource manager 1234 may be implemented as a processor, circuit, and/or instructions 1226 stored in the memory 1224 and executed by the processor(s) 1222. In some examples, the radio resource manager 1234 may be integrated within the processor(s) 1222 and/or the transceiver(s) 1228. For example, the radio resource manager 1234 may be implemented by a combination of software components (e.g., executed by a DSP or a general processor) and hardware components (e.g., logic gates and circuitry) within the processor(s) 1222 or the transceiver(s) 1228.

[0138] The radio resource manager 1234 may be used for various aspects of the present disclosure, for example, aspects of FIGs. 1-12, from a network device perspective. The radio resource manager 1234 may be configured to, for example, transmit, to a user equipment (UE) via the transceiver(s) 1228, an indication of a plurality of component carriers for the UE to measure

for radio resource management, each component carrier of the plurality of component carriers configured to carry, on a first set of beams for the component carrier, a set of reference signals for the UE to measure, the set of reference signals associated with one or more network devices; receive, from the UE via the transceiver(s) 1228, control signaling indicating a UE capability to perform a beam prediction using component carrier measurement groups; transmit, to the UE via the transceiver(s) 1228 and at least in part in response to the UE capability, an indication of a set of component carrier measurement groups for the plurality of component carriers, each component measurement group of the set of component carrier measurement groups corresponding to a BEP model; and receive, from the UE via the transceiver(s) 1228, a report comprising the beam prediction for the plurality of component carriers.

[0139] For one or more embodiments, at least one of the components set forth in one or more of the preceding figures may be configured to perform one or more operations, techniques, processes, and/or methods as set forth herein. For example, a baseband processor (or processor) as described herein in connection with one or more of the preceding figures may be configured to operate in accordance with one or more of the examples set forth herein. For another example, circuitry associated with a UE, network device, network element, etc. as described above in connection with one or more of the preceding figures may be configured to operate in accordance with one or more of the examples set forth herein.

[0140] Any of the above described embodiments may be combined with any other embodiment (or combination of embodiments), unless explicitly stated otherwise. The foregoing description of one or more implementations provides illustration and description but is not intended to be exhaustive or to limit the scope of embodiments to the precise form described. Modifications and variations are possible in light of the above teachings or may be acquired from practice of various embodiments.

[0141] Embodiments and implementations of the systems and methods described herein may include various operations, which may be embodied in machine-executable instructions to be executed by a computer system. A computer system may include one or more general-purpose or special-purpose computers (or other electronic devices). The computer system may include hardware components that include specific logic for performing the operations or may include a combination of hardware, software, and/or firmware.

[0142] The systems described herein pertain to specific embodiments but are provided as examples. These embodiments can be combined into single systems, partially combined into other systems, split into multiple systems, or divided or combined in other ways. In addition, it is contemplated that parameters, attributes, aspects, etc. of one embodiment can be used in another embodiment. The parameters, attributes, aspects, etc. are merely described in one or more embodiments for clarity, and it is recognized that the parameters, attributes, aspects, etc. can be combined with or substituted for parameters, attributes, aspects, etc. of another embodiment unless specifically disclaimed herein.

[0143] Although the foregoing has been described in some detail for purposes of clarity, it will be apparent that changes and modifications may be made without departing from the principles thereof. It should be noted that there are many alternative ways of implementing both the processes and apparatuses described herein. Accordingly, the present embodiments are to be considered illustrative and not restrictive, and the description is not to be limited to the details given herein but may be modified within the scope and equivalents of the appended claims.

CLAIMS

1. A user equipment (UE), comprising:
a transceiver; and
a processor configured to cause the UE to,
 receive, via the transceiver, an indication of a plurality of component carriers for the UE to measure for radio resource management, each component carrier of the plurality of component carriers configured to carry, on a first set of beams for the component carrier, a set of reference signals for the UE to measure, the set of reference signals associated with one or more network devices;
 receive, via the transceiver, an indication of a set of component carrier measurement groups for the plurality of component carriers;
 measure the set of reference signals for each component carrier measurement group of the set of component carrier measurement groups, the set of reference signals received using a second set of beams and on one component carrier of the component carrier measurement group, the second set of beams having a relationship with the first set of beams;
 determine, for each component carrier measurement group, beam predictions for one or more beams of the second set of beams based at least in part on the measurement of the set of reference signals; and
 transmit, to a network device via the transceiver, a report comprising the beam predictions for the plurality of component carriers.
2. The UE of claim 1, wherein the indication of the set of component carrier measurement groups comprises an indication of a selection criteria for grouping component carriers into component carrier measurement groups, and the processor is further configured to cause the UE to:
 select, from the plurality of component carriers and according to the indication of the selection criteria, a set of component carriers for each component carrier measurement group of the set of component carrier measurement groups.

3. The UE of claim 2, wherein the selection criteria comprises a frequency separation threshold, and the processor is configured to cause the UE to select the set of component carriers by being configured to:

identify a frequency distance between component carriers of the plurality of component carriers; and

group the component carriers into the component carrier measurement groups based at least in part on the frequency distance for the component carriers satisfying the frequency separation threshold.

4. The UE of claim 1, wherein the processor is further configured to cause the UE to: receive, via the transceiver and for each component carrier of the plurality of component carriers, an indication of a component carrier measurement group for the component carrier.

5. The UE of claim 1, wherein the processor is further configured to cause the UE to: receive, via the transceiver and for each component carrier of the plurality of component carriers, an indication of the BEP model for the component carrier.

6. The UE of claim 1, wherein the set of component carrier measurement groups comprises: a first component carrier measurement group for component carriers of a first radio frequency spectrum band; and

a second component carrier measurement group for component carriers of a second radio frequency spectrum band.

7. The UE of claim 6, wherein the beam predictions for the one or more beams are determined using a beam estimation/prediction (BEP) model, wherein the BEP model for each component carrier measurement group comprises a first BEP model for the first component carrier measurement group, and a second BEP model for the second component carrier measurement group; and

the processor is further configured to cause the UE to determine the beam predictions using the first BEP model and the second BEP model.

8. The UE of claim 1, wherein the set of component carrier measurement groups comprises:

a first component carrier measurement group for component carriers that are served by a first network entity; and

a second component carrier measurement group for component carriers that are served by a second network entity.

9. The UE of claim 8, wherein the component carriers that are served by the first network entity are in a same radio frequency spectrum band as the component carriers that are served by the second network entity.

10. The UE of claim 1, wherein the set of component carrier measurement groups comprises at least:

a first component carrier measurement group for component carriers of a first radio frequency spectrum band; and

a second component carrier measurement group for component carriers of a second radio frequency spectrum band.

11. The UE of claim 1, wherein the processor is further configured to cause the UE to: transmit, via the transceiver, control signaling indicating a UE capability to perform the beam predictions using component carrier measurement groups, the indication of the set of component carrier measurement groups received at least in part in response to transmitted control signaling.

12. The UE of claim 1, wherein the set of reference signals comprise one or more of a set of synchronization signal blocks (SSB) or a set of channel state information reference signals (CSI-RS).

13. A network device, comprising:

a transceiver; and

a processor configured to cause the network device to,

transmit, to a user equipment (UE) via the transceiver, an indication of a plurality of component carriers for the UE to measure for radio resource management, each component carrier of the plurality of component carriers configured to carry, on a first set

of beams for the component carrier, a set of reference signals for the UE to measure, the set of reference signals associated with one or more network devices;

receive, from the UE via the transceiver, control signaling indicating a UE capability to perform a beam prediction using component carrier measurement groups;

transmit, to the UE via the transceiver and at least in part in response to the UE capability, an indication of a set of component carrier measurement groups for the plurality of component carriers; and

receive, from the UE via the transceiver, a report comprising the beam prediction for the plurality of component carriers.

14. The network device of claim 13, wherein the indication of the set of component carrier measurement groups comprises an indication of a selection criteria for grouping component carriers into the component carrier measurement groups.

15. The network device of claim 14, wherein the selection criteria comprises a frequency separation threshold for the UE to use to group component carriers of the plurality of component carriers into the component carrier measurement groups.

16. The network device of claim 13, wherein the processor is further configured to cause the network device to:

transmit, to the UE via the transceiver and for each component carrier of the plurality of component carriers, one or more of an indication of a component carrier measurement group for the component carrier or an indication of a beam estimation/prediction (BEP) model for the component carrier.

17. A method of wireless communication at a user equipment (UE), comprising:

receiving an indication of a plurality of component carriers for the UE to measure for radio resource management, each component carrier of the plurality of component carriers configured to carry, on a first set of beams for the component carrier, a set of reference signals for the UE to measure, the set of reference signals associated with one or more network devices;

receiving an indication of a set of component carrier measurement groups for the plurality of component carriers;

measuring the set of reference signals for each component carrier measurement group of the set of component carrier measurement groups, the set of reference signals received using a second set of beams on one component carrier of the component carrier measurement group, the second set of beams having a relationship with the first set of beams;

determining beam predictions for one or more beams of the second set of beams based at least in part on the measurement of the set of reference signals; and

transmitting, to a network device, a report comprising the beam predictions for the plurality of component carriers.

18. The method of wireless communication of claim 17, wherein the indication of the set of component carrier measurement groups comprises an indication of a selection criteria for grouping component carriers into component carrier measurement groups, the method of wireless communication further comprising:

selecting, from the plurality of component carriers and according to the indication of the selection criteria, a set of component carriers for each component carrier measurement group of the set of component carrier measurement groups.

19. The method of wireless communication of claim 18, wherein the selection criteria comprises a frequency separation threshold, and selecting the set of component carriers comprises:

identifying a frequency distance between component carriers of the plurality of component carriers; and

grouping the component carriers into the component carrier measurement groups based at least in part on the frequency distance for the component carriers satisfying the frequency separation threshold.

20. The method of wireless communication of claim 17, further comprising:

receiving, for each component carrier of the plurality of component carriers, one or more of an indication of a component carrier measurement group for the component carrier or an indication of a beam estimation/prediction (BEP) model for the component carrier.

ABSTRACT

A user equipment (UE) that includes a transceiver and a processor is described. In one example, the UE receives an indication of component carriers for the UE to measure for radio resource management (RRM), each component carrier carrying, on a first set of beams, a set of reference signals for the UE to measure. The set of reference signals are associated with one or more network devices. The UE also receives an indication of a set of component carrier measurement groups for the component carriers. The UE then measures, for each component carrier measurement group, reference signals received using a second set of beams on one component carrier of the group. The UE then determines, for each group, a beam prediction based on the reference signal measures, and transmits a report based on the beam prediction.