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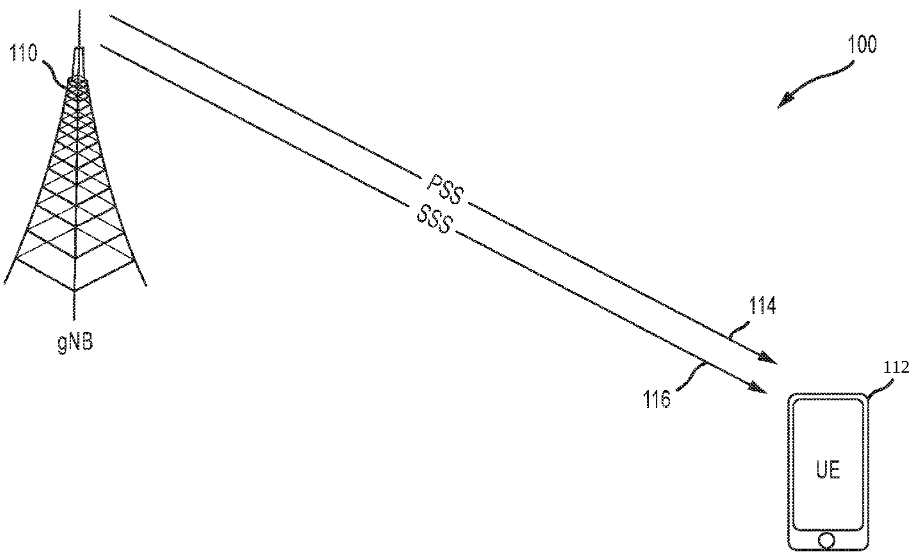


FIG. 1

(57) **Abstract:** Briefly, in accordance with one or more embodiments, an apparatus of an Fifth Generation NodeB (gNB), comprises one or more baseband processors to configure one or more synchronization signal bursts to be transmitted to a user equipment (UE), wherein the synchronization signal bursts comprise one or more synchronization signal blocks, and a memory to store configuration information for the synchronization signal bursts.

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# SYNCHRONIZATION SIGNAL TRANSMISSION FOR NEW RADIO STANDARD

## CROSS-REFERENCE TO RELATED APPLICATIONS

The present application claims the benefit of US Provisional Application No. 62/373,194 (P108081Z) filed August 10, 2016. Said Application No. 62/373,194 is hereby incorporated herein by reference in its entirety.

## BACKGROUND

Synchronization signal blocks are transmitted by a Fifth Generation (5G) New Radio (NR) standard NodeB (gNB), which more generally may be referred to as an access node, to one or more user equipment (UE) devices to allow the UE to synchronize with the gNB and to communicate on the network. By detecting the transmitted synchronization signal blocks, the UE acquires the physical cell identifier, time slot, frame synchronization, and/or frequency synchronization. In order to support New Radio (NR) standards, the synchronization signal blocks should accommodate multi-beam operation with beam sweeping on synchronization signal blocks, single beam transmission with multiple repetition for extended coverage, and/or reduced overhead transmission of synchronization signal blocks in the single beam transmission.

## DESCRIPTION OF THE DRAWING FIGURES

Claimed subject matter is particularly pointed out and distinctly claimed in the concluding portion of the specification. However, such subject matter may be understood by reference to the following detailed description when read with the accompanying drawings in which:

FIG. 1 is a diagram of transmission of synchronization signal blocks in accordance with one or more embodiments;

FIG. 2 is a diagram of a structure of synchronization signal blocks for a Long-Term Evolution (LTE) standard in accordance with one or more embodiments;

FIG. 3 is a diagram of another structure of synchronization signal blocks for a new radio standard in accordance with one or more embodiments;

FIG. 4 is a diagram of assignment of beamforming for synchronization signal blocks in multibeam mode in accordance with one or more embodiments;

FIG. 5 is a diagram of selection of synchronization signal blocks within a synchronization burst in accordance with one or more embodiments;

FIG. 6 is a diagram of an alternative assignment of beamforming for synchronization of signals in multibeam mode in accordance with one or more embodiments;

FIG. 7 is a diagram of assignment for a synchronization signal blocks in a single beam mode in accordance with one or more embodiments;

FIG. 8 is a diagram of a time-frequency domain structure of synchronization signal blocks in accordance with one or more embodiments;

FIG. 9 illustrates an architecture of a system of a network in accordance with some embodiments; and

FIG. 10 illustrates example components of a device in accordance with some embodiments.

It will be appreciated that for simplicity and/or clarity of illustration, elements illustrated in the figures have not necessarily been drawn to scale. For example, the dimensions of some of the elements may be exaggerated relative to other elements for clarity. Further, if considered appropriate, reference numerals have been repeated among the figures to indicate corresponding and/or analogous elements.

DETAILED DESCRIPTION

In the following detailed description, numerous specific details are set forth to provide a thorough understanding of claimed subject matter. It will, however, be understood by those skilled in the art that claimed subject matter may be practiced without these specific details. In other instances, well-known methods, procedures, components and/or circuits have not been described in detail.

Referring now to FIG. 1, a diagram of transmission of synchronization signal blocks in accordance with one or more embodiments will be discussed. As shown in FIG. 1, synchronization signal blocks may be transmitted by a Fifth Generation (5G) New Radio (NR) standard NodeB (gNB) 110, which generally may be referred to as an access node, to a user equipment (UE) 112 to assist UE 112 with entry onto network 100. Synchronization signal blocks are fundamental communications used by UE 112 during entry onto network 100 to get synchronized to gNB 110. The synchronization signal blocks also may be used by UE 112 to maintain synchronization with gNB 110. In accordance with a Third Generation Partnership Project (3GPP) Long Term Evolution (LTE) standard, two synchronization signal blocks are supported, a primary synchronization signal (PSS) 114, and a secondary synchronization signal (SSS) 116. By detecting the transmitted synchronization signal blocks PSS 114 and SSS 116, UE 112 acquires the physical cell id, time slot and frame synchronization, which is used for reading essential system information blocks from network 100.

During network entry, UE 112 tunes its radio to different frequency channels depending on the supported bands. Once UE 112 is currently tuned to a specific band and/or channel, UE

112 first finds the primary synchronization signal (PSS) 114 which in frequency division duplexing (FDD) systems is located in the last orthogonal frequency-division multiplexing (OFDM) symbol of the first time slot of the first subframe, subframe 0. Such an arrangement enables UE 112 to be synchronized on subframe level. The PSS 114 is repeated in subframe 5 which means UE 112 is synchronized on a 5 millisecond (ms) basis since each subframe is 1 ms in duration. From the PSS 114, UE 112 is also able to obtain part of physical cell identity. In a next step UE 112 finds the secondary synchronization signal (SSS) 116. It should be noted that SSS 116 symbols are also located in the same subframe as the PSS 114 but in the symbol before the PSS 114. From the SSS 116, UE 112 is able to obtain full physical layer cell identity. An example of the structure of synchronization signal blocks for an LTE standard is shown in and described with respect to FIG. 2, below.

Referring now to FIG. 2, a diagram of a structure of synchronization signal blocks for a Long-Term Evolution (LTE) standard in accordance with one or more embodiments will be discussed. As shown in FIG. 2, the PSS 114 and the SSS 116 are transmitted in downlink (DL) subframe 0 as shown at 210, and in DL subframe 5 as shown at 212. In these DL subframes, the synchronization bandwidth 216 may occupy a center portion of the system bandwidth 218. The structure of synchronization signal blocks for a new radio standard is shown in and described with respect to FIG. 3, below.

Referring now to FIG. 3, a diagram of another structure of synchronization signal blocks for a new radio standard in accordance with one or more embodiments will be discussed. In accordance with one or more embodiments, structure of synchronization signal blocks 300 for the new radio (NR) standard may be designed to support multi-beam operation with beam sweeping on synchronization signal blocks, to support single beam transmission with multiple repetition for extended coverage, and/or to support reduced overhead transmission of synchronization signal blocks in the single beam transmission.

In accordance with one or more embodiments, the time-domain structure of a NR synchronization signal may comprise periodical transmission of the Synchronization signal burst 310, where each Synchronization signal burst 310 may include one or multiple Synchronization signal blocks 312. The periodicity 314 and the duration 316 of Synchronization signal bursts set 318 and/or Synchronization signal burst 310 may be configured by higher signaling or predetermined as defined in the NR standard. In one or more embodiments, higher layers may include layers higher than the Physical layer, for example at the Media Access Control (MAC) layer, Radio Link Control (RLC) layer, Packet Data Convergence Protocol (PDCP) layer, Radio

Resource Control (RRC) layer, or Non-Access Stratum (NAS) layer, and so on, although the scope of the claimed subject matter is not limited in this respect.

In one or more embodiments, PSS 114, SSS 116, and/or physical broadcast channel (PBCH) may be transmitted within a synchronization signal (SS) block 312, and multiplexing of other signals is not precluded within an SS block 312 An SS burst 310 may comprise one or more SS blocks 312, wherein a number of SS blocks 312 may define a duration of an SS burst 310. An SS burst 318 set may comprise one or more SS bursts 310. It should be noted that the structure of synchronization in the NR standard may support various cases including support of multi-beam operation with beam sweeping on synchronization signals, support of single beam transmission with multiple repetition for extended coverage, and/or reduced overhead transmission of synchronization signals in the single beam transmission, although the scope of the claimed subject matter is not limited in these respects. As will be discussed in further detail, below, transmission may be omnidirectional, quasi-omnidirectional using the same beam with an SS burst 310, different beams between SS bursts 310, and a regular beam pattern between SS bursts sets 318, or directional with different (narrow or wide) beams between SS blocks 312 within an SS burst 310, different beams between SS bursts 310, and a regular beam pattern between SS bursts sets 318, although the scope of the claimed subject matter is not limited in these respects.

Referring now to FIG. 4, a diagram of assignment of beamforming for synchronization signal blocks in multibeam mode in accordance with one or more embodiments will be discussed. In order to support scenarios with multi-beam transmission, different transmit beamforming may be used by gNB 110 for transmission of the Synchronization signal blocks 312 in the Synchronization signal burst 310 within one Synchronization signal bursts set 318. The transmit beamforming pattern may be the same across Synchronization signal burst set 318.

FIG. 4 illustrates the beamforming assignment to different Synchronization signal blocks 312 within Synchronization signal bursts set 318 wherein the different beamforming patterns 410 are applied across the different Synchronization signal bursts 310 within the same Synchronization signal bursts set 318. Although another Synchronization signal bursts set 318 is not shown, it may be assumed that gNB 110 may applies the same beamforming patterns as in the current beam Synchronization signal bursts set 318.

Multiple Synchronization bursts 310 in the Synchronization signal bursts set 318 may be involved when the number of beams supported gNB 110 is relatively large. In one example, the Synchronization signal bursts set 318 may contain only one Synchronization signal burst 310. In such an example, the number of Synchronization signal blocks 312 in the Synchronization signal burst 310 may be a variable number to support gNB 110 with different beamforming configurations.

Referring now to FIG. 5, a diagram of selection of synchronization signal blocks within a synchronization burst in accordance with one or more embodiments will be discussed. In another embodiment, gNB 110 may transmit a subset of Synchronization signal blocks 312 within the Synchronization signal burst 310. In such an embodiment, the selected Synchronization signal pattern may be maintained either across multiple Synchronization signal blocks bursts 310 or one or more Synchronization signal bursts set 318. In one particular embodiment, only one Synchronization signal 312 may be used within the synchronization burst 310 as shown in FIG. 5. The synchronization signal pattern may vary for different gNBs 110 to facilitate interference mitigation in time domain for Synchronization signal blocks 312 or for overhead reduction. The overhead reduction also may be facilitated by indicating in broadcast control message the actual number of the transmitted synchronization signal and the pattern thereof, which may be signaled using a bitmap, although the scope of the claimed subject matter is not limited in this respect.

In another embodiment, referring again to FIG. 3, gNB 110 may autonomously turn on or off synchronization signal transmission for overhead control or interference management. In other words, for various reasons, such an on/off mechanism for synchronization signal transmission, for example for PSS 114, SSS 116, or an entire Synchronization signal block 312, may be considered in order for gNB 110 to effectively control overhead, interference control, and so on. In such an arrangement, UE 112 may assume that a Synchronization signal 312 may not be present so that the signal existence detection may be performed by UE 112. The signal existence may be realized at UE 112 by threshold detection or other means, for example if there is a Secondary Synchronization Channel (S-SCH) based on forward error correction (FEC) with cyclic redundancy check (CRC), the detection may be performed by blind decoding and checking CRC of the S-SCH. On the other hand, given the detection of PSS 114 would relatively complex for UE 112 to perform, a fixed transmission for PSS 114 may be considered while SSS 116 or other channels may be transmitted in an opportunistic manner. A synchronization signal burst 310 comprises multiple time/frequency instances across the repetitions within the given Synchronization signal burst 310. In conjunction with on/off operation of synchronization signal 312, the gNB 110 autonomous on/off operation may be performed at the OFDM symbol level within a synchronization signal burst 310 or at the synchronization signal burst 310 level within a synchronization signal bursts set 318, or at the synchronization signal bursts set level 318.

In a case where PSS 114 is always transmitted without on/off operation, the predetermined locations may be assumed for UE 112 to safely accumulate multiple instances. In particular for PSS 114, a common PSS 114 sequence may be defined from all gNBs and/or Cell, or a subset or a group of gNBs and/or Cells, which also may offer single frequency network (SFN) gain. For SSS 116, the detection of opportunistic transmission may be realized at UE 112 by search space based detection wherein the search space may be predetermined, and gNB 112 may autonomously select one space to send SSS 116. Another approach to enable such opportunistic transmission may be based on forward error correction (FEC) with cyclic redundancy check (CRC) as discussed above so that UE 112 does not necessarily implement threshold detection to recognize the signal existence.

Referring now to FIG. 6, a diagram of an alternative assignment of beamforming for synchronization of signals in multibeam mode in accordance with one or more embodiments will be discussed. The assignment shown in FIG. 6 may be utilized for example when wider beams that used for the embodiment of FIG. 4 are applied, and the same beam is used to transmit synchronization signal blocks with a synchronization signal burst. In the embodiment shown in FIG. 4, gNB 110 may transmit all Synchronization signal blocks 312 within the burst using the same beamforming to facilitate coherent processing of the Synchronization signal burst 310. In the present embodiment, the beamforming patterns such as beamforming pattern 610, beamforming pattern 612, and beamforming pattern 614, may be different across the Synchronization signal bursts 310 within the Synchronization signal bursts set 318. The assignment of the beamforming patterns may be the same across the Synchronization signal bursts set 318, for example to facilitate non-coherent combining of the beams at the UE 112.

Referring now to FIG. 7, a diagram of assignment for a synchronization signal blocks in a single beam mode in accordance with one or more embodiments will be discussed. The embodiment of FIG. 7 may be utilized for example when the same beam is used to transmit synchronization signal blocks within all synchronization signal bursts. FIG. 7 shows an alternative to the assignment of beamforming patterns of FIG. 6, above, wherein the structure 300 of FIG. 7 omits the Synchronization signal bursts set 318 comprising multiple synchronization signal bursts 310 as shown in FIG. 6. Instead, in FIG. 7 a Synchronization signal bursts set 318 comprises a single burst 310. In the example embodiment shown in FIG. 7, the assignment of the beamforming patterns 710 may be the same across multiple synchronization signal bursts 310.

For a code-domain structure, the synchronization signal blocks within the burst may be the same and modulated using cover code. For example, the synchronization signal may correspond to a Zadoff-Chu sequence of length equal to an OFDM symbol length, and a cover code may be another Zadoff-Chu sequence having a length equal to the number of synchronization signal blocks 310 within the synchronization signal burst 310. An example equation that may be used to generate such a Zadoff-Chu sequence is provided below:

$$x(m) = e^{-j\pi \frac{q \cdot m \cdot (m+1)}{N}}$$

where q (root of the sequence) and N are parameters. Each element of cover code should multiply the corresponding synchronization signal to enhance the cross-correlation properties of the transmitted signal.

In another embodiment, it is known that a Zadoff-Chu sequence generated from a prime number exhibits good cross-correlation properties. Thus, the covered Zadoff-Chu sequence over the OFDM symbol level may be generated by a prime number, for example in a first case from the smallest number greater than the number of OFDM symbols to be covered, or in a second case from the largest number smaller than the number of OFDM symbols to be covered. For the first case, one or more sequence elements may be discarded to fit into the OFDM symbols, for example the last element parts may be truncated, wherein if the number of OFDM symbols to be covered is twelve, the last one element may be truncated from length-13 Zadoff-Chu sequence. For the second case, one or more sequence elements may be added to fit into the OFDM symbols, for example the first part of the elements can be copied to the end part of the sequence, wherein if the number of OFDM symbols to be covered is twelve, the last one element may be copied from the first element of length-11 Zadoff-Chu sequence.

Referring now to FIG. 8, a diagram of a time-frequency domain structure of synchronization signal blocks in accordance with one or more embodiments will be discussed. In the frequency domain, in one example 812, the synchronization signal may comprise the PSS 114 and the SSS 116 transmitted in the same OFDM symbol on the frequency adjacent subcarriers. In another other example 810, the synchronization signal may comprise the PSS 114 and the SSS 116 transmitted in two OFDM symbols on the same subcarriers. In the either example, the frequency resources occupied by PSS 114 and SSS 116 may be different. For example, the frequency resource occupied by the SSS 116 may be larger than the frequency resource for the PSS 114, although the scope of the claimed subject matter is not limited in this respect.

Referring now to FIG. 9, and illustration of an architecture of a system 900 of a network in accordance with some embodiments will be discussed. The system 900 is shown to include a user equipment (UE) 901 and a UE 902. The UEs 901 and 902 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, such as Personal Data Assistants (PDAs), pagers, laptop computers, desktop computers, wireless handsets, or any computing device including a wireless communications interface.

In some embodiments, any of the UEs 901 and 902 can comprise an Internet of Things (IoT) UE, which can comprise a network access layer designed for low-power IoT applications utilizing short-lived UE connections. An IoT UE can utilize technologies such as machine-to-machine (M2M) or machine-type communications (MTC) for exchanging data with an MTC server or device via a public land mobile network (PLMN), Proximity-Based Service (ProSe) or device-to-device (D2D) communication, sensor networks, or IoT networks. The M2M or MTC exchange of data may be a machine-initiated exchange of data. An IoT network describes interconnecting IoT UEs, which may include uniquely identifiable embedded computing devices (within the Internet infrastructure), with short-lived connections. The IoT UEs may execute background applications (e.g., keep-alive messages, status updates, etc.) to facilitate the connections of the IoT network.

The UEs 901 and 902 may be configured to connect, e.g., communicatively couple, with a radio access network (RAN) 910 — the RAN 910 may be, for example, an Evolved Universal Mobile Telecommunications System (UMTS) Terrestrial Radio Access Network (E-UTRAN), a NextGen RAN (NG RAN), or some other type of RAN. The UEs 901 and 902 utilize connections 903 and 904, respectively, each of which comprises a physical communications interface or layer (discussed in further detail below); in this example, the connections 903 and 904 are illustrated as an air interface to enable communicative coupling, and can be consistent with cellular communications protocols, such as a Global System for Mobile Communications (GSM) protocol, a code-division multiple access (CDMA) network protocol, a Push-to-Talk (PTT) protocol, a PTT over Cellular (POC) protocol, a Universal Mobile Telecommunications System (UMTS) protocol, a 3GPP Long Term Evolution (LTE) protocol, a fifth generation (5G) protocol, a New Radio (NR) protocol, and the like.

In this embodiment, the UEs 901 and 902 may further directly exchange communication data via a ProSe interface 905. The ProSe interface 905 may alternatively be referred to as a sidelink interface comprising one or more logical channels, including but not limited to a Physical Sidelink Control Channel (PSCCH), a Physical Sidelink Shared Channel (PSSCH), a

Physical Sidelink Discovery Channel (PSDCH), and a Physical Sidelink Broadcast Channel (PSBCH).

The UE 902 is shown to be configured to access an access point (AP) 906 via connection 907. The connection 907 can comprise a local wireless connection, such as a connection consistent with any IEEE 802.11 protocol, wherein the AP 906 would comprise a wireless fidelity (WiFi®) router. In this example, the AP 906 is shown to be connected to the Internet without connecting to the core network of the wireless system (described in further detail below).

The RAN 910 can include one or more access nodes that enable the connections 903 and 904. These access nodes (ANs) can be referred to as base stations (BSs), NodeBs, evolved NodeBs (eNBs), Fifth Generation NodeBs (gNB), RAN nodes, and so forth, and can comprise ground stations (e.g., terrestrial access points) or satellite stations providing coverage within a geographic area (e.g., a cell). The RAN 910 may include one or more RAN nodes for providing macrocells, e.g., macro RAN node 911, and one or more RAN nodes for providing femtocells or picocells (e.g., cells having smaller coverage areas, smaller user capacity, or higher bandwidth compared to macrocells), e.g., low power (LP) RAN node 912.

Any of the RAN nodes 911 and 912 can terminate the air interface protocol and can be the first point of contact for the UEs 901 and 902. In some embodiments, any of the RAN nodes 911 and 912 can fulfill various logical functions for the RAN 910 including, but not limited to, radio network controller (RNC) functions such as radio bearer management, uplink and downlink dynamic radio resource management and data packet scheduling, and mobility management.

In accordance with some embodiments, the UEs 901 and 902 can be configured to communicate using Orthogonal Frequency-Division Multiplexing (OFDM) communication signals with each other or with any of the RAN nodes 911 and 912 over a multicarrier communication channel in accordance 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.

In some embodiments, a downlink resource grid can be used for downlink transmissions from any of the RAN nodes 911 and 912 to the UEs 901 and 902, while uplink transmissions can utilize similar techniques. The grid can be a time-frequency grid, called a resource grid or time-frequency resource grid, which is the physical resource in the downlink in each slot. Such a time-frequency plane representation is a common practice for OFDM systems, which makes it intuitive for radio resource allocation. Each column and each row of the resource grid corresponds to one OFDM symbol and one OFDM subcarrier, respectively. The duration of the resource grid in the time domain corresponds to one slot in a radio frame. The smallest time-frequency unit in a resource grid is denoted as a resource element. Each resource grid comprises a number of resource blocks, which describe the mapping of certain physical channels to resource elements. Each resource block comprises a collection of resource elements; in the frequency domain, this may represent the smallest quantity of resources that currently can be allocated. There are several different physical downlink channels that are conveyed using such resource blocks.

The physical downlink shared channel (PDSCH) may carry user data and higher-layer signaling to the UEs 901 and 902. The physical downlink control channel (PDCCH) may carry information about the transport format and resource allocations related to the PDSCH channel, among other things. It may also inform the UEs 901 and 902 about the transport format, resource allocation, and H-ARQ (Hybrid Automatic Repeat Request) information related to the uplink shared channel. Typically, downlink scheduling (assigning control and shared channel resource blocks to the UE 102 within a cell) may be performed at any of the RAN nodes 911 and 912 based on channel quality information fed back from any of the UEs 901 and 902. The downlink resource assignment information may be sent on the PDCCH used for (e.g., assigned to) each of the UEs 901 and 902.

The PDCCH may use control channel elements (CCEs) to convey the control information. Before being mapped to resource elements, the PDCCH complex-valued symbols may first be organized into quadruplets, which may then be permuted using a sub-block interleaver for rate matching. Each PDCCH may be transmitted using one or more of these CCEs, where each CCE may correspond to nine sets of four physical resource elements known as resource element groups (REGs). Four Quadrature Phase Shift Keying (QPSK) symbols may be mapped to each REG. The PDCCH can be transmitted using one or more CCEs, depending on the size of the downlink control information (DCI) and the channel condition. There can be four or more different PDCCH formats defined in LTE with different numbers of CCEs (e.g., aggregation level, L=l, 2, 4, or 8).

Some embodiments may use concepts for resource allocation for control channel information that are an extension of the above-described concepts. For example, some embodiments may utilize an enhanced physical downlink control channel (EPDCCH) that uses PDSCH resources for control information transmission. The EPDCCH may be transmitted using one or more enhanced the control channel elements (ECCEs). Similar to above, each ECCE may correspond to nine sets of four physical resource elements known as an enhanced resource element groups (EREGs). An ECCE may have other numbers of EREGs in some situations.

The RAN 910 is shown to be communicatively coupled to a core network (CN) 920 — via an SI interface 913. In embodiments, the CN 920 may be an evolved packet core (EPC) network, a NextGen Packet Core (NPC) network, or some other type of CN. In this embodiment the SI interface 913 is split into two parts: the Sl-U interface 914, which carries traffic data between the RAN nodes 911 and 912 and the serving gateway (S-GW) 922, and the Sl-mobility management entity (MME) interface 915, which is a signaling interface between the RAN nodes 911 and 912 and MMEs 921.

In this embodiment, the CN 920 comprises the MMEs 921, the S-GW 922, the Packet Data Network (PDN) Gateway (P-GW) 923, and a home subscriber server (HSS) 924. The MMEs 921 may be similar in function to the control plane of legacy Serving General Packet Radio Service (GPRS) Support Nodes (SGSN). The MMEs 921 may manage mobility aspects in access such as gateway selection and tracking area list management. The HSS 924 may comprise a database for network users, including subscription-related information to support the network entities' handling of communication sessions. The CN 920 may comprise one or several HSSs 924, depending on the number of mobile subscribers, on the capacity of the equipment, on the organization of the network, etc. For example, the HSS 924 can provide support for routing/roaming, authentication, authorization, naming/addressing resolution, location dependencies, etc.

The S-GW 922 may terminate the SI interface 913 towards the RAN 910, and routes data packets between the RAN 910 and the CN 920. In addition, the S-GW 922 may be a local mobility anchor point for inter-RAN node handovers and also may provide an anchor for inter-3GPP mobility. Other responsibilities may include lawful intercept, charging, and some policy enforcement.

The P-GW 923 may terminate an SGi interface toward a PDN. The P-GW 923 may route data packets between the EPC network 923 and external networks such as a network including the application server 930 (alternatively referred to as application function (AF)) via an Internet Protocol (IP) interface 925. Generally, the application server 930 may be an element offering applications that use IP bearer resources with the core network (e.g., UMTS Packet Services (PS) domain, LTE PS data services, etc.). In this embodiment, the P-GW 923 is shown to be communicatively coupled to an application server 930 via an IP communications interface 925. The application server 930 can also be configured to support one or more communication services (e.g., Voice-over-Internet Protocol (VoIP) sessions, PTT sessions, group communication sessions, social networking services, etc.) for the UEs 901 and 902 via the CN 920.

The P-GW 923 may further be a node for policy enforcement and charging data collection. Policy and Charging Enforcement Function (PCRF) 926 is the policy and charging control element of the CN 920. In a non-roaming scenario, there may be a single PCRF in the Home Public Land Mobile Network (HPLMN) associated with a UE's Internet Protocol Connectivity Access Network (IP-CAN) session. In a roaming scenario with local breakout of traffic, there may be two PCRFs associated with a UE's IP-CAN session: a Home PCRF (H-PCRF) within a HPLMN and a Visited PCRF (V-PCRF) within a Visited Public Land Mobile Network (VPLMN). The PCRF 926 may be communicatively coupled to the application server 930 via the P-GW 923. The application server 930 may signal the PCRF 926 to indicate a new service flow and select the appropriate Quality of Service (QoS) and charging parameters. The PCRF 926 may provision this rule into a Policy and Charging Enforcement Function (PCEF) (not shown) with the appropriate traffic flow template (TFT) and QoS class of identifier (QCI), which commences the QoS and charging as specified by the application server 930.

Referring now to FIG. 10, an illustration of example components of a device 1000 in accordance with some embodiments will be discussed. In some embodiments, the device 1000 may include application circuitry 1002, baseband circuitry 1004, Radio Frequency (RF) circuitry 1006, front-end module (FEM) circuitry 1008, one or more antennas 1010, and power management circuitry (PMC) 1012 coupled together at least as shown. The components of the illustrated device 1000 may be included in a UE or a RAN node. In some embodiments, the device 1000 may include less elements (e.g., a RAN node may not utilize application circuitry 1002, and instead include a processor/controller to process IP data received from an EPC). In some embodiments, the device 1000 may include additional elements such as, for example, memory/storage, display, camera, sensor, or input/output (I/O) interface. In other embodiments, the components described below may be included in more than one device (e.g., said circuitries may be separately included in more than one device for Cloud-RAN (C-RAN) implementations).

The application circuitry 1002 may include one or more application processors. For example, the application circuitry 1002 may include circuitry such as, but not limited to, one or more single-core or multi-core processors. The processor(s) may include any combination of general-purpose processors and dedicated processors (e.g., graphics processors, application processors, etc.). The processors may be coupled with or may include memory/storage and may be configured to execute instructions stored in the memory/storage to enable various applications or operating systems to run on the device 1000. In some embodiments, processors of application circuitry 1002 may process IP data packets received from an EPC.

The baseband circuitry 1004 may include circuitry such as, but not limited to, one or more single-core or multi-core processors. The baseband circuitry 1004 may include one or more baseband processors or control logic to process baseband signals received from a receive signal path of the RF circuitry 1006 and to generate baseband signals for a transmit signal path of the RF circuitry 1006. Baseband processing circuity 1004 may interface with the application circuitry 1002 for generation and processing of the baseband signals and for controlling operations of the RF circuitry 1006. For example, in some embodiments, the baseband circuitry 1004 may include a third generation (3G) baseband processor 1004A, a fourth generation (4G) baseband processor 1004B, a fifth generation (5G) baseband processor 1004C, or other baseband processor(s) 1004D for other existing generations, generations in development or to be developed in the future (e.g., second generation (2G), silOh generation (6G), etc.). The baseband circuitry 1004 (e.g., one or more of baseband processors 1004A-D) may handle various radio control functions that enable communication with one or more radio networks via the RF circuitry 1006. In other embodiments, some or all of the functionality of baseband processors 1004A-D may be included in modules stored in the memory 1004G and executed via a Central Processing Unit (CPU) 1004E. The radio control functions may include, but are not limited to, signal modulation/demodulation, encoding/decoding, radio frequency shifting, etc. In some embodiments, modulation/demodulation circuitry of the baseband circuitry 1004 may include Fast-Fourier Transform (FFT), precoding, or constellation mapping/demapping functionality. In some embodiments, encoding/decoding circuitry of the baseband circuitry 1004 may include convolution, tail-biting convolution, turbo, Viterbi, or Low Density Parity Check (LDPC) encoder/decoder functionality. Embodiments of modulation/demodulation and encoder/decoder functionality are not limited to these examples and may include other suitable functionality in other embodiments.

In some embodiments, the baseband circuitry 1004 may include one or more audio digital signal processor(s) (DSP) 1004F. The audio DSP(s) 1004F may be include elements for compression/decompression and echo cancellation and may include other suitable processing elements in other embodiments. Components of the baseband circuitry may be suitably combined in a single chip, a single chipset, or disposed on a same circuit board in some embodiments. In some embodiments, some or all of the constituent components of the baseband circuitry 1004 and the application circuitry 1002 may be implemented together such as, for example, on a system on a chip (SOC).

In some embodiments, the baseband circuitry 1004 may provide for communication compatible with one or more radio technologies. For example, in some embodiments, the baseband circuitry 1004 may support communication with an evolved universal terrestrial radio access network (EUTRAN) or other wireless metropolitan area networks (WMAN), a wireless local area network (WLAN), a wireless personal area network (WPAN). Embodiments in which the baseband circuitry 1004 is configured to support radio communications of more than one wireless protocol may be referred to as multi-mode baseband circuitry.

RF circuitry 1006 may enable communication with wireless networks using modulated electromagnetic radiation through a non-solid medium. In various embodiments, the RF circuitry 1006 may include switches, filters, amplifiers, etc. to facilitate the communication with the wireless network. RF circuitry 1006 may include a receive signal path which may include circuitry to down-convert RF signals received from the FEM circuitry 1008 and provide baseband signals to the baseband circuitry 1004. RF circuitry 1006 may also include a transmit signal path which may include circuitry to up-convert baseband signals provided by the baseband circuitry 1004 and provide RF output signals to the FEM circuitry 1008 for transmission.

In some embodiments, the receive signal path of the RF circuitry 1006 may include mixer circuitry 1006a, amplifier circuitry 1006b and filter circuitry 1006c. In some embodiments, the transmit signal path of the RF circuitry 1006 may include filter circuitry 1006c and mixer circuitry 1006a. RF circuitry 1006 may also include synthesizer circuitry 1006d for synthesizing a frequency for use by the mixer circuitry 1006a of the receive signal path and the transmit signal path. In some embodiments, the mixer circuitry 1006a of the receive signal path may be configured to down-convert RF signals received from the FEM circuitry 1008 based on the synthesized frequency provided by synthesizer circuitry 1006d. The amplifier circuitry 1006b may be configured to amplify the down-converted signals and the filter circuitry 1006c may be a low-pass filter (LPF) or band-pass filter (BPF) configured to remove unwanted signals from the down-converted signals to generate output baseband signals. Output baseband signals may be provided to the baseband circuitry 1004 for further processing. In some embodiments, the output baseband signals may be zero-frequency baseband signals, although this is not a requirement. In some embodiments, mixer circuitry 1006a of the receive signal path may comprise passive mixers, although the scope of the embodiments is not limited in this respect.

In some embodiments, the mixer circuitry 1006a of the transmit signal path may be configured to up-convert input baseband signals based on the synthesized frequency provided by the synthesizer circuitry 1006d to generate RF output signals for the FEM circuitry 1008. The baseband signals may be provided by the baseband circuitry 1004 and may be filtered by filter circuitry 1006c.

In some embodiments, the mixer circuitry 1006a of the receive signal path and the mixer circuitry 1006a of the transmit signal path may include two or more mixers and may be arranged for quadrature downconversion and upconversion, respectively. In some embodiments, the mixer circuitry 1006a of the receive signal path and the mixer circuitry 1006a of the transmit signal path may include two or more mixers and may be arranged for image rejection (e.g., Hartley image rejection). In some embodiments, the mixer circuitry 1006a of the receive signal path and the mixer circuitry 1006a may be arranged for direct downconversion and direct upconversion, respectively. In some embodiments, the mixer circuitry 1006a of the receive signal path and the mixer circuitry 1006a of the transmit signal path may be configured for super-heterodyne operation.

In some embodiments, the output baseband signals and the input baseband signals may be analog baseband signals, although the scope of the embodiments is not limited in this respect. In some alternate embodiments, the output baseband signals and the input baseband signals may be digital baseband signals. In these alternate embodiments, the RF circuitry 1006 may include analog-to-digital converter (ADC) and digital-to-analog converter (DAC) circuitry and the baseband circuitry 1004 may include a digital baseband interface to communicate with the RF circuitry 1006.

In some dual-mode embodiments, a separate radio IC circuitry may be provided for processing signals for each spectrum, although the scope of the embodiments is not limited in this respect. In some embodiments, the synthesizer circuitry 1006d may be a fractional-N synthesizer or a fractional N/N+l synthesizer, although the scope of the embodiments is not limited in this respect as other types of frequency synthesizers may be suitable. For example, synthesizer circuitry 1006d may be a delta-sigma synthesizer, a frequency multiplier, or a synthesizer comprising a phase-locked loop with a frequency divider.

The synthesizer circuitry 1006d may be configured to synthesize an output frequency for use by the mixer circuitry 1006a of the RF circuitry 1006 based on a frequency input and a divider control input. In some embodiments, the synthesizer circuitry 1006d may be a fractional N/N+l synthesizer.

In some embodiments, frequency input may be provided by a voltage controlled oscillator (VCO), although that is not a requirement. Divider control input may be provided by either the baseband circuitry 1004 or the applications processor 1002 depending on the desired output frequency. In some embodiments, a divider control input (e.g., N) may be determined from a look-up table based on a channel indicated by the applications processor 1002.

Synthesizer circuitry 1006d of the RF circuitry 1006 may include a divider, a delay-locked loop (DLL), a multiplexer and a phase accumulator. In some embodiments, the divider may be a dual modulus divider (DMD) and the phase accumulator may be a digital phase accumulator (DPA). In some embodiments, the DMD may be configured to divide the input signal by either N or N+l (e.g., based on a carry out) to provide a fractional division ratio. In some example embodiments, the DLL may include a set of cascaded, tunable, delay elements, a phase detector, a charge pump and a D-type flip-flop. In these embodiments, the delay elements may be configured to break a VCO period up into Nd equal packets of phase, where Nd is the number of delay elements in the delay line. In this way, the DLL provides negative feedback to help ensure that the total delay through the delay line is one VCO cycle.

In some embodiments, synthesizer circuitry 1006d may be configured to generate a carrier frequency as the output frequency, while in other embodiments, the output frequency may be a multiple of the carrier frequency (e.g., twice the carrier frequency, four times the carrier frequency) and used in conjunction with quadrature generator and divider circuitry to generate multiple signals at the carrier frequency with multiple different phases with respect to each other. In some embodiments, the output frequency may be a LO frequency (fLO). In some embodiments, the RF circuitry 1006 may include an IQ/polar converter.

FEM circuitry 1008 may include a receive signal path which may include circuitry configured to operate on RF signals received from one or more antennas 1010, amplify the received signals and provide the amplified versions of the received signals to the RF circuitry 1006 for further processing. FEM circuitry 1008 may also include a transmit signal path which may include circuitry configured to amplify signals for transmission provided by the RF circuitry 1006 for transmission by one or more of the one or more antennas 1010. In various embodiments, the amplification through the transmit or receive signal paths may be done solely in the RF circuitry 1006, solely in the FEM 1008, or in both the RF circuitry 1006 and the FEM 1008.

In some embodiments, the FEM circuitry 1008 may include a TX/RX switch to switch between transmit mode and receive mode operation. The FEM circuitry may include a receive signal path and a transmit signal path. The receive signal path of the FEM circuitry may include an LNA to amplify received RF signals and provide the amplified received RF signals as an output (e.g., to the RF circuitry 1006). The transmit signal path of the FEM circuitry 1008 may include a power amplifier (PA) to amplify input RF signals (e.g., provided by RF circuitry 1006), and one or more filters to generate RF signals for subsequent transmission (e.g., by one or more of the one or more antennas 1010).

In some embodiments, the PMC 1012 may manage power provided to the baseband circuitry 1004. In particular, the PMC 1012 may control power-source selection, voltage scaling, battery charging, or DC-to-DC conversion. The PMC 1012 may often be included when the device 1000 is capable of being powered by a battery, for example, when the device is included in a UE. The PMC 1012 may increase the power conversion efficiency while providing desirable implementation size and heat dissipation characteristics. While FIG. 10 shows the PMC 1012 coupled only with the baseband circuitry 1004. However, in other embodiments, the PMC 10 12 may be additionally or alternatively coupled with, and perform similar power management operations for, other components such as, but not limited to, application circuitry 1002, RF circuitry 1006, or FEM 1008.

In some embodiments, the PMC 1012 may control, or otherwise be part of, various power saving mechanisms of the device 1000. For example, if the device 1000 is in an RRC_Connected state, where it is still connected to the RAN node as it expects to receive traffic shortly, then it may enter a state known as Discontinuous Reception Mode (DRX) after a period of inactivity. During this state, the device 1000 may power down for brief intervals of time and thus save power.

If there is no data traffic activity for an elOended period of time, then the device 1000 may transition off to an RRC_Idle state, where it disconnects from the network and does not perform operations such as channel quality feedback, handover, etc. The device 1000 goes into a very low power state and it performs paging where again it periodically wakes up to listen to the network and then powers down again. The device 1000 may not receive data in this state, in order to receive data, it must transition back to RRC_Connected state.

An additional power saving mode may allow a device to be unavailable to the network for periods longer than a paging interval (ranging from seconds to a few hours). During this time, the device is totally unreachable to the network and may power down completely. Any data sent during this time incurs a large delay and it is assumed the delay is acceptable.

Processors of the application circuitry 1002 and processors of the baseband circuitry 1004 may be used to execute elements of one or more instances of a protocol stack. For example, processors of the baseband circuitry 1004, alone or in combination, may be used execute Layer 3, Layer 2, or Layer 1 functionality, while processors of the application circuitry 1004 may utilize data (e.g., packet data) received from these layers and further execute Layer 4 functionality (e.g., transmission communication protocol (TCP) and user datagram protocol

(UDP) layers). As referred to herein, Layer 3 may comprise a radio resource control (RRC) layer, described in further detail below. As referred to herein, Layer 2 may comprise a medium access control (MAC) layer, a radio link control (RLC) layer, and a packet data convergence protocol (PDCP) layer, described in further detail below. As referred to herein, Layer 1 may comprise a physical (PHY) layer of a UE/RAN node, described in further detail below.

As used herein, the terms "circuit" or "circuitry" may refer to, be part of, or include an Application Specific Integrated Circuit (ASIC), an electronic circuit, a processor (shared, dedicated, or group), and/or memory (shared, dedicated, or group) that execute one or more software or firmware programs, a combinational logic circuit, and/or other suitable hardware components that provide the described functionality. In some embodiments, the circuitry may be implemented in, or functions associated with the circuitry may be implemented by, one or more software or firmware modules. In some embodiments, circuitry may include logic, at least partially operable in hardware. Embodiments described herein may be implemented into a system using any suitably configured hardware and/or software.

The following are example implementations of the subject matter described herein. It should be noted that any of the examples and the variations thereof described herein may be used in any permutation or combination of any other one or more examples or variations, although the scope of the claimed subject matter is not limited in these respects.

In example one, an apparatus of a Fifth Generation (5G) NodeB (gNB) comprises one or more baseband processors to configure one or more synchronization signal bursts to be transmitted to a user equipment (UE), wherein the synchronization signal bursts comprise one or more synchronization signal blocks, and a memory to store configuration information for the synchronization signal bursts. Example two may include the subject matter of example one or any of the examples described herein, wherein the one or more baseband processors are to configure a duration of the synchronization signal bursts, or a periodicity of the synchronization signal bursts, or a combination thereof, via higher layer signaling or is predetermined. Example three may include the subject matter of example one or any of the examples described herein, wherein beamforming at the gNB varies across two or more of the synchronization signal blocks, or is the same for two or more of the synchronization signal blocks of the synchronization signal burst. Example four may include the subject matter of example one or any of the examples described herein, wherein the two or more baseband processors are to configure a synchronization signal bursts set comprising one or more synchronization signal bursts, and wherein beamforming at the gNB varies across two or more synchronization signal bursts of the synchronization signal bursts set, or is the same across two or more synchronization signal bursts of the synchronization signal bursts set. Example five may include the subject matter of example one or any of the examples described herein, wherein the two or more baseband processors are to configure a synchronization signal bursts set comprising one or more synchronization signal bursts, and wherein beamforming at the gNB varies within the synchronization signal bursts set or is the same within the synchronization signal bursts set. Example six may include the subject matter of example one or any of the examples described herein, further comprising a radio-frequency (RF) transceiver to transmit a subset of the synchronization signal blocks within the synchronization signal burst. Example seven may include the subject matter of example one or any of the examples described herein, further comprising a radio-frequency (RF) transceiver to transmit a same subset of the synchronization signal blocks across two or more synchronization signal bursts, or a same subset of the synchronization signal blocks within a synchronization signal blocks bursts set. Example eight may include the subject matter of example one or any of the examples described herein, wherein the one or more baseband processors are to encode an indication of an existence of one or more of the synchronization signal blocks in control information that is protected by channel coding and cyclic redundancy check (CRC), and is modulated using a cover code sequence that is capable of being extended or punctured. Example nine may include the subject matter of example one or any of the examples described herein, wherein the synchronization signal blocks comprise at least a primary synchronization signal (PSS), a secondary synchronization signal (SSS), a physical broadcast channel (PBCH), or a demodulation reference signal, (DMRS), or a combination thereof, wherein at least the PSS and the SSS are transmitted in different symbols or in the same symbol. Example ten may include the subject matter of example one or any of the examples described herein, wherein the synchronization signal blocks comprise at least a primary synchronization signal (PSS) and a secondary synchronization signal (SSS), wherein the PSS and the SSS are transmitted on the same frequency resources or on different frequency resources.

In example eleven, one or more machine-readable media may have instructions stored thereon that, if executed by an apparatus of a Fifth Generation (5G) evolved NodeB (gNB), result in configuring one or more synchronization signal bursts to be transmitted to a user equipment (UE), wherein the synchronization signal bursts comprise one or more synchronization signal blocks, and storing configuration information for the synchronization signal bursts in a memory. Example twelve may include the subject matter of example eleven or any of the examples described herein, wherein the instructions, if executed, further result in configuring a duration of the synchronization signal bursts, or a periodicity of the synchronization signal bursts, or a combination thereof, via higher layer signaling or to a predetermined value. Example thirteen may include the subject matter of example eleven or any of the examples described herein, wherein beamforming at the gNB varies across two or more of the synchronization signal blocks, or is the same for two or more of the synchronization signal blocks of the synchronization signal burst. Example fourteen may include the subject matter of example eleven or any of the examples described herein, wherein the instructions, if executed, further result in configuring a synchronization signal bursts set comprising one or more synchronization signal bursts, and wherein beamforming at the gNB varies across two or more synchronization signal bursts of the synchronization signal bursts set, or is the same across two or more synchronization signal bursts of the synchronization signal bursts set. Example fifteen may include the subject matter of example eleven or any of the examples described herein, wherein the instructions, if executed, further result in configuring a synchronization signal bursts set comprising one or more synchronization signal bursts, and wherein beamforming at the gNB varies within the synchronization signal bursts set or is the same within the synchronization signal bursts set. Example sixteen may include the subject matter of example eleven or any of the examples described herein, wherein the instructions, if executed, further result in causing a radio-frequency (RF) transceiver to transmit a subset of the synchronization signal blocks within the synchronization signal burst. Example seventeen may include the subject matter of example eleven or any of the examples described herein, wherein the instructions, if executed, further result in causing a radio-frequency (RF) transceiver to transmit a same subset of the synchronization signal blocks across two or more synchronization signal bursts, or a same subset of the synchronization signal blocks within a synchronization signal blocks bursts set. Example eighteen may include the subject matter of example eleven or any of the examples described herein, wherein the instructions, if executed, further result in encoding an indication of an existence of one or more of the synchronization signal blocks in control information that is protected by channel coding and cyclic redundancy check (CRC), and is modulated using a cover code sequence that is capable of being extended or punctured. Example nineteen may include the subject matter of example eleven or any of the examples described herein, wherein the synchronization signal blocks comprise at least a primary synchronization signal (PSS) and a secondary synchronization signal (SSS), wherein the PSS and the SSS are transmitted in different symbols or in the same symbol. Example twenty may include the subject matter of example eleven or any of the examples described herein, wherein the synchronization signal blocks comprise at least a primary synchronization signal (PSS) and a secondary synchronization signal (SSS), wherein the PSS and the SSS are transmitted on the same frequency resources or on different frequency resources.

In example twenty-one, an apparatus of a Fifth Generation (5G) evolved NodeB (gNB) comprises means for configuring one or more synchronization signal bursts to be transmitted to a user equipment (UE), wherein the synchronization signal bursts comprise one or more synchronization signal blocks, and means for storing configuration information for the synchronization signal bursts. Example twenty-two may include the subject matter of example twenty-one or any of the examples described herein, further comprising means for configuring a duration of the synchronization signal bursts, or a periodicity of the synchronization signal bursts, or a combination thereof, via higher layer signaling or to a predetermined value. Example twenty-three may include the subject matter of example twenty-one or any of the examples described herein, wherein beamforming at the gNB varies across two or more of the synchronization signal blocks, or is the same for two or more of the synchronization signal blocks of the synchronization signal burst. Example twenty-four may include the subject matter of example twenty-one or any of the examples described herein, further comprising means for configuring a synchronization signal bursts set comprising one or more synchronization signal bursts, and wherein beamforming at the gNB varies across two or more synchronization signal bursts of the synchronization signal bursts set, or is the same across two or more synchronization signal bursts of the synchronization signal bursts set. Example twenty-five may include the subject matter of example twenty-one or any of the examples described herein, further comprising means for configuring a synchronization signal bursts set comprising one or more synchronization signal bursts, and wherein beamforming at the gNB varies within the synchronization signal bursts set or is the same within the synchronization signal bursts set. Example twenty-six may include the subject matter of example twenty-one or any of the examples described herein, further comprising means for transmitting a subset of the synchronization signal blocks within the synchronization signal burst. Example twenty-seven may include the subject matter of example twenty-one or any of the examples described herein, further comprising means for transmitting a same subset of the synchronization signal blocks across two or more synchronization signal bursts, or a same subset of the synchronization signal blocks within a synchronization signal blocks bursts set. Example twenty-eight may include the subject matter of example twenty-one or any of the examples described herein, further comprising means for encoding an indication of an existence of one or more of the synchronization signal blocks in control information that is protected by channel coding and cyclic redundancy check (CRC), and is modulated using a cover code sequence that is capable of being extended or punctured. Example twenty-nine may include the subject matter of example twenty-one or any of the examples described herein, wherein the synchronization signal blocks comprise at least a primary synchronization signal (PSS) and a secondary synchronization signal (SSS), wherein the PSS and the SSS are transmitted in different symbols or in the same symbol. Example thirty may include the subject matter of example twenty-one or any of the examples described herein, wherein the synchronization signal blocks comprise at least a primary synchronization signal (PSS) and a secondary synchronization signal (SSS), wherein the PSS and the SSS are transmitted on the same frequency resources or on different frequency resources. In example thirty-one, machine-readable storage may include machine-readable instructions, when executed, to realize an apparatus as claimed in any preceding claim.

In the description herein and/or claims, the terms coupled and/or connected, along with their derivatives, may be used. In particular embodiments, connected may be used to indicate that two or more elements are in direct physical and/or electrical contact with each other. Coupled may mean that two or more elements are in direct physical and/or electrical contact. Coupled, however, may also mean that two or more elements may not be in direct contact with each other, but yet may still cooperate and/or interact with each other. For example, "coupled" may mean that two or more elements do not contact each other but are indirectly joined together via another element or intermediate elements. Finally, the terms "on," "overlying," and "over" may be used in the following description and claims. "On," "overlying," and "over" may be used to indicate that two or more elements are in direct physical contact with each other. It should be noted, however, that "over" may also mean that two or more elements are not in direct contact with each other. For example, "over" may mean that one element is above another element but not contact each other and may have another element or elements in between the two elements. Furthermore, the term "and/or" may mean "and", it may mean "or", it may mean "exclusive-or", it may mean "one", it may mean "some, but not all", it may mean "neither", and/or it may mean "both", although the scope of claimed subject matter is not limited in this respect. In the description herein and/or claims, the terms "comprise" and "include," along with their derivatives, may be used and are intended as synonyms for each other.

Although the claimed subject matter has been described with a certain degree of particularity, it should be recognized that elements thereof may be altered by persons skilled in the art without departing from the spirit and/or scope of claimed subject matter. It is believed that the subject matter pertaining to synchronization signal transmission for new radio standard and many of its attendant utilities will be understood by the forgoing description, and it will be apparent that various changes may be made in the form, construction and/or arrangement of the components thereof without departing from the scope and/or spirit of the claimed subject matter or without sacrificing all of its material advantages, the form herein before described being merely an explanatory embodiment thereof, and/or further without providing substantial change thereto. It is the intention of the claims to encompass and/or include such changes.

CLAIMS

What is claimed is:

1. An apparatus of a Fifth Generation (5G) NodeB (gNB), comprising:

one or more baseband processors to configure one or more synchronization signal bursts to be transmitted to a user equipment (UE), wherein the synchronization signal bursts comprise one or more synchronization signal blocks; and

a memory to store configuration information for the synchronization signal bursts.

2. The apparatus of claim 1, wherein the one or more baseband processors are to configure a duration of the synchronization signal bursts, or a periodicity of the synchronization signal bursts, or a combination thereof, via higher layer signaling or is predetermined.

3. The apparatus of any one of claims 1-2, wherein beamforming at the gNB varies across two or more of the synchronization signal blocks, or is the same for two or more of the synchronization signal blocks of the synchronization signal burst.

4. The apparatus of any one of claims 1-3, wherein the two or more baseband processors are to configure a synchronization signal bursts set comprising one or more synchronization signal bursts, and wherein beamforming at the gNB varies across two or more synchronization signal bursts of the synchronization signal bursts set, or is the same across two or more synchronization signal bursts of the synchronization signal bursts set.

5. The apparatus of any one of claims 1-4, wherein the two or more baseband processors are to configure a synchronization signal bursts set comprising one or more synchronization signal bursts, and wherein beamforming at the gNB varies within the synchronization signal bursts set or is the same within the synchronization signal bursts set.

6. The apparatus of any one of claims 1-5, further comprising a radio-frequency (RF) transceiver to transmit a subset of the synchronization signal blocks within the synchronization signal burst.

7. The apparatus of any one of claims 1-6, further comprising a radio-frequency (RF) transceiver to transmit a same subset of the synchronization signal blocks across two or more synchronization signal bursts, or a same subset of the synchronization signal blocks within a synchronization signal blocks bursts set.

8. The apparatus of any one of clams 1-7, wherein the one or more baseband processors are to encode an indication of an existence of one or more of the synchronization signal blocks in control information that is protected by channel coding and cyclic redundancy check (CRC), and is modulated using a cover code sequence that is capable of being extended or punctured.

9. The apparatus of any one of claims 1-8, wherein the synchronization signal blocks comprise at least a primary synchronization signal (PSS), a secondary synchronization signal (SSS), a physical broadcast channel (PBCH), or a demodulation reference signal, (DMRS), or a combination thereof, wherein at least the PSS and the SSS are transmitted in different symbols or in the same symbol.

10. The apparatus of any one of claims 1-9, wherein the synchronization signal blocks comprise at least a primary synchronization signal (PSS) and a secondary synchronization signal (SSS), wherein the PSS and the SSS are transmitted on the same frequency resources or on different frequency resources.

11. One or more machine-readable media having instructions stored thereon that, if executed by an apparatus of a Fifth Generation (5G) evolved NodeB (gNB), result in:

configuring one or more synchronization signal bursts to be transmitted to a user equipment (UE), wherein the synchronization signal bursts comprise one or more synchronization signal blocks; and

storing configuration information for the synchronization signal bursts in a memory.

12. The one or more machine-readable media of claim 11, wherein the instructions, if executed, further result in configuring a duration of the synchronization signal bursts, or a periodicity of the synchronization signal bursts, or a combination thereof, via higher layer signaling or to a predetermined value.

13. The one or more machine-readable media of any one of claims 11-12, wherein beamforming at the gNB varies across two or more of the synchronization signal blocks, or is the same for two or more of the synchronization signal blocks of the synchronization signal burst.

14. The one or more machine-readable media of any one of claims 11-13, wherein the instructions, if executed, further result in configuring a synchronization signal bursts set comprising one or more synchronization signal bursts, and wherein beamforming at the gNB varies across two or more synchronization signal bursts of the synchronization signal bursts set, or is the same across two or more synchronization signal bursts of the synchronization signal bursts set.

15. The one or more machine-readable media of any one of claims 11-14, wherein the instructions, if executed, further result in configuring a synchronization signal bursts set comprising one or more synchronization signal bursts, and wherein beamforming at the gNB varies within the synchronization signal bursts set or is the same within the synchronization signal bursts set.

16. The one or more machine-readable media of any one of claims 11-15, wherein the instructions, if executed, further result in causing a radio-frequency (RF) transceiver to transmit a subset of the synchronization signal blocks within the synchronization signal burst.

17. The one or more machine-readable media of any one of claims 11-16, wherein the instructions, if executed, further result in causing a radio-frequency (RF) transceiver to transmit a same subset of the synchronization signal blocks across two or more synchronization signal bursts, or a same subset of the synchronization signal blocks within a synchronization signal blocks bursts set.

18. The one or more machine-readable media of any one of clams 11-17, wherein the instructions, if executed, further result in encoding an indication of an existence of one or more of the synchronization signal blocks in control information that is protected by channel coding and cyclic redundancy check (CRC), and is modulated using a cover code sequence that is capable of being extended or punctured.

19. The one or more machine-readable media of any one of claims 11-18, wherein the synchronization signal blocks comprise at least a primary synchronization signal (PSS) and a

secondary synchronization signal (SSS), wherein the PSS and the SSS are transmitted in different symbols or in the same symbol.

20. The one or more machine-readable media of any one of claims 11-19, wherein the synchronization signal blocks comprise at least a primary synchronization signal (PSS) and a secondary synchronization signal (SSS), wherein the PSS and the SSS are transmitted on the same frequency resources or on different frequency resources.

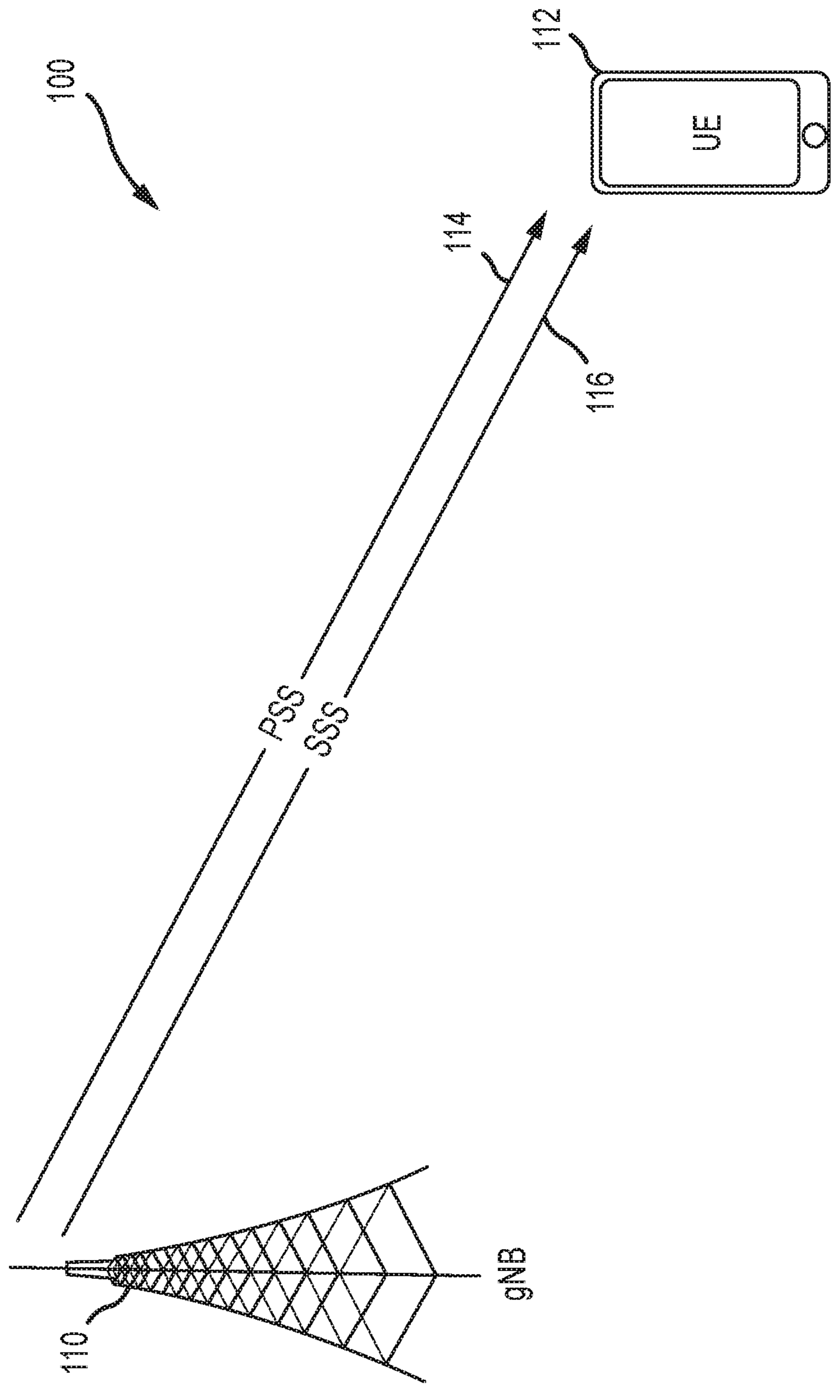


FIG. 1

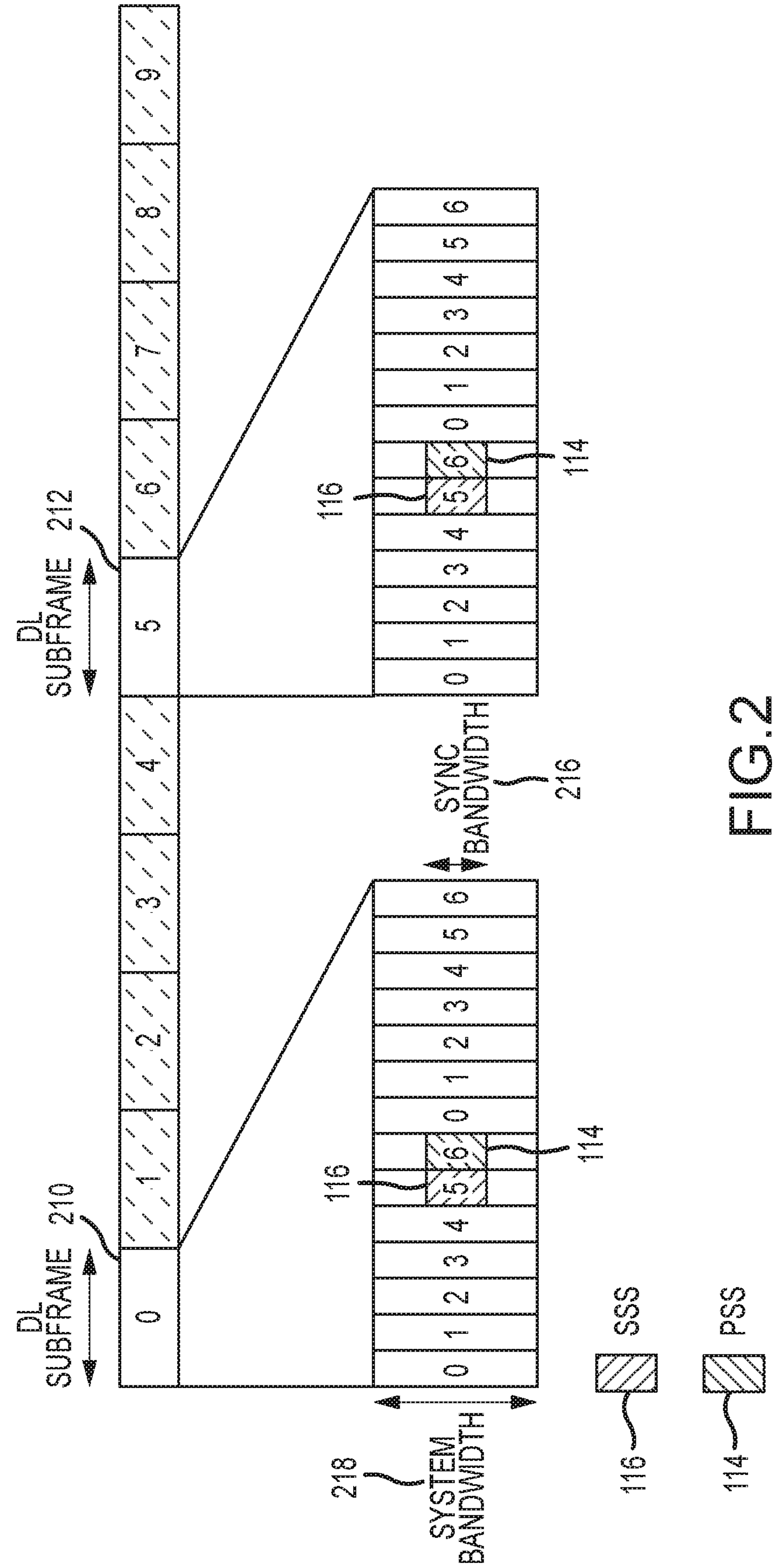
DL SUBFRAME
210
DL SUBFRAME
212
SYNC BANDWIDTH
216
SYSTEM BANDWIDTH
218
116
114
SSS
PSS

FIG.2

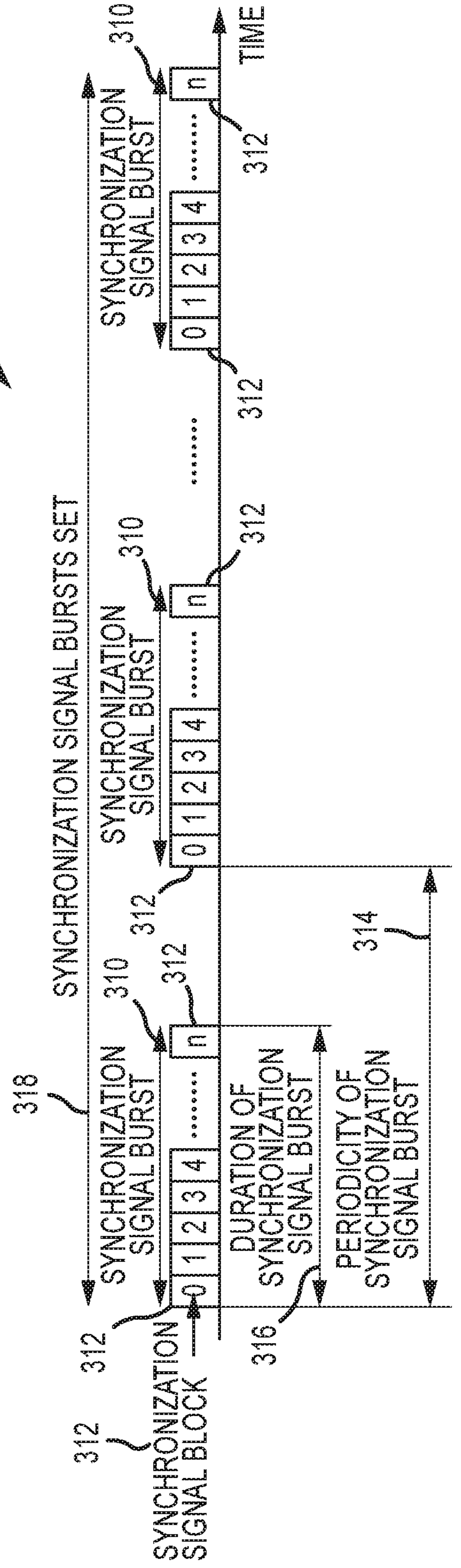
300
SYNCHRONIZATION SIGNAL BURSTS SET
318
SYNCHRONIZATION SIGNAL BURST
310
312
0
1
2
3
4
n
TIME
SYNCHRONIZATION SIGNAL BLOCK
DURATION OF SYNCHRONIZATION SIGNAL BURST
316
PERIODICITY OF SYNCHRONIZATION SIGNAL BURST
314

FIG.3

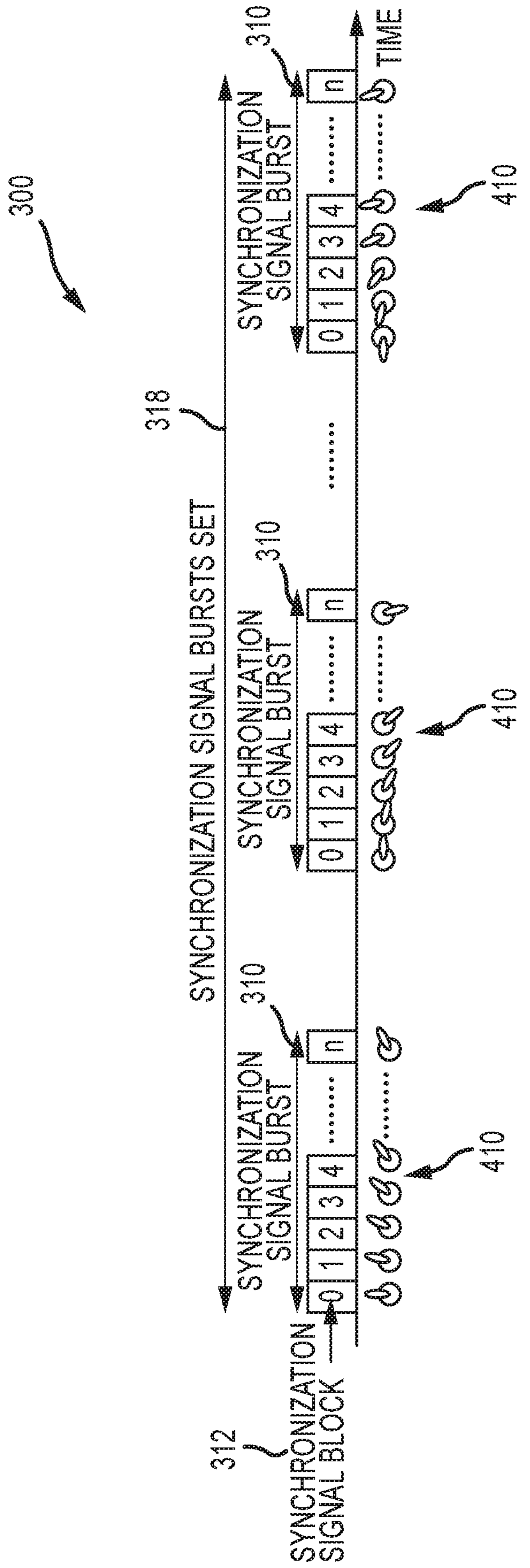
300
SYNCHRONIZATION SIGNAL BURSTS SET
318
SYNCHRONIZATION SIGNAL BURST
310
0
1
2
3
4
n
410
TIME
312
SYNCHRONIZATION SIGNAL BLOCK

FIG.4

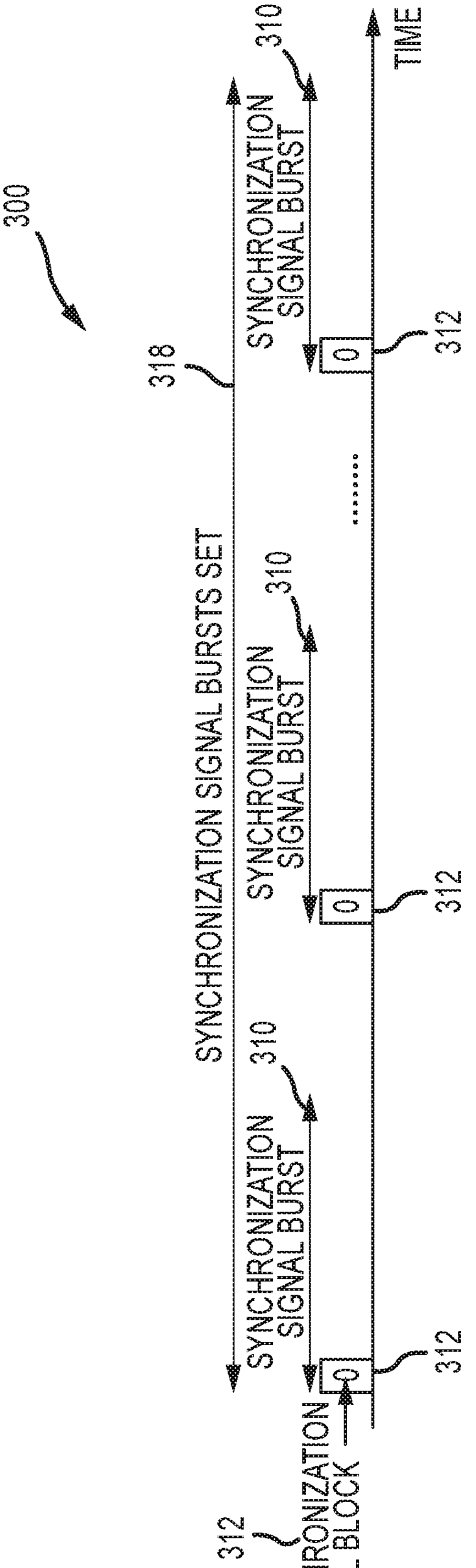
300
318
SYNCHRONIZATION SIGNAL BURSTS SET
310
SYNCHRONIZATION SIGNAL BURST
310
SYNCHRONIZATION SIGNAL BURST
310
SYNCHRONIZATION SIGNAL BURST
312
SYNCHRONIZATION SIGNAL BLOCK
0
312
0
312
0
312
TIME

FIG.5

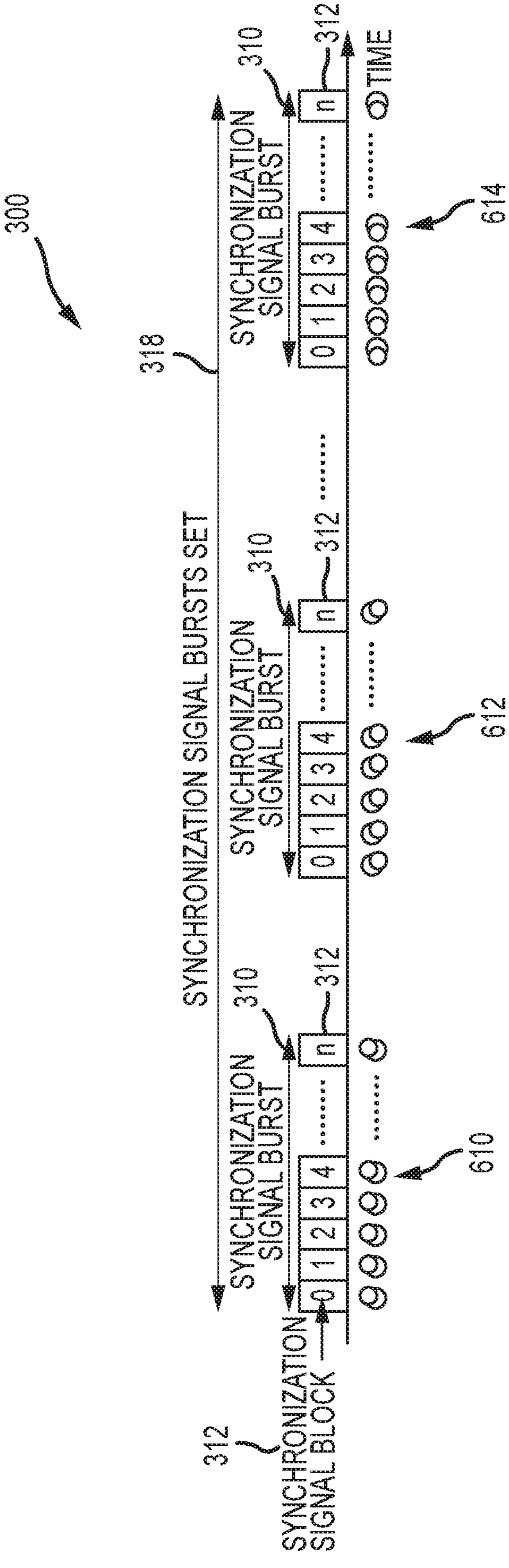
300
318
SYNCHRONIZATION SIGNAL BURSTS SET
SYNCHRONIZATION SIGNAL BURST
SYNCHRONIZATION SIGNAL BURST
SYNCHRONIZATION SIGNAL BURST
310
312
SYNCHRONIZATION SIGNAL BLOCK
0
1
2
3
4
n
610
612
614
TIME

FIG.6

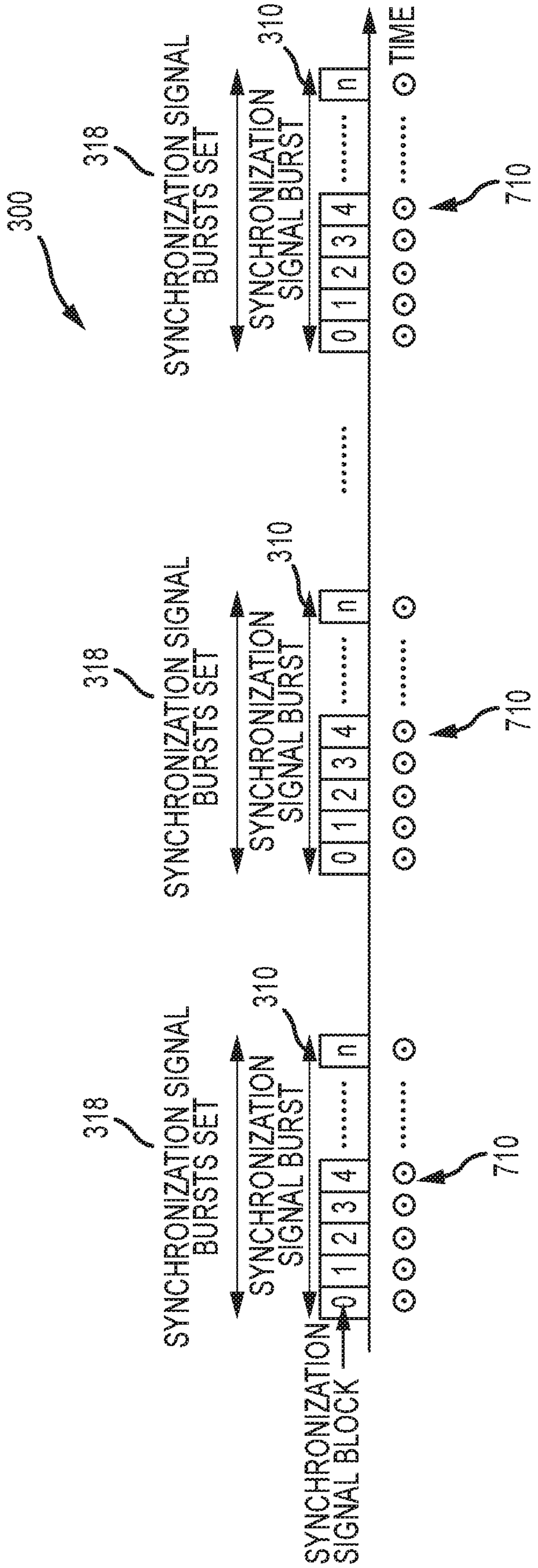
300
318
SYNCHRONIZATION SIGNAL BURSTS SET
310
SYNCHRONIZATION SIGNAL BURST
0
1
2
3
4
n
710
SYNCHRONIZATION SIGNAL BLOCK
TIME

FIG.7

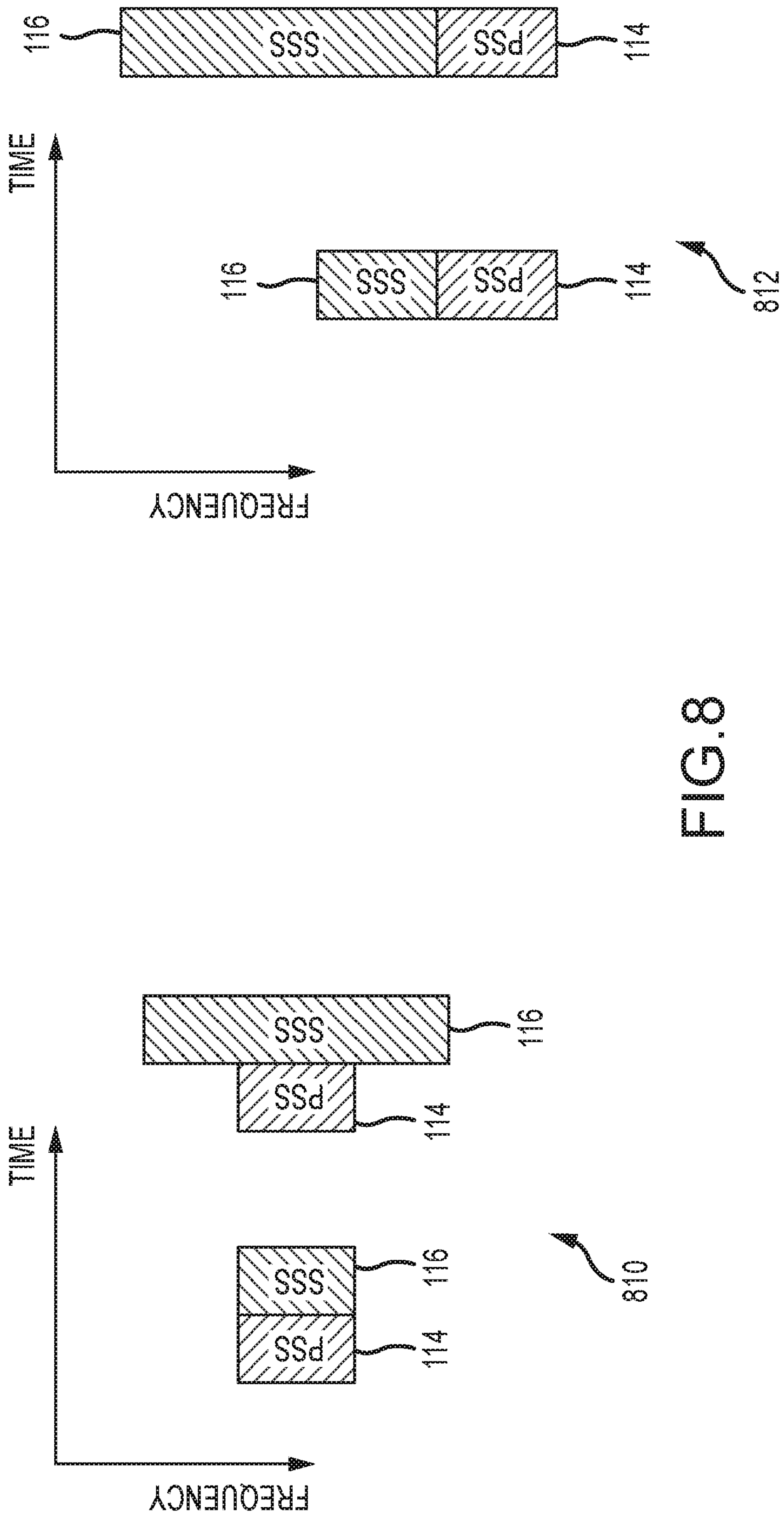


FIG.8

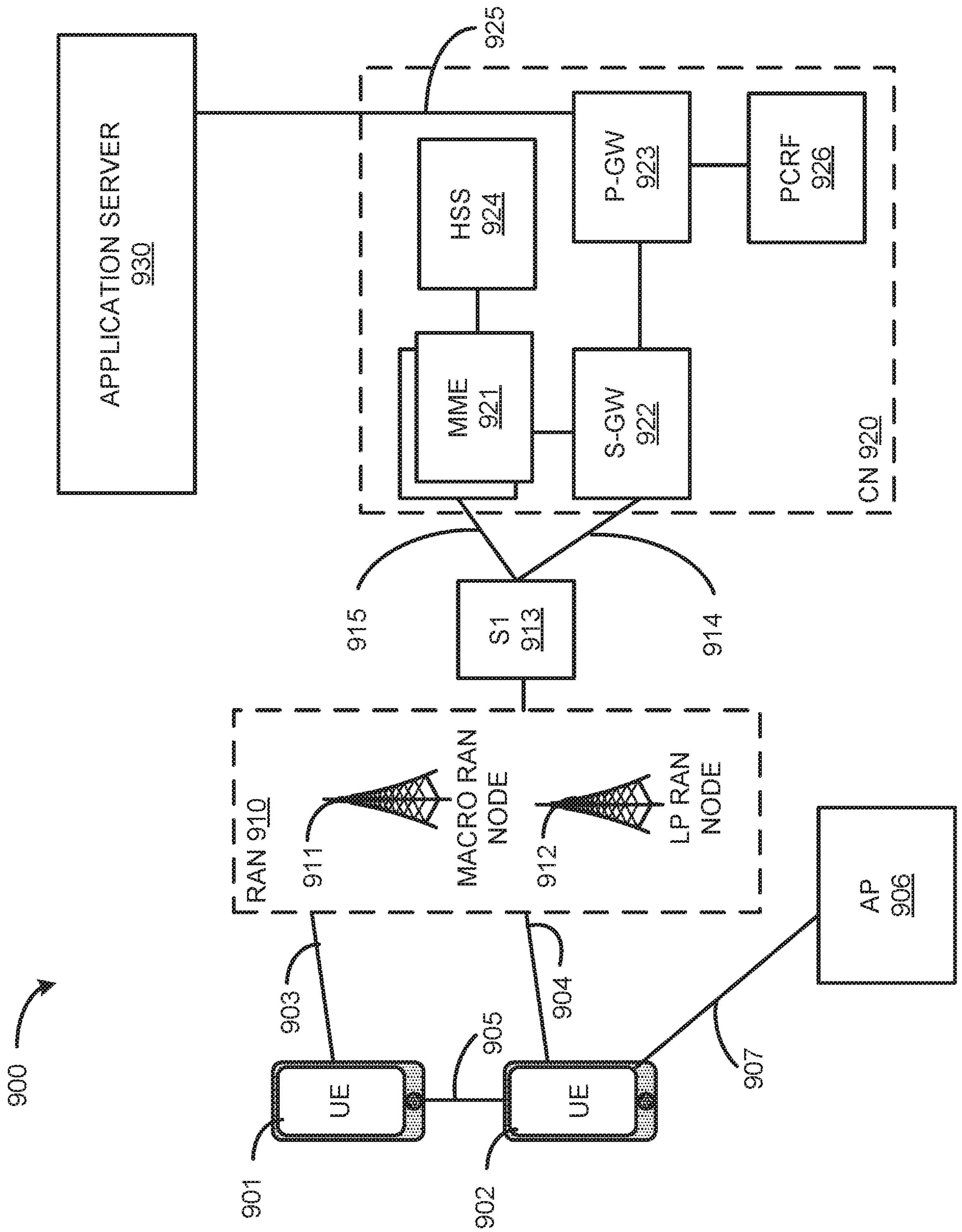
APPLICATION SERVER
930
925
HSS
924
P-GW
923
PCRF
926
MME
921
S-GW
922
CN 920
915
S1
913
914
RAN 910
911
MACRO RAN NODE
912
LP RAN NODE
AP
906
903
904
905
907
UE
UE
901
902
900

FIG. 9

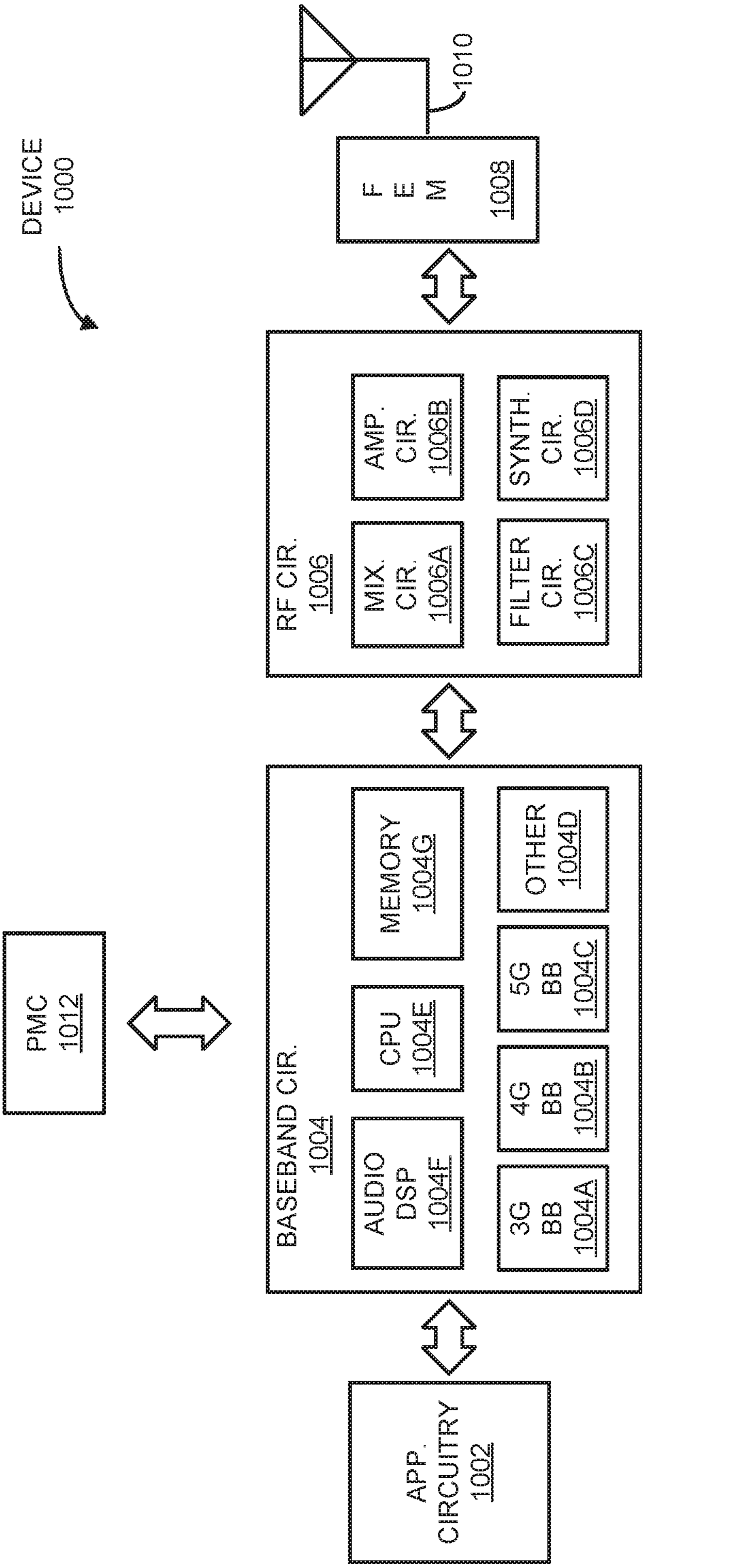
DEVICE 1000
1010
FEM 1008
RF CIR. 1006
MIX. CIR. 1006A
AMP. CIR. 1006B
FILTER CIR. 1006C
SYNTH. CIR. 1006D
BASEBAND CIR. 1004
AUDIO DSP 1004F
CPU 1004E
MEMORY 1004G
3G BB 1004A
4G BB 1004B
5G BB 1004C
OTHER 1004D
PMC 1012
APP. CIRCUITRY 1002

FIG. 10

# INTERNATIONAL SEARCH REPORT

International application No
PCT/US2017/044835

A. CLASSIFICATION OF SUBJECT MATTER
INV. H04W48/00 H04B7/02 H04W56/00
ADD.

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H04W H04B

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

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

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| Y | US 2016/227502 A1 (VOS GUSTAV GERALD [CA] ET AL) 4 August 2016 (2016-08-04)<br>paragraphs [0023], [0029]<br>paragraphs [0030] - [0032], [0038], [0039]<br>paragraph [0041]<br>paragraphs [0055] - [0057]<br>paragraphs [0072] - [0075]<br>paragraphs [0101], [0102], [0103]<br>----- | 1-20 |
| Y | WO 2015/080648 A1 (ERICSSON TELEFON AB L M [SE]) 4 June 2015 (2015-06-04)<br>page 13, lines 23-29<br>page 14, lines 5-14<br>page 15, line 33 - page 16, line 7<br>page 26, line 33 - page 27, line 6<br>-----<br>-/-- | 1-6, 11-16 |

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

[X] See patent family annex.

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

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"&" document member of the same patent family

| Date of the actual completion of the international search | Date of mailing of the international search report |
|---|---|
| 18 September 2017 | 27/09/2017 |

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

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## INTERNATIONAL SEARCH REPORT

International application No
PCT/US2017/044835

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| Y | US 2015/156763 A1 (SEO DONGYOUN [KR] ET AL) 4 June 2015 (2015-06-04) paragraphs [0057] - [0060], [0102] | 7-10, 17-20 |
| T | WO 2016/086144 A1 (INTERDIGITAL PATENT HOLDINGS [US]) 2 June 2016 (2016-06-02) paragraphs [0091], [0092], [0101], [0117], [0135], [0136] | 1-20 |
| T | WO 2015/080645 A1 (ERICSSON TELEFON AB L M [SE]) 4 June 2015 (2015-06-04) abstract | 1-20 |

1

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Information on patent family members

International application No
PCT/US2017/044835

| Patent document cited in search report | Publication date | Patent family member(s) | Publication date |
|---|---|---|---|
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| | | WO 2016119061 A1 | 04-08-2016 |
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| | | JP 5945073 B2 | 05-07-2016 |
| | | JP 2015527781 A | 17-09-2015 |
| | | KR 20150023363 A | 05-03-2015 |
| | | US 2015156763 A1 | 04-06-2015 |
| | | US 2016248571 A1 | 25-08-2016 |
| | | WO 2014007548 A1 | 09-01-2014 |
| WO 2016086144 A1 | 02-06-2016 | EP 3225070 A1 | 04-10-2017 |
| | | WO 2016086144 A1 | 02-06-2016 |
| WO 2015080645 A1 | 04-06-2015 | NONE | |