

LOW POWER SYNCHRONIZATION SIGNAL TRANSMISSION AND CONFIGURATION

TECHNICAL FIELD

[0001] The present disclosure relates to wireless communications, and more specifically to synchronization signal transmission and configuration.

BACKGROUND

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

SUMMARY

[0003] An article “a” before an element is unrestricted and understood to refer to “at least one” of those elements or “one or more” of those elements. The terms “a,” “at least one,” “one or more,” and “at least one of one or more” may be interchangeable. As used herein, including in the claims, “or” as used in a list of items (e.g., a list of items prefaced by a phrase such as “at least one of” or “one or more of” or “one or both of”) indicates an inclusive list such that, for example, a list of at least one of A, B, or C means A or B or C or AB or AC or BC or ABC (i.e., A and B and C). Also, as used herein, the phrase “based on”

shall not be construed as a reference to a closed set of conditions. For example, an example step that is described as “based on condition A” may be based on both a condition A and a condition B without departing from the scope of the present disclosure. In other words, as used herein, the phrase “based on” shall be construed in the same manner as the phrase “based at least in part on. Further, as used herein, including in the claims, a “set” may include one or more elements.

[0004] The present disclosure relates to methods, apparatuses, and systems that support lower power synchronization signal transmission and configuration.

[0005] Some implementations of the method and apparatuses described herein may further include a user equipment (UE) for wireless communication, comprising: at least one memory; and at least one processor coupled with the at least one memory and configured to cause the UE to: receive a first synchronization signal (SS) in a first frequency band; and receive a second SS in a second frequency band, wherein the second SS is associated with a second period and an offset.

[0006] Some implementations of the method and apparatuses described herein may include a processor in a UE for wireless communication, the processor comprising: at least one controller coupled with at least one memory and configured to cause the processor to: receive a first synchronization signal (SS) in a first frequency band; and receive a second SS in a second frequency band, wherein the second SS is associated with a second period and an offset.

[0007] Some implementations of the method and apparatuses described herein may include a method performed by a user equipment (UE), the method comprising: receiving a first synchronization signal (SS) in a first frequency band; and receiving a second SS in a second frequency band, wherein the second SS is associated with a second period and an offset.

[0008] In some implementations of the method and apparatuses described herein, the first frequency band and the second frequency band are the same frequency band.

[0009] In some implementations of the method and apparatuses described herein, the second period is configured with a scaling factor of the period of the first SS. The offset

includes a frame number offset within the second period. The offset may further include indication of first half frame or second half frame.

[0010] In some implementations of the method and apparatuses described herein, the second SS is transmitted with one of multiple second SS blocks within each second period. The second SS block is comprised of one or multiple associated beams and one or more repetitions. The interval of the second SS blocks within each period is determined by higher layer or by a default value in unit of half frame or by the period of the first SS.

[0011] In some implementations of the method and apparatuses described herein, the second SS with the same beam is mapped to one or multiple second SS resources.

[0012] In some implementations of the method and apparatuses described herein, the symbol index(ice) of the second SS are determined by the symbol index(ice) of the first SS within a half frame. The at least one processor is further configured to cause the UE to: receive an indication of QCL information of the first SS and the second SS.

[0013] In some implementations of the method and apparatuses described herein, the first symbol index of the second SS within a half frame is determined by carrier of the second SS, subcarrier spacing of the second SS and a slot offset. The slot offset may be determined by the subcarrier spacing of the second SS, and the total number of first SSs within a half frame, or determined by the period of the first SS, or configured by higher layer. The slot offset may be determined by second SS frame type indication or reserved frame indication.

[0014] In some implementations of the method and apparatuses described herein, the second SS includes cell ID information. The second SS may further include indication of switching to the first frequency band.

[0015] In some implementations of the method and apparatuses described herein, the transmission power of the second SS is determined by the transmission power of the first SS or a wake-up signal and a power offset.

[0016] Some implementations of the method and apparatuses described herein may include a base station for wireless communication, comprising: at least one memory; and at

least one processor coupled with the at least one memory and configured to cause the base station to: transmit a first synchronization signal (SS) in a first frequency band; and transmit a second SS in a second frequency band, wherein the second SS is associated with a second period and an offset.

[0017] Some implementations of the method and apparatuses described herein may include a processor in a base station for wireless communication, comprising: at least one controller coupled with at least one memory and configured to cause the processor to: transmit a first synchronization signal (SS) in a first frequency band; and transmit a second SS in a second frequency band, wherein the second SS is associated with a second period and an offset

[0018] Some implementations of the method and apparatuses described herein may include a method performed by a base station, the method comprising: transmitting a first synchronization signal (SS) in a first frequency band; and transmitting a second SS in a second frequency band, wherein the second SS is associated with a second period and an offset

[0019] In some implementations of the method and apparatuses described herein, the first frequency band and the second frequency band are the same frequency band.

[0020] In some implementations of the method and apparatuses described herein, the second period is configured with a scaling factor of the period of the first SS. The offset includes a frame number offset within the second period. The offset may further include indication of first half frame or second half frame.

[0021] In some implementations of the method and apparatuses described herein, the second SS is transmitted with one of multiple second SS blocks within each second period. The second SS block is comprised of one or multiple associated beams and one or more repetitions. The interval of the second SS blocks within each period is determined by higher layer or by a default value in unit of half frame or by the period of the first SS.

[0022] In some implementations of the method and apparatuses described herein, the second SS with the same beam is mapped to one or multiple second SS resources.

[0023] In some implementations of the method and apparatuses described herein, the symbol index(ice) of the second SS are determined by the symbol index(ice) of the first SS within a half frame. The at least one processor is further configured to cause the base station to: transmit an indication of QCL information of the first SS and the second SS.

[0024] In some implementations of the method and apparatuses described herein, the first symbol index of the second SS within a half frame is determined by carrier of the second SS, subcarrier spacing of the second SS and a slot offset. The slot offset may be determined by the subcarrier spacing of the second SS, and the total number of first SSs within a half frame, or determined by the period of the first SS, or configured by higher layer. The slot offset may be determined by second SS frame type indication or reserved frame indication.

[0025] In some implementations of the method and apparatuses described herein, the second SS includes cell ID information. The second SS may further include indication of switching to the first frequency band.

[0026] In some implementations of the method and apparatuses described herein, the transmission power of the second SS is determined by the transmission power of the first SS or a wake-up signal and a power offset.

BRIEF DESCRIPTION OF THE DRAWINGS

[0027] Figure 1 illustrates an example of a wireless communications system in accordance with aspects of the present disclosure.

[0028] Figure 2 illustrates an example of a user equipment (UE) 200 in accordance with aspects of the present disclosure.

[0029] Figure 3 illustrates an example of a processor 300 in accordance with aspects of the present disclosure.

[0030] Figure 4 illustrates an example of a network equipment (NE) 400 in accordance with aspects of the present disclosure.

[0031] Figure 5(a) and 5(b) illustrate ultra-low power wake-up receiver and main radio.

- [0032] Figure 6 illustrates periodical transmission of SSB.
- [0033] Figure 7(a) illustrates an example of LP-SS (lower power synchronization signal) period and LP-SS offset.
- [0034] Figure 7(b) illustrates an example of LP-SS period, LP-SS offset and LP-SS block.
- [0035] Figure 8(a) illustrates an example of consecutive repetition.
- [0036] Figure 8(b) illustrates an example of discrete repetition or an example of one LP-SS mapped to two LP-SS resources.
- [0037] Figure 9(a) illustrates a first example of transmission of LP-SS and SSB with FDM.
- [0038] Figure 9(b) illustrates a second example of transmission of LP-SS and SSB with FDM.
- [0039] Figure 9(c) illustrates a third example of transmission of LP-SS and SSB with FDM and with repetitions.
- [0040] Figure 10(a) illustrates a first example of transmission of LP-SS and SSB with TDM.
- [0041] Figure 10(b) illustrates a second example of transmission of LP-SS and SSB with TDM.
- [0042] Figure 11(a) illustrates an example of transmission of LP-SS and SSB with TDM with consecutive repetition.
- [0043] Figure 11(b) illustrates an example of transmission of LP-SS and SSB with TDM with discrete repetition.
- [0044] Figure 12 illustrates a flowchart of method performed by a UE in accordance with aspects of the present disclosure.
- [0045] Figure 13 illustrates a flowchart of method performed by a NE in accordance with aspects of the present disclosure.

DETAILED DESCRIPTION

[0046] Aspects of the present disclosure are described in the context of a wireless communications system.

[0047] Figure 1 illustrates an example of a wireless communications system 100 in accordance with aspects of the present disclosure. The wireless communications system 100 may include one or more NE 102, one or more UE 104, and a core network (CN) 106. The wireless communications system 100 may support various radio access technologies. In some implementations, the wireless communications system 100 may be a 4G network, such as an LTE (Long Term Evolution) network or an LTE-Advanced (LTE-A) network. In some other implementations, the wireless communications system 100 may be a New Radio (NR) network, such as a 5G network, a 5G-Advanced (5G-A) network, or a 5G ultrawideband (5G-UWB) network. In other implementations, the wireless communications system 100 may be a combination of a 4G network and a 5G network, or other suitable radio access technology including Institute of Electrical and Electronics Engineers (IEEE) 802.11 (Wi-Fi), IEEE 802.16 (WiMAX), IEEE 802.20. The wireless communications system 100 may support radio access technologies beyond 5G, for example, 6G. Additionally, the wireless communications system 100 may support technologies, such as time division multiple access (TDMA), frequency division multiple access (FDMA), or code division multiple access (CDMA), etc.

[0048] The one or more NE 102 may be dispersed throughout a geographic region to form the wireless communications system 100. One or more of the NE 102 described herein may be or include or may be referred to as a network node, a base station, a network element, a network function, a network entity, a radio access network (RAN), a NodeB, an eNodeB (eNB), a next-generation NodeB (gNB), or other suitable terminology. An NE 102 and a UE 104 may communicate via a communication link 110, which may be a wireless or wired connection. For example, an NE 102 and a UE 104 may perform wireless communication (e.g., receive signaling, transmit signaling) over a Uu interface.

[0049] An NE 102 may provide a geographic coverage area for which the NE 102 may support services for one or more UEs 104 within the geographic coverage area. For

example, an NE 102 and a UE 104 may support wireless communication of signals related to services (e.g., voice, video, packet data, messaging, broadcast, etc.) according to one or multiple radio access technologies. In some implementations, an NE 102 may be moveable, for example, a satellite associated with a non-terrestrial network (NTN). In some implementations, different geographic coverage areas 112 associated with the same or different radio access technologies may overlap, but the different geographic coverage areas may be associated with different NE 102.

[0050] The one or more UE 104 may be dispersed throughout a geographic region of the wireless communications system 100. A UE 104 may include or may be referred to as a remote unit, a mobile device, a wireless device, a remote device, a subscriber device, a transmitter device, a receiver device, or some other suitable terminology. In some implementations, the UE 104 may be referred to as a unit, a station, a terminal, or a client, among other examples. Additionally, or alternatively, the UE 104 may be referred to as an Internet-of-Things (IoT) device, an Internet-of-Everything (IoE) device, or machine-type communication (MTC) device, among other examples.

[0051] A UE 104 may be able to support wireless communication directly with other UEs 104 over a communication link. For example, a UE 104 may support wireless communication directly with another UE 104 over a device-to-device (D2D) communication link. In some implementations, such as vehicle-to-vehicle (V2V) deployments, vehicle-to-everything (V2X) deployments, or cellular-V2X deployments, the communication link 114 may be referred to as a sidelink. For example, a UE 104 may support wireless communication directly with another UE 104 over a PC5 interface.

[0052] An NE 102 may support communications with the CN 106, or with another NE 102, or both. For example, an NE 102 may interface with other NE 102 or the CN 106 through one or more backhaul links 116 (e.g., S1, N2, N2, or network interface). The network entities 102 may communicate with each other over the backhaul links 116 (e.g., via an X2, Xn, or another network interface). In some implementations, the NE 102 may communicate with each other directly. In some other implementations, the NE 102 may communicate with each other or indirectly (e.g., via the CN 106). In some implementations, one or more NE 102 may include subcomponents, such as an access network entity, which

may be an example of an access node controller (ANC). An ANC may communicate with the one or more UEs 104 through one or more other access network transmission entities, which may be referred to as a radio heads, smart radio heads, or transmission-reception points (TRPs).

[0053] The CN 106 may support user authentication, access authorization, tracking, connectivity, and other access, routing, or mobility functions. The CN 106 may be an evolved packet core (EPC), or a 5G core (5GC), which may include a control plane entity that manages access and mobility (e.g., a mobility management entity (MME), an access and mobility management functions (AMF)) and a user plane entity that routes packets or interconnects to external networks (e.g., a serving gateway (S-GW), a Packet Data Network (PDN) gateway (P-GW), or a user plane function (UPF)). In some implementations, the control plane entity may manage non-access stratum (NAS) functions, such as mobility, authentication, and bearer management (e.g., data bearers, signal bearers, etc.) for the one or more UEs 104 served by the one or more NE 102 associated with the CN 106.

[0054] The CN 106 may communicate with a packet data network 108 over one or more backhaul links (e.g., via an S1, N2, N2, or another network interface). The packet data network 108 may include an application server 118. In some implementations, one or more UEs 104 may communicate with the application server 118. A UE 104 may establish a session (e.g., a protocol data unit (PDU) session, or the like) with the CN 106 via an NE 102. The CN 106 may route traffic (e.g., control information, data, and the like) between the UE 104 and the application server 118 using the established session (e.g., the established PDU session). The PDU session may be an example of a logical connection between the UE 104 and the CN 106 (e.g., one or more network functions of the CN 106).

[0055] In the wireless communications system 100, the NEs 102 and the UEs 104 may use resources of the wireless communications system 100 (e.g., time resources (e.g., symbols, slots, subframes, frames, or the like) or frequency resources (e.g., subcarriers, carriers)) to perform various operations (e.g., wireless communications). In some implementations, the NEs 102 and the UEs 104 may support different resource structures. For example, the NEs 102 and the UEs 104 may support different frame structures. In some implementations, such as in 4G, the NEs 102 and the UEs 104 may support a single frame

structure. In some other implementations, such as in 5G and among other suitable radio access technologies, the NEs 102 and the UEs 104 may support various frame structures (i.e., multiple frame structures). The NEs 102 and the UEs 104 may support various frame structures based on one or more numerologies.

[0056] One or more numerologies may be supported in the wireless communications system 100, and a numerology may include a subcarrier spacing and a cyclic prefix. A first numerology (e.g., $\mu=0$) may be associated with a first subcarrier spacing (e.g., 15 kHz) and a normal cyclic prefix. In some implementations, the first numerology (e.g., $\mu=0$) associated with the first subcarrier spacing (e.g., 15 kHz) may utilize one slot per subframe. A second numerology (e.g., $\mu=1$) may be associated with a second subcarrier spacing (e.g., 30 kHz) and a normal cyclic prefix. A third numerology (e.g., $\mu=2$) may be associated with a third subcarrier spacing (e.g., 60 kHz) and a normal cyclic prefix or an extended cyclic prefix. A fourth numerology (e.g., $\mu=3$) may be associated with a fourth subcarrier spacing (e.g., 120 kHz) and a normal cyclic prefix. A fifth numerology (e.g., $\mu=4$) may be associated with a fifth subcarrier spacing (e.g., 240 kHz) and a normal cyclic prefix.

[0057] A time interval of a resource (e.g., a communication resource) may be organized according to frames (also referred to as radio frames). Each frame may have a duration, for example, a 10 millisecond (ms) duration. In some implementations, each frame may include multiple subframes. For example, each frame may include 10 subframes, and each subframe may have a duration, for example, a 1 ms duration. In some implementations, each frame may have the same duration. In some implementations, each subframe of a frame may have the same duration.

[0058] Additionally or alternatively, a time interval of a resource (e.g., a communication resource) may be organized according to slots. For example, a subframe may include a number (e.g., quantity) of slots. The number of slots in each subframe may also depend on the one or more numerologies supported in the wireless communications system 100. For instance, the first, second, third, fourth, and fifth numerologies (i.e., $\mu=0$, $\mu=1$, $\mu=2$, $\mu=3$, $\mu=4$) associated with respective subcarrier spacings of 15 kHz, 30 kHz, 60 kHz, 120 kHz, and 240 kHz may utilize a single slot per subframe, two slots per subframe, four slots per subframe, eight slots per subframe, and 16 slots per subframe, respectively.

Each slot may include a number (e.g., quantity) of symbols (e.g., OFDM symbols). In some implementations, the number (e.g., quantity) of slots for a subframe may depend on a numerology. For a normal cyclic prefix, a slot may include 14 symbols. For an extended cyclic prefix (e.g., applicable for 60 kHz subcarrier spacing), a slot may include 12 symbols. The relationship between the number of symbols per slot, the number of slots per subframe, and the number of slots per frame for a normal cyclic prefix and an extended cyclic prefix may depend on a numerology. It should be understood that reference to a first numerology (e.g., $\mu=0$) associated with a first subcarrier spacing (e.g., 15 kHz) may be used interchangeably between subframes and slots.

[0059] In the wireless communications system 100, an electromagnetic (EM) spectrum may be split, based on frequency or wavelength, into various classes, frequency bands, frequency channels, etc. By way of example, the wireless communications system 100 may support one or multiple operating frequency bands, such as frequency range designations FR1 (410 MHz – 7.125 GHz), FR2 (24.25 GHz – 52.6 GHz), FR3 (7.125 GHz – 24.25 GHz), FR4 (52.6 GHz – 114.25 GHz), FR4a or FR4-1 (52.6 GHz – 71 GHz), and FR5 (114.25 GHz – 300 GHz). In some implementations, the NEs 102 and the UEs 104 may perform wireless communications over one or more of the operating frequency bands. In some implementations, FR1 may be used by the NEs 102 and the UEs 104, among other equipment or devices for cellular communications traffic (e.g., control information, data). In some implementations, FR2 may be used by the NEs 102 and the UEs 104, among other equipment or devices for short-range, high data rate capabilities.

[0060] FR1 may be associated with one or multiple numerologies (e.g., at least three numerologies). For example, FR1 may be associated with a first numerology (e.g., $\mu=0$), which includes 15 kHz subcarrier spacing; a second numerology (e.g., $\mu=1$), which includes 30 kHz subcarrier spacing; and a third numerology (e.g., $\mu=2$), which includes 60 kHz subcarrier spacing. FR2 may be associated with one or multiple numerologies (e.g., at least 2 numerologies). For example, FR2 may be associated with a third numerology (e.g., $\mu=2$), which includes 60 kHz subcarrier spacing; and a fourth numerology (e.g., $\mu=3$), which includes 120 kHz subcarrier spacing.

[0061] Figure 2 illustrates an example of a UE 200 in accordance with aspects of the present disclosure. The UE 200 may include a processor 202, a memory 204, a controller 206, and a transceiver 208. The processor 202, the memory 204, the controller 206, or the transceiver 208, or various combinations thereof or various components thereof may be examples of means for performing various aspects of the present disclosure as described herein. These components may be coupled (e.g., operatively, communicatively, functionally, electronically, electrically) via one or more interfaces.

[0062] The processor 202, the memory 204, the controller 206, or the transceiver 208, or various combinations or components thereof may be implemented in hardware (e.g., circuitry). The hardware may include a processor, a digital signal processor (DSP), an application-specific integrated circuit (ASIC), or other programmable logic device, or any combination thereof configured as or otherwise supporting a means for performing the functions described in the present disclosure.

[0063] The processor 202 may include an intelligent hardware device (e.g., a general-purpose processor, a DSP, a CPU, an ASIC, an FPGA, or any combination thereof). In some implementations, the processor 202 may be configured to operate the memory 204. In some other implementations, the memory 204 may be integrated into the processor 202. The processor 202 may be configured to execute computer-readable instructions stored in the memory 204 to cause the UE 200 to perform various functions of the present disclosure.

[0064] The memory 204 may include volatile or non-volatile memory. The memory 204 may store computer-readable, computer-executable code including instructions when executed by the processor 202 cause the UE 200 to perform various functions described herein. The code may be stored in a non-transitory computer-readable medium such the memory 204 or another type of memory. Computer-readable media includes both non-transitory computer storage media and communication media including any medium that facilitates transfer of a computer program from one place to another. A non-transitory storage medium may be any available medium that may be accessed by a general-purpose or special-purpose computer.

[0065] In some implementations, the processor 202 and the memory 204 coupled with the processor 202 may be configured to cause the UE 200 to perform one or more of the functions described herein (e.g., executing, by the processor 202, instructions stored in the memory 204). For example, the processor 202 may support wireless communication at the UE 200 in accordance with examples as disclosed herein. The UE 200 may be configured to support a means for determining that a Physical Uplink Shared Channel (PUSCH) transmission is associated with a plurality of Phase-Tracking Reference Signal (PTRS) ports; and transmitting the PUSCH transmission together with the plurality of PTRS ports.

[0066] The controller 206 may manage input and output signals for the UE 200. The controller 206 may also manage peripherals not integrated into the UE 200. In some implementations, the controller 206 may utilize an operating system such as iOS®, ANDROID®, WINDOWS®, or other operating systems. In some implementations, the controller 206 may be implemented as part of the processor 202.

[0067] In some implementations, the UE 200 may include at least one transceiver 208. In some other implementations, the UE 200 may have more than one transceiver 208. The transceiver 208 may represent a wireless transceiver. The transceiver 208 may include one or more receiver chains 210, one or more transmitter chains 212, or a combination thereof.

[0068] A receiver chain 210 may be configured to receive signals (e.g., control information, data, packets) over a wireless medium. For example, the receiver chain 210 may include one or more antennas for receive the signal over the air or wireless medium. The receiver chain 210 may include at least one amplifier (e.g., a low-noise amplifier (LNA)) configured to amplify the received signal. The receiver chain 210 may include at least one demodulator configured to demodulate the receive signal and obtain the transmitted data by reversing the modulation technique applied during transmission of the signal. The receiver chain 210 may include at least one decoder for decoding the processing the demodulated signal to receive the transmitted data.

[0069] A transmitter chain 212 may be configured to generate and transmit signals (e.g., control information, data, packets). The transmitter chain 212 may include at least one modulator for modulating data onto a carrier signal, preparing the signal for transmission

over a wireless medium. The at least one modulator may be configured to support one or more techniques such as amplitude modulation (AM), frequency modulation (FM), or digital modulation schemes like phase-shift keying (PSK) or quadrature amplitude modulation (QAM). The transmitter chain 212 may also include at least one power amplifier configured to amplify the modulated signal to an appropriate power level suitable for transmission over the wireless medium. The transmitter chain 212 may also include one or more antennas for transmitting the amplified signal into the air or wireless medium.

[0070] Figure 3 illustrates an example of a processor 300 in accordance with aspects of the present disclosure. The processor 300 may be an example of a processor configured to perform various operations in accordance with examples as described herein. The processor 300 may include a controller 302 configured to perform various operations in accordance with examples as described herein. The processor 300 may optionally include at least one memory 304, which may be, for example, an L1/L2/L3 cache. Additionally, or alternatively, the processor 300 may optionally include one or more arithmetic-logic units (ALUs) 306. One or more of these components may be in electronic communication or otherwise coupled (e.g., operatively, communicatively, functionally, electronically, electrically) via one or more interfaces (e.g., buses).

[0071] The processor 300 may be a processor chipset and include a protocol stack (e.g., a software stack) executed by the processor chipset to perform various operations (e.g., receiving, obtaining, retrieving, transmitting, outputting, forwarding, storing, determining, identifying, accessing, writing, reading) in accordance with examples as described herein. The processor chipset may include one or more cores, one or more caches (e.g., memory local to or included in the processor chipset (e.g., the processor 300) or other memory (e.g., random access memory (RAM), read-only memory (ROM), dynamic RAM (DRAM), synchronous dynamic RAM (SDRAM), static RAM (SRAM), ferroelectric RAM (FeRAM), magnetic RAM (MRAM), resistive RAM (RRAM), flash memory, phase change memory (PCM), and others).

[0072] The controller 302 may be configured to manage and coordinate various operations (e.g., signaling, receiving, obtaining, retrieving, transmitting, outputting, forwarding, storing, determining, identifying, accessing, writing, reading) of the processor

300 to cause the processor 300 to support various operations in accordance with examples as described herein. For example, the controller 302 may operate as a control unit of the processor 300, generating control signals that manage the operation of various components of the processor 300. These control signals include enabling or disabling functional units, selecting data paths, initiating memory access, and coordinating timing of operations.

[0073] The controller 302 may be configured to fetch (e.g., obtain, retrieve, receive) instructions from the memory 304 and determine subsequent instruction(s) to be executed to cause the processor 300 to support various operations in accordance with examples as described herein. The controller 302 may be configured to track memory address of instructions associated with the memory 304. The controller 302 may be configured to decode instructions to determine the operation to be performed and the operands involved. For example, the controller 302 may be configured to interpret the instruction and determine control signals to be output to other components of the processor 300 to cause the processor 300 to support various operations in accordance with examples as described herein. Additionally, or alternatively, the controller 302 may be configured to manage flow of data within the processor 300. The controller 302 may be configured to control transfer of data between registers, arithmetic logic units (ALUs), and other functional units of the processor 300.

[0074] The memory 304 may include one or more caches (e.g., memory local to or included in the processor 300 or other memory, such as RAM, ROM, DRAM, SDRAM, SRAM, MRAM, flash memory, etc. In some implementations, the memory 304 may reside within or on a processor chipset (e.g., local to the processor 300). In some other implementations, the memory 304 may reside external to the processor chipset (e.g., remote to the processor 300).

[0075] The memory 304 may store computer-readable, computer-executable code including instructions that, when executed by the processor 300, cause the processor 300 to perform various functions described herein. The code may be stored in a non-transitory computer-readable medium such as system memory or another type of memory. The controller 302 and/or the processor 300 may be configured to execute computer-readable instructions stored in the memory 304 to cause the processor 300 to perform various

functions. For example, the processor 300 and/or the controller 302 may be coupled with or to the memory 304, the processor 300, the controller 302, and the memory 304 may be configured to perform various functions described herein. In some examples, the processor 300 may include multiple processors and the memory 304 may include multiple memories. One or more of the multiple processors may be coupled with one or more of the multiple memories, which may, individually or collectively, be configured to perform various functions herein.

[0076] The one or more ALUs 306 may be configured to support various operations in accordance with examples as described herein. In some implementations, the one or more ALUs 306 may reside within or on a processor chipset (e.g., the processor 300). In some other implementations, the one or more ALUs 306 may reside external to the processor chipset (e.g., the processor 300). One or more ALUs 306 may perform one or more computations such as addition, subtraction, multiplication, and division on data. For example, one or more ALUs 306 may receive input operands and an operation code, which determines an operation to be executed. One or more ALUs 306 be configured with a variety of logical and arithmetic circuits, including adders, subtractors, shifters, and logic gates, to process and manipulate the data according to the operation. Additionally, or alternatively, the one or more ALUs 306 may support logical operations such as AND, OR, exclusive-OR (XOR), not-OR (NOR), and not-AND (NAND), enabling the one or more ALUs 306 to handle conditional operations, comparisons, and bitwise operations.

[0077] The processor 300 may support wireless communication in accordance with examples as disclosed herein. The processor 300 may be configured to or operable to support a means for determining that a Physical Uplink Shared Channel (PUSCH) transmission is associated with a plurality of Phase-Tracking Reference Signal (PTRS) ports; and transmitting the PUSCH transmission together with the plurality of PTRS ports.

[0078] Figure 4 illustrates an example of a NE 400 in accordance with aspects of the present disclosure. The NE 400 may include a processor 402, a memory 404, a controller 406, and a transceiver 408. The processor 402, the memory 404, the controller 406, or the transceiver 408, or various combinations thereof or various components thereof may be examples of means for performing various aspects of the present disclosure as described

herein. These components may be coupled (e.g., operatively, communicatively, functionally, electronically, electrically) via one or more interfaces.

[0079] The processor 402, the memory 404, the controller 406, or the transceiver 408, or various combinations or components thereof may be implemented in hardware (e.g., circuitry). The hardware may include a processor, a digital signal processor (DSP), an application-specific integrated circuit (ASIC), or other programmable logic device, or any combination thereof configured as or otherwise supporting a means for performing the functions described in the present disclosure.

[0080] The processor 402 may include an intelligent hardware device (e.g., a general-purpose processor, a DSP, a CPU, an ASIC, an FPGA, or any combination thereof). In some implementations, the processor 402 may be configured to operate the memory 404. In some other implementations, the memory 404 may be integrated into the processor 402. The processor 402 may be configured to execute computer-readable instructions stored in the memory 404 to cause the NE 400 to perform various functions of the present disclosure.

[0081] The memory 404 may include volatile or non-volatile memory. The memory 404 may store computer-readable, computer-executable code including instructions when executed by the processor 402 cause the NE 400 to perform various functions described herein. The code may be stored in a non-transitory computer-readable medium such the memory 404 or another type of memory. Computer-readable media includes both non-transitory computer storage media and communication media including any medium that facilitates transfer of a computer program from one place to another. A non-transitory storage medium may be any available medium that may be accessed by a general-purpose or special-purpose computer.

[0082] In some implementations, the processor 402 and the memory 404 coupled with the processor 402 may be configured to cause the NE 400 to perform one or more of the functions described herein (e.g., executing, by the processor 402, instructions stored in the memory 404). For example, the processor 402 may support wireless communication at the NE 400 in accordance with examples as disclosed herein. The NE 400 may be configured to support a means for determining that a Physical Uplink Shared Channel (PUSCH)

transmission is associated with a plurality of Phase-Tracking Reference Signal (PTRS) ports; and receiving the PUSCH transmission together with the plurality of PTRS ports.

[0083] The controller 406 may manage input and output signals for the NE 400. The controller 406 may also manage peripherals not integrated into the NE 400. In some implementations, the controller 406 may utilize an operating system such as iOS®, ANDROID®, WINDOWS®, or other operating systems. In some implementations, the controller 406 may be implemented as part of the processor 402.

[0084] In some implementations, the NE 400 may include at least one transceiver 408. In some other implementations, the NE 400 may have more than one transceiver 408. The transceiver 408 may represent a wireless transceiver. The transceiver 408 may include one or more receiver chains 410, one or more transmitter chains 412, or a combination thereof.

[0085] A receiver chain 410 may be configured to receive signals (e.g., control information, data, packets) over a wireless medium. For example, the receiver chain 410 may include one or more antennas for receive the signal over the air or wireless medium. The receiver chain 410 may include at least one amplifier (e.g., a low-noise amplifier (LNA)) configured to amplify the received signal. The receiver chain 410 may include at least one demodulator configured to demodulate the receive signal and obtain the transmitted data by reversing the modulation technique applied during transmission of the signal. The receiver chain 410 may include at least one decoder for decoding the processing the demodulated signal to receive the transmitted data.

[0086] A transmitter chain 412 may be configured to generate and transmit signals (e.g., control information, data, packets). The transmitter chain 412 may include at least one modulator for modulating data onto a carrier signal, preparing the signal for transmission over a wireless medium. The at least one modulator may be configured to support one or more techniques such as amplitude modulation (AM), frequency modulation (FM), or digital modulation schemes like phase-shift keying (PSK) or quadrature amplitude modulation (QAM). The transmitter chain 412 may also include at least one power amplifier configured to amplify the modulated signal to an appropriate power level suitable

for transmission over the wireless medium. The transmitter chain 412 may also include one or more antennas for transmitting the amplified signal into the air or wireless medium.

[0087] In NR, the UE may use Discontinuous Reception (DRX) in RRC_IDLE state (or idle mode) or RRC_INACTIVE state (or inactive mode) in order to reduce power consumption. The UE monitors one paging occasion (PO) per DRX cycle (which may also be referred to as DRX period).

[0088] UEs need to periodically wake up once per DRX cycle if DRX transmission is configured by higher layer, which dominates the power consumption in periods with no signaling or data traffic. If UEs are able to wake up only when they are triggered, e.g., when they are paged, power consumption could be dramatically reduced. This can be achieved by using a wake-up signal (WUS). For UE in idle or inactive mode, the WUS conveyed in DCI format 2-7 indicates whether there is paging process in a pre-defined PO (or MO (monitoring occasion) for a particular UE) in the DRX ON duration.

[0089] DRX in RRC_CONNECTED state (or connected mode) (i.e., C-DRX) is also supported. For UE in connected mode, WUS conveyed by DCI format 2-6 is also introduced to inform UE whether or not to wake up to monitor PDCCH (Physical Downlink Control Channel) for data transmission and reception.

[0090] Lower power WUS (LP-WUS) was further introduced. A separate receiver, e.g., an ultra-low power wake-up receiver or wake-up radio (LP-WUR, which can be abbreviated as “WUR”), was included in the UE in addition to the main radio (MR). In short, LP-WUR refers to the receiver (Rx) module operating for receiving and processing signals and channel related to low-power wake-up; MR refers to the Tx/Rx (receiver and transmitter) module operating for NR signals and channels apart from signals and channel related to low-power wake-up. The LP-WUS is monitored by the UE by WUR. As shown in Figure 5(a), if a WUS (OFF) indicates that there is no paging process in the PO for the UE, the MR in the UE is not triggered by the WUR and remains in OFF state or deep sleep state. On the other hand, as shown in Figure 5(b), if a WUS (ON) indicates that there is paging process in the PO for the UE, the WUR triggers the MR in the UE to ON state for data transmission and reception (e.g., for receiving paging in PO in the DRX ON duration).

[0091] The MR needs to monitor SSB (SS/PBCH block, i.e., synchronization signal / Physical Broadcast Channel). The WUR needs to monitor lower power synchronization signal (LP-SS). LP-WUS in WUR and SSB in MR can be within same frequency band (e.g., FR1 band or even in the same BWP) or different frequency bands. Since LP-SS and LP-WUS are in the same frequency band, LP-SS and SSB can be configured in the same frequency band or different frequency bands.

[0092] In this disclosure, it is assumed that LP-SS is transmitted periodically. However, the configuration and content of LP-SS can be also adopted to aperiodical LP-SS or one-shot LP-SS transmission. The following embodiments discuss the configuration and transmission of the periodical LP-SS.

[0093] Before discussing the embodiment, a brief introduction of the periodical transmission of SSB is provided with reference to Figure 6.

[0094] The period (or interval) of SSB transmission (referred to as “SSB period” hereinafter) can be 5 millisecond (ms), 10 ms, 20 ms, 40 ms, 80 ms or 160 ms. In Figure 6, the SSB period (T_{SSB}) is 10 ms. The transmission of SSB within an SSB block is confined to a 5 ms window. A radio frame (referred to as “frame” hereinafter) is 10 ms. So, 5 ms is equivalent to a half frame.

[0095] Within an SSB block (which can also be referred to as “SSB set”), each SSB is transmitted with an associated beam. The maximum number of SSBs within an SSB block (i.e., within 5ms period) is specified to be 4 for frequency ranges up to 3 GHz, 8 for 3 to 6 GHz, or 64 for 6 to 52.6 GHz in order to achieve a trade-off between coverage and resource overhead. In the example of Figure 6, each of 8 SSBs (S0 to S7) in the SSB block is transmitted with an associated beam (e.g., beam #0 to beam #7).

[0096] The first symbol of each SSB within 5ms half frame is determined by the subcarrier spacing of SSB. For different types (e.g., Type A, Type B, Type C), the SSB first symbol index in half frame (5ms) is indicated in Table 1.

Type	Subcarrier Spacing (kHz)	SSB first symbol index in half radio frame (5ms)
A	15	$\{2,8\}+14n$

B	30	$\{4,8,16,20\}+28n$
C	30	$\{2,8\}+14n$

Table 1

[0097] As shown in Figure 6, if the subcarrier spacing is assumed to be 15 kHz, the first symbol index of S0, S2, S4 and S6 is $2+14n$ (where $n = 0, 1, 2, 3$) and the first symbol index of S1, S3, S5 and S7 is $8+14n$ (where $n = 0, 1, 2, 3$). Note that the SSB block is only transmitted in the first 4 subframes (where one subframe is 1 ms) within the half frame, which implies that the last subframe of the half frame is not used for SSB transmission no matter the SSB period is.

[0098] A first embodiment relates to period and offset of the periodical LP-SS.

[0099] For periodical LP-SS transmission, the LP-SS is transmitted with a period T_{LP-SS} and an offset.

[0100] The period T_{LP-SS} is configured with multiple times of the SSB period (T_{SSB}), in consideration of similar or same cell coverage of the cell for SSB and the cell for LP-SS. That is, $T_{LP-SS} = K * T_{SSB}$, where, T_{SSB} is the SSB period (where the SSB refers to the SSB associated with the LP-SS, e.g., cell defined SSB in MR), and K is a scaling factor, which can be configured by higher layer.

[0101] The offset refers to the frame number offset within the period T_{LP-SS} (that is, the number of frames from the start of a period T_{LP-SS} to the start of LP-SS transmission). The start of LP-SS transmission meets the requirement of $n_f \bmod (T_{LP-SS}/10) = O_{LP-SS}$, where, n_f is the index number of the first frame in which LP-SS is transmitted, O_{LP-SS} is configured by higher layer or determined by cell ID. In addition, the offset may further include indication of whether the LP-SS is transmitted in the first or second 5 ms half frame to avoid potential collision with SSB transmission. Optionally, the first or second half frame is implied by the occupation of SSB in the first or second 5 ms half frame (e.g., determined by the opposite occupation of SSB). It means that if the SSB is transmitted in the first half frame, the LP-SS is transmitted in the second half frame; while if the SSB is transmitted in the second half frame, the LP-SS is transmitted in the first half frame.

[0102] Figure 7(a) illustrates an example of the period T_{LP-SS} and the offset. As shown in Figure 7(a), it is assumed that $T_{SSB}=10$ ms, and the scaling factor K is 2, and $O_{LP-SS} = 1$. So, $T_{LP-SS} = K * T_{SSB} = 2 * 10 = 20$ ms; The start of LP-SS transmission (within the period T_{LP-SS}) $n_f \bmod (T_{LP-SS}/10) = O_{LP-SS}$, that is, $n_f \bmod (20/10) = n_f \bmod 2 = O_{LP-SS} = 1$, i.e., $n_f \bmod 2 = 1$. In Figure 7(a), the LP-SS block is transmitted in frame #1 and frame #3. Incidentally, in the example of Figure 7(a), the LP-SS is transmitted in the first 5 ms half frame (of frame #1 and frame #3).

[0103] LP-SS block is a period in which LP-SS is transmitted with one or multiple associated beams and one or more repetitions. The one or multiple associated beams and/or the one or more repetitions can facilitate UE quick synchronization and measurement (e.g., UE power saving).

[0104] $T_{LP-SS-Block} (= N_{LP-SS-Block} * 5 \text{ ms})$ can be configured, so that LP-SS, if necessary to be transmitted in multiple 5 ms half frames, is transmitted in $T_{LP-SS-Block}$ interval or period within the period T_{LP-SS} . If $T_{LP-SS-Block}$ (or $N_{LP-SS-Block}$) is not configured, it is assumed that LP-SS is transmitted every 5 ms half frame interval or period (i.e., in consecutive 5ms half frame(s)). In other words, if $T_{LP-SS-Block}$ (or $N_{LP-SS-Block}$) is not configured, $T_{LP-SS-Block}$ can be regarded as 5 ms, or $N_{LP-SS-Block}$ can be regarded as 1. $T_{LP-SS-Block}$ or $N_{LP-SS-Block}$ can facilitate interlace transmission between SSB and LP-SS in time domain.

[0105] Figure 7(b) illustrates an example of the period T_{LP-SS} , the offset and the $T_{LP-SS-Block}$. As shown in Figure 7(b), it is assumed that $T_{SSB}=10$ ms, and the scaling factor K is 4, and $O_{LP-SS} = 0$. So, $T_{LP-SS} = K * T_{SSB} = 4 * 10 = 40$ ms; the start of LP-SS transmission (within the period T_{LP-SS}) $n_f \bmod (T_{LP-SS}/10) = O_{LP-SS}$, that is, $n_f \bmod (40/10) = n_f \bmod 4 = O_{LP-SS} = 0$, i.e., $n_f \bmod 4 = 0$. In Figure 7(b), the first frame in which the LP-SS block is transmitted within the period T_{LP-SS} is frame #0 and frame #4. Incidentally, in the example of Figure 7(b), the LP-SS is transmitted in the second 5 ms half frame. $T_{LP-SS-Block} = 10$ ms (or $N_{LP-SS-Block} = 2$) is also configured. So, the LP-SS block is also transmitted in the second half frame of frame #1 and the second half frame of frame #5. It can be seen from Figure 7(b) that SSB is transmitted in the first 5 ms half frame in each frame within the SSB period, so that interlace transmission between SSB and LP-SS in time domain can be achieved.

[0106] The $T_{LP-SS-Block}$ interval or period within the period T_{LP-SS} may be determined by the SSB period. For a first example, if the SSB period is 5 ms, the $T_{LP-SS-Block}$ interval can only be 5 ms. For a second example, if the SSB period is 10 ms (e.g., the SSB is transmitted only in the first half frame of the 10ms), the $T_{LP-SS-Block}$ interval can be 10 ms (e.g., the LP-SS is transmitted in the second half frame of the 10 ms) so that SSB and LP-SS are transmitted in interfaced manner (see Figure 7(b)). For a third example, if the SSB period is 20 ms (e.g., the SSB is transmitted only in the first half frame of the first frame of 20 ms), the $T_{LP-SS-Block}$ interval can be 5 ms (e.g., the LP-SS transmission starts from the second half frame of the first frame of 20 ms), which can avoid the transmission of SSB and LP-SS in the same half frame.

[0107] A second embodiment relates to repetition and mapping of the LP-SS block.

[0108] As mentioned above, LP-SS block is comprised of one or more LP-SS blocks with one or more repetitions.

[0109] As shown in Figure 8(a), it is assumed that $T_{SSB}=10\text{ms}$, and the scaling factor K is 2, and $O_{LP-SS} = 1$. So, $T_{LP-SS} = K * T_{SSB} = 2 * 10 = 20\text{ms}$; The start of LP-SS transmission $n_f \bmod (T_{LP-SS}/10) = O_{LP-SS}$, that is, $n_f \bmod (20/10) = n_f \bmod 2 = O_{LP-SS} = 1$, i.e., $n_f \bmod 2 = 1$. In the example of Figure 8(a), it is assumed that the LP-SS is transmitted with 8 beams (#0 to #7). In particular, in time domain, the LP-SS is transmitted with beam #0 to beam #7, respectively, in the first 5 ms half frame of frame #1, and is repeatedly transmitted with beam #0 to beam #7, respectively, in the second 5 ms half frame of frame #1 (suppose $T_{LP-SS-Block}$ is configured as 5 ms, or is not configured (that is, it is 5 ms by default)). The transmission of the LP-SS in frame #3 is the same as that in frame #1.

[0110] It can be seen that the two LP-SSs transmitted with beam #N (e.g., N is from 0 to 7) are discrete (i.e., not consecutive). For example, the repetition of the LP-SS transmitted with beam #0 is transmitted in the second half frame before the LP-SSs transmitted with beams #0 to #7 in the first half frame, where the LP-SS transmitted with a beam (e.g., beam #0) can be referred to as the LP-SS associated with the beam (e.g., beam #0).

[0111] In a variety of the configuration of the LP-SS block, the LP-SSs transmitted with the same beam #N (e.g., N is from 0 to 7) can be consecutive. As shown in Figure 8(b), the two LP-SSs transmitted with beam #0 are transmitted consecutively and before the transmission of the two LP-SSs transmitted with beam #1, the two LP-SSs transmitted with beam #1 are transmitted consecutively and before the transmission of the two LP-SSs transmitted with beam #2, and so on. The expression “two LP-SSs transmitted consecutively” means that they are transmitted in two consecutive LP-SS resources, where an LP-SS resource is a resource with consecutive symbols in time domain depending on the subcarrier spacing (e.g., 4 symbols for 15 kHz, 8 symbols for 30 kHz, ...), and each LP-SS resource is associated with one beam.

[0112] It can be seen that the LP-SS resources with the same beam can be consecutive (in Figure 8(b)) or discrete (in Figure 8(a)) among LP-SS resources.

[0113] In the above description, it is assumed that one LP-SS is mapped to one LP-SS resource (e.g., 4 symbols for 15 kHz subcarrier spacing), i.e., one LP-SS is transmitted in one LP-SS resource. However, it is possible that one LP-SS is longer than one LP-SS resource (which means that one LP-SS cannot be transmitted in only one LP-SS resource. Accordingly, an LP-SS can be mapped to two or more LP-SS resources to transmit. It is obvious that the number of LP-SS resources to which an LP-SS is mapped depends on the number of symbols of the LP-SS and the number of symbols of the LP-SS resource.

[0114] Figure 8(b) can be reused as an example of one LP-SS mapped to two LP-SS resources. For example, each LP-SS (e.g., LP-SS associated with beam #0) is mapped to two LP-SS resources.

[0115] A third embodiment relates to configuration of transmission of LP-SS and SSB with FDM (frequency division multiplex).

[0116] If the LP-SS and SSB are transmitted in the same carrier or the same BWP, they can be transmitted with FDM, which facilitates gNB beam management and hardware implementation. For example, the same transmission beam is assumed for SSB in MR and LP-SS in WUR, for the same time duration (or the same symbols).

[0117] The symbol index of LP-SS transmission is determined by the symbol index of associated SSB within 5 ms half frame. gNB may further indicate whether the LP-SS and the SSB are QCLed.

[0118] It is assumed that the LP-SS is transmitted in BWP#1 which has subcarrier spacing μ_1 , and the SSB is transmitted in BWP#2 which has subcarrier spacing μ_2 . In addition, the first symbol index of SSB in 5 ms half frame is shown in Table 1 and is denoted as m . Accordingly, the first symbol index of each LP-SS resource (where the LP-SS block is mapped to one or more LP-SS resources) in 5ms half frame is $m * 2^{\mu_1 - \mu_2}$, and the length of each LP-SS resource (where an LP-SS resource is used to transmit an LP-SS associated with a beam) is $4 * 2^{\mu_1 - \mu_2}$ (where it is implied that each SSB occupies 4 symbols). UE assumes that each LP-SS resource is associated with same SSB (where an SSB can be identified by an index or its associated beam).

[0119] For a first example, as shown in Figure 9(a), the subcarrier spacing of BWP#2 in which SSB is transmitted is 15kHz (i.e., $\mu_2=0$), the first symbol indices in the first and second SSB transmissions are $\{2, 8\}$. The subcarrier spacing of BWP#1 in which LP-SS is transmitted is 30kHz (i.e., $\mu_1=1$). So, the first symbols of the first and second LP-SS transmissions are $\{2, 8\} * 2^{\mu_1 - \mu_2} = \{2, 8\} * 2^{1-0} = \{4, 16\}$, and the length of each LP-SS resource is $4 * 2^{\mu_1 - \mu_2} = 4 * 2^{1-0} = 8$ symbols. For example, UE assumes that the LP-SS resource (that is used to transmit LP-SS #0) with first symbol index of 4 (and length of 8) is associated with the same SSB index (i.e., SSB #0) with first symbol index of 2 (and length of 4). The 8 symbols associated with same SSB index (i.e., SSB#0) starting from symbol index 4 can be used to transmit LP-SS (e.g., LP-SS#0). The LP-SS being transmitted in how many symbols of the 8 symbols depends on the length of LP-SS. For example, the LP-SS may be transmitted in all 8 symbols or in 4 of the 8 symbols.

[0120] For a second example, as shown in Figure 9(b), the subcarrier spacing of BWP#2 in which SSB is transmitted is 30 kHz (i.e., $\mu_2=1$), the first symbol index in half frame is $\{2, 8, 16, 22\}$. The subcarrier spacing of BWP#1 in which LP-SS is transmitted is 15 kHz (i.e., $\mu_1=0$). So, the first symbol in half frame is $\{2, 8, 16, 22\} * 2^{\mu_1 - \mu_2} = \{2, 8, 16, 22\} * 2^{0-1} = \{1, 4, 8, 11\}$, and the length of each LP-SS resource is $4 * 2^{\mu_1 - \mu_2} = 4 * 2^{0-1} = 2$.

[0121] Figure 9(c) illustrates a third example. The left part of Figure 9(c) is the same as Figure 9(b). Figure 9(c) differs from Figure 9(b) in that each LP-SS (e.g., LP-SS #0 to #3) is repeatedly transmitted in a next subframe (where one subframe is 1 ms). It means that each of LP-SS #0 to #3 is transmitted twice in two discrete LP-SS resources.

[0122] A fourth embodiment relates to configuration of transmission of LP-SS and SSB with TDM (time division multiplex).

[0123] LP-SS and SSB are transmitted in the same carrier or the same BWP with TDM. In this condition, LP-SS and SSB cannot be transmitted in the same time duration.

[0124] The first symbol index of each SSB within 5ms half frame is shown in Table 1. The first symbol index of LP-SS transmission within 5ms half frame is determined by the carrier of LP-SS (which implies the maximum number of subframes (where one subframe is 1 ms) that can be occupied by SSB block in a 5 ms period), subcarrier spacing of LP-SS (e.g., subcarrier spacing of the BWP in which LP-SS is transmitted) and the slot offset n_{offset} . If LP-SS and SSB are transmitted in the same BWP or the same carrier, the slot offset n_{offset} may be determined by subcarrier spacing of LP-SS, the total number of SSBs in an SSB block transmitted in the half frame. Alternatively, the slot offset n_{offset} may be implied (implicitly determined) by SSB period in the BWP or carrier. For example, if the SSB period is 40 ms, which implies that many half frames that are not used for SSB transmission can be used for LP-SS transmission in which the slot offset n_{offset} can be 0 with proper starting half frame of LP-SS transmission configuration. Further alternatively, the slot offset n_{offset} is configured by higher layer. In particular, the first symbol index of LP-SS transmission within 5ms half frame is indicated in Table 2.

Type	Subcarrier Spacing (kHz)	LP-SS first symbol index in half radio frame (5ms)
A	15	$\{2,8\}+14(n+n_{offset})$
B	30	$\{4,8,16,20\}+28(n+n_{offset})$
C	30	$\{2,8\}+14(n+n_{offset})$

Table 2

[0125] The slot offset n_{offset} is equal to $\text{ceil}(M/S)$ if the SSB is transmitted within half frame (5 ms). M is the total actual number of SSBs in an SSB block transmitted in the half frame. M can be configured or indicated by higher layer. S is the number of SSBs transmitted in a slot, that depends on the subcarrier spacing of SSBs (e.g., $S=2$ for subcarrier spacing of 15 kHz, $S=4$ for subcarrier spacing of 30 kHz, ...).

[0126] Figure 10(a) illustrates a first example. As shown in Figure 10(a), the SSB period is 10ms; and the total number of SSBs in the SSB block is 2 (i.e., $M=2$). The two SSBs (SSB #0 (S0) and SSB #1 (S1)) are transmitted in the first half frame (5 ms), and in particular, transmitted in the first subframe (1 ms) (subframe #0) of the first half frame. The SSBs are not transmitted in the remaining subframes (subframes #1, #2, #3 and #4) within the first half frame. The subcarrier spacing of LP-SS is 15 kHz (that is, $S=2$). Accordingly, $n_{offset} = \text{ceil}(M/S) = \text{ceil}(2/2) = 1$. The first symbol index of SSB transmission in the first half frame is $\{2, 8\} + 14n$, where $n=0$, that is, the first symbol index of SSB #0 and SSB #1 is 2 and 8. So, the first symbol index of LP-SS transmission in the first half frame is $\{2, 8\} + 14(n + n_{offset})$ (where $n=0$, and $n_{offset}=1$). That is, the first symbol indices of two LP-SSs (s0 and s1) are $\{2, 8\} + 14 = \{16, 22\}$.

[0127] If M can range from 2 to 8 and $S=2$, n_{offset} ranges from 1 to 4.

[0128] Figure 10(b) illustrates a second example. As shown in Figure 10(b), the SSB period is 20 ms; and the total number of SSBs in the SSB block is 7 (i.e., $M=7$). The seven SSBs (SSB #0 (S0) to SSB #6 (S6)) are transmitted in the first half frame (5 ms), and in particular, transmitted in the first two subframes (subframes #0 and #1) of the first half frame. The SSBs are not transmitted in the remaining subframes (e.g., subframes #2, #3, and #4) within the first half frame. The subcarrier spacing of LP-SS is 30 kHz (that is, $S=4$). Accordingly, $n_{offset} = \text{ceil}(M/S) = \text{ceil}(7/4) = 2$. The first symbol index of SSB transmission in the one half frame is $\{4, 8, 16, 20\} + 28n$, where $n=0, 1$. In particular, the first symbol indices of S0 to S6 are $\{4, 8, 16, 20, 32, 36, 44\}$. So, the first symbol index of LP-SS transmission in the first half frame is $\{4, 8, 16, 20\} + 28(n + n_{offset})$. In particular, the first symbol indices of seven LP-SSs (s0 to s6) are $\{4, 8, 16, 20, 32, 36, 44\} + 56$. Note that only s0, s1, s2 and s3 are shown in Figure 10(b) and s4, s5 and s6 are not shown.

[0129] In the above examples shown in Figures 10(a) and 10(b), the LP-SS is transmitted by each beam once in an LP-SS block. Alternatively, the LP-SS transmitted by each beam can be repeated (e.g., by a repetition number configured by higher layer).

[0130] Figure 11(a) illustrates a first example in which the repetition number is 2. As shown in Figure 11(a), the SSB period is 10ms; and the total number of SSBs in the SSB block is 8 (i.e., $M=8$). The eight SSBs (SSB #0 (S0) to SSB #7 (S7)) are transmitted in the first half frame (5 ms), and in particular, transmitted in the first four subframes (subframes #0, #1, #2 and #3) of the first half frame. The SSBs are not transmitted in the remaining subframe (subframe #4) within the first half frame. The subcarrier spacing of LP-SS is 15 kHz (that is, $S=2$). Accordingly, $n_{offset} = \text{ceil}(M/S) = \text{ceil}(8/2) = 4$. The first symbol index of SSB transmission in the first half frame is $\{2, 8\} + 14n$, where $n=0, 1, 2, 3$. So, the first symbol index of LP-SS transmission in the first half frame shall be $\{2, 8\} + 14(n + n_{offset}) = \{2, 8\} + 14*(4, 5, 6, 7)$. In consideration of the repetition number of 2, each LP-SS (each of s0 to s7) is transmitted twice. If the repetition is consecutive, each LP-SS transmitted by one beam is transmitted twice before the LP-SS transmitted by another beam. As shown in Figure 11(a), the LP-SS s0 is transmitted twice before the LP-SS s1 is transmitted twice. LP-SS s0 and its repetition are transmitted in the fifth subframe (subframe #4) within the first half frame, and s1 and its repetition to s5 and its repetition are transmitted in the five subframes within the second half frame. Since SSBs are transmitted in the first four subframes within the third half frame, s6 and its repetition are transmitted in the fifth subframe within the third half frame, and s7 and its repetition are transmitted in the first subframe within the fourth half frame.

[0131] Figure 11(b) illustrates a second example in which the repetition number is 2 while the repetition is discrete repetition. As shown in Figure 11(b), the SSB period is 10ms; and the total number of SSBs in the SSB block is 8 (i.e., $M=8$). The eight SSBs (SSB #0 (S0) to SSB #7 (S7)) are transmitted in the first half frame (5 ms), and in particular, transmitted in the first four subframes (subframes #0, #1, #2 and #3) within the first half frame. The SSBs are not transmitted in the remaining subframe (subframe #4) within the first half frame. The subcarrier spacing of LP-SS is 15 kHz (that is, $S=2$). Accordingly, $n_{offset} = \text{ceil}(M/S) = \text{ceil}(8/2) = 4$. The first symbol index of SSB transmission in the one

half frame is $\{2, 8\} + 14n$, where $n=0, 1, 2, 3$. In the example of Figure 11(b), it is assumed that the LP-SS does not transmit in the first four subframes (in which SSBs are possibly transmitted or gNB resource are reserved for other purposes) within any half frame. It suggests that UE assumes that the first four subframes within any half frame are reserved (e.g., for SSB transmission) and cannot be used for LP-SS transmission. Accordingly, the LP-SS is only transmitted in the fifth subframe of each half frame. It means that LP-SS s_0 and s_1 are transmitted in the first half frame; LP-SS s_2 and s_3 are transmitted in the second half frame; LP-SS s_4 and s_5 are transmitted in the third half frame; LP-SS s_6 and s_7 are transmitted in the fourth half frame. Based on the repetition number of 2 of discrete repetition, the repetitions of LP-SS s_0 and s_1 are transmitted in the fifth half frame; the repetitions of LP-SS s_2 and s_3 are transmitted in the sixth half frame; the repetitions of LP-SS s_4 and s_5 are transmitted in the seventh half frame; the repetitions of LP-SS s_6 and s_7 are transmitted in the eighth half frame. In each half frame, LP-SS (or its repetition) is transmitted in the fifth subframe with first symbol index $\{2, 8\}$.

[0132] Incidentally, if the slot offset n_{offset} is not configured, the slot offset n_{offset} is zero by default. For example, if SSBs and LP-SSs are transmitted in different half frames in the same carrier or BWP, the slot offset n_{offset} can be zero.

[0133] If LP-SSs and SSBs are transmitted in different BWPs (or different carriers), the slot offset n_{offset} can be determined by LP-SS frame type indication or LP-SS reserved half-frame or subframe indication.

[0134] The LP-SS frame type indication is to indicate all slots in the half frame or only the last slot(s) or partial slot(s) in the half frame are available for LP-SS transmission. For example, LP-SS transmission frame type “1001” (where each bit indicates one half frame within 20 ms) indicates that, for the first and the fourth half frames (i.e., indicated by ‘1’ of the first and the fourth bits), only partial slots (e.g., the last 3 slots) are available for LP-SS transmission, and for the second and the third half frames (i.e., indicated by ‘0’ of the second and the third bits), all slots are available for LP-SS transmission. If only partial slot(s) are available for LP-SS transmission (which may imply that the remaining slot(s) are reserved for SSB transmission or other purposes), the slot offset n_{offset} can be indicated by

higher layer. If all slots are available for LP-SS transmission (which may imply that no SSB transmission in any slot), the slot offset n_{offset} can be 0.

[0135] The LP-SS reserved frame indication is to indicate the frame reserved for other purposes (e.g., for SSB transmission) instead of LP-SS transmission, while the remaining frames are available for LP-SS transmission. The slot offset n_{offset} is indicated by higher layer for the frame reserved for other purposes (e.g., for SSB transmission). For the remaining frames available for LP-SS transmission, the slot offset n_{offset} can be 0. For example, in a 100 ms period (which includes 10 frames), a time offset $O_{offset} = 3$ may indicate that the third frame is reserved (i.e., not for LP-SS transmission).

[0136] In the above description of the LP-SS reserved frame indication, the granularity is frame. Alternatively, the granularity can be half frame or subframe. For example, in a 50 ms period (which includes 10 half frames), a time offset $O_{offset} = 3$ may indicate that the third half frame is reserved (i.e., not for LP-SS transmission). For another example, in a 10 ms period (which includes 10 subframes), a time offset $O_{offset} = 3$ may indicate that the third subframe is reserved (i.e., not for LP-SS transmission).

[0137] A fifth embodiment relates to information carried in LP-SS.

[0138] The LP-SS transmission may include the cell ID information, and may further include the indication of switching to MR. For example, due to system information change, gNB scheduling implementation of switch off WUR, channel condition change, etc, the UE needs to switch to MR.

[0139] The number of NR cell IDs is 1008, which means that 10 bits are necessary to carry the whole cell ID information. Generally, the LP-SS carries lower than 10 bits. So, a cell ID information, which carried a part of the cell ID, can be included in LP-SS. If M is the bits carried by LP-SS, partial cell ID information $X (= \text{cell ID mod } M)$ may be included in the LP-SS.

[0140] The bits carried by LP-SS are determined by the LP-SS length (i.e., the number of symbols per LP-SS) and transmission bit or segment of symbol (i.e., the number of bits that are carried in one symbol).

[0141] LP-SS can be generated by various methods, e.g., MC-OOK. For example, a first waveform (e.g., OOK-1) can be used to generate LP-SS, where each OFDM symbol carries one bit. For another example, a second waveform (e.g., OOK-4) can be used to generate LP-SS information of LP-SS, where each OFDM symbol carries multiple bits (e.g., 2 bits) information of LP-SS. For example, the OOK-4 may need DFT precoder before mapping the signal to frequency domain. The sequence of LP-SS (e.g., OOK-1 or OOK-4) can be generated with random QPSK sequence or ZC sequence.

[0142] For OOK-1, one bit is transmitted in each OFDM symbol. It means that two different states, one of which modulates 'on' chip and the other of which modulates 'off' chip, are mapped to resource elements (REs). For example, the random QPSK sequence or ZC sequence is mapped to REs to modulate 'on' chip in time domain, and zeros are mapped to the REs to modulate 'off' chip. OOK=1 means all subcarriers are modulated (can be modulated as random QPSK, ZC sequence). OOK=0 means all SCs are zero power (from base-band point of view).

[0143] For OOK-4, M-bits (e.g., 2 bits) on/off chip is mapped to one OFDM symbol.

[0144] For example, if the LP-SS length is configured as 4 symbols, and OOK-1 is used to generate LP-SS (e.g., one OFDM symbol carries 1 bit), then, only 4 bits can be included for LP-SS. So, partial cell ID information $X (= \text{cell ID} \bmod 4)$ is included in the LP-SS.

[0145] If for coverage enhancement consideration, the LP-SS length is configured as 8 symbols, and OOK-1 is used to generate LP-SS, then, 8 bits can be included for LP-SS. So, partial cell ID information $X (= \text{cell ID} \bmod 8)$ is included in the LP-SS.

[0146] For another example, the LP-SS length is configured as 4 symbols, and OOK-4 is used to generate LP-SS (e.g., one OFDM symbol carries 2 bits), then, 8 bits can be included for LP-SS. If one bit included in the LP-SS is used for indication of switching to MR, the remaining 7 bits in the LP-SS can be used for partial cell ID information $X (= \text{cell ID} \bmod 7)$.

[0147] A sixth embodiment relates to transmission power of LP-SS.

[0148] The transmission power of LP-SS is determined by higher layer. In particular, the transmission power of LP-SS can be configured as an offset to the the power of SSB, or an offset to the transmission power of LP-WUS.

[0149] Figure 12 illustrates a flowchart of a method 1200 in accordance with aspects of the present disclosure. The operations of the method may be implemented by a UE as described herein. In some implementations, the UE may execute a set of instructions to control the function elements of the UE to perform the described functions.

[0150] At 1202, receiving a first synchronization signal (SS) in a first frequency band.

[0151] At 1204, receiving a second SS in a second frequency band, wherein the second SS is associated with a second period and an offset.

[0152] Figure 13 illustrates a flowchart of a method 1300 in accordance with aspects of the present disclosure. The operations of the method may be implemented by a NE as described herein. In some implementations, the NE may execute a set of instructions to control the function elements of the NE to perform the described functions.

[0153] At 1302, transmitting a first synchronization signal (SS) in a first frequency band.

[0154] At 1304, transmitting a second SS in a second frequency band, wherein the second SS is associated with a second period and an offset.

[0155] It should be noted that the method described herein describes a possible implementation, and that the operations and the steps may be rearranged or otherwise modified and that other implementations are possible.

[0156] The description herein is provided to enable a person having ordinary skill in the art to make or use the disclosure. Various modifications to the disclosure will be apparent to a person having ordinary skill in the art, and the generic principles defined herein may be applied to other variations without departing from the scope of the disclosure. Thus, the disclosure is not limited to the examples and designs described herein but is to be accorded the broadest scope consistent with the principles and novel features disclosed herein.

CLAIMS

What is claimed is:

1. A user equipment (UE) for wireless communication, comprising:
at least one memory; and
at least one processor coupled with the at least one memory and
configured to cause the UE to:
receive a first synchronization signal (SS) in a first frequency
band; and
receive a second SS in a second frequency band, wherein
the second SS is associated with a second period and an offset.
2. The UE of claim 1, wherein,
the first frequency band and the second frequency band are the same
frequency band.
3. The UE of claim 1, wherein,
the second period is configured with a scaling factor of the period of
the first SS.
4. The UE of claim 1, wherein,
the offset includes a frame number offset within the second period.
5. The UE of claim 4, wherein,
the offset further includes indication of first half frame or second half
frame.
6. The UE of claim 1, wherein,
the second SS is transmitted with one of multiple second SS blocks
within each second period.
7. The UE of claim 6, wherein,

the second SS block is comprised of one or multiple associated beams and one or more repetitions.

8. The UE of claim 6, wherein,
the interval of the second SS blocks within each period is determined by higher layer or
by a default value in unit of half frame or
by the period of the first SS.
9. The UE of claim 1, wherein,
the second SS with the same beam is mapped to one or multiple second SS resources.
10. The UE of claim 1, wherein,
the symbol index(ice) of the second SS are determined by the symbol index(ice) of the first SS within a half frame.
11. The UE of claim 10, wherein, at least one processor is further configured to cause the UE to:
receive an indication of QCL information of the first SS and the second SS.
12. The UE of claim 1, wherein,
the first symbol index of the second SS within a half frame is determined by carrier of the second SS, subcarrier spacing of the second SS and a slot offset.
13. The UE of claim 12, wherein,
the slot offset
is determined by the subcarrier spacing of the second SS, and the total number of first SSs within a half frame, or
is determined by the period of the first SS, or
is configured by higher layer.

14. The UE of claim 12, wherein,
the slot offset is determined by second SS frame type indication or reserved frame indication.
15. The UE of claim 1, wherein,
the second SS includes cell ID information.
16. The UE of claim 15, wherein,
the second SS further includes indication of switching to the first frequency band.
17. The UE of claim 1, wherein,
the transmission power of the second SS is determined by the transmission power of the first SS or a wake-up signal and a power offset.
18. A processor in a UE for wireless communication, comprising:
at least one controller coupled with at least one memory and configured to cause the processor to:
receive a first synchronization signal (SS) in a first frequency band; and
receive a second SS in a second frequency band, wherein
the second SS is associated with a second period and an offset.
19. A method performed by a user equipment (UE), the method comprising:
receiving a first synchronization signal (SS) in a first frequency band; and
receiving a second SS in a second frequency band, wherein
the second SS is associated with a second period and an offset.
20. A base station for wireless communication, comprising:

at least one memory; and
at least one processor coupled with the at least one memory and
configured to cause the base station to:
transmit a first synchronization signal (SS) in a first frequency
band; and
transmit a second SS in a second frequency band, wherein
the second SS is associated with a second period and an offset.