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(54) Title: TRANSMISSION DETECTION OF NON-SCHEDULED UPLINK TRANSMISSIONS

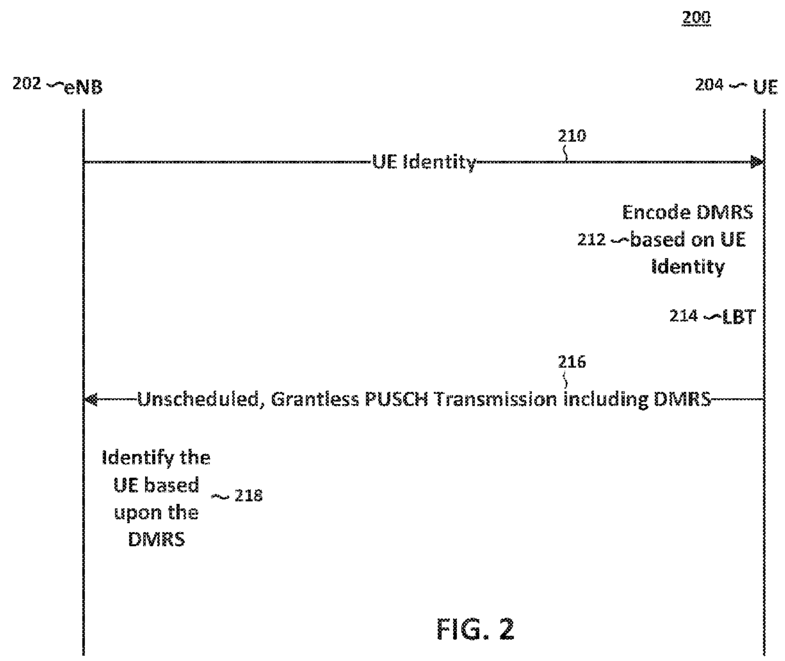

FIG. 2

(57) **Abstract**: Methods and apparatus are described by which user equipment (UE) transmits data over unlicensed spectrum using systems, such as Multe-Fire and enhanced Licensed-Assisted Access (eLAA). Embodiments transmit data over a physical uplink shared channel (PUSCH) channel to an evolved Node B (eNB) without first receiving an uplink (UL) grant from the eNB. Embodiments of DeModulation Reference Signals (DMRS) are described that allow the eNB to detect a presence of an uplink transmission and identify the UE transmitting data.

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TRANSMISSION DETECTION OF NON-SCHEDULED UPLINK TRANSMISSIONS

Priority Claim

[0001] This application claims priority to United States Provisional Patent Application Serial No. 62/299,995 filed February 25, 2016, entitled "PUSCH DETECTION AND UE IDENTIFICATION FOR NON-SCHEDULED MODE IN MULTEFIRE/ELAA SYSTEMS" which is incorporated herein by reference in its entirety.

Technical Field

[0002] Embodiments described herein relate generally to wireless networks and communications systems. Some embodiments relate to cellular communication networks including 3GPP (Third Generation Partnership Project) networks, 3GPP LTE (Long Term Evolution) networks, and 3GPP LTE-A (LTE Advanced) networks, MulteFire™ (MF) networks, and 5G networks, although the scope of the embodiments is not limited in this respect. Some embodiments relate to an evolved NodeB (eNB) identifying user equipment (UE) that has transmitted data to the eNB over unlicensed spectrum based upon how the UE generates a DeModulation reference signal (DMRS). Other embodiments relate to the UE generating the DMRS to indicate the origin and presence of data transmissions.

Background

[0003] The explosive growth in wireless traffic growth has led to an urgent need for rate improvement. With mature physical layer techniques, further improvement in spectral efficiency will be marginal. On the other hand, the scarcity of licensed spectrum in the low frequency band makes spectral expansion problematic. Thus, there are emerging interests in the operation of LTE systems in unlicensed spectrum. One such technique is labeled enhanced Licensed-Assisted Access (eLAA), which expands the system bandwidth by utilizing the flexible carrier aggregation (CA) framework introduced by the LTE-Advanced where a primary component carrier (termed the primary cell or PCell) is operated in licensed spectrum and one or secondary component carriers (termed secondary cells or SCells) are operated in unlicensed spectrum. Another approach is a standalone LTE system in the unlicensed spectrum, where LTE-based technology solely operates in unlicensed spectrum without requiring an "anchor" in licensed spectrum. This is an MF system.

[0004] In order to operate in unlicensed spectrum, MF and eLAA systems require signal structures and signaling techniques different from those of legacy LTE systems. For example, the non-exclusive nature of unlicensed spectrum requires a mechanism for eLAA/MF systems to fairly share the wireless medium with other systems including those operating with other technologies such as Wi-Fi. eLAA/MF incorporate a LBT procedure where radio transmitters first sense the medium and transmit only if the medium is sensed to be idle.

[0005] The LBT procedure can cause performance issues. For example, in eLAA and MF systems, the uplink (UL) throughput performance can be noticeably degraded. One cause of this degradation is due to the inefficiency of operating a scheduled system in unlicensed spectrum. The UL grant transmission requires a completion of multiple LBT procedures. For example, a LBT procedure occurs at the evolved NodeB (eNB) on the component carrier over which physical downlink control channel (PDCCH) scheduling a physical uplink shared channel (PUSCH) transmission or a physical uplink control channel (PUCCH) (*e.g.*, enhanced PUCCH (ePUCCH) in MF systems) is expected. Upon the reception of the UL grant carried in the PDCCH, the scheduled UE also performs an LBT before transmission. In addition, the at least four subframe latency between UL grant and the corresponding PUSCH/PUCCH transmission can also attribute to the UL performance issue.

[0006] One way to reduce these performance issues is to allow UEs to transmit data on the PUSCH without requiring the UE to receive a UL grant. The present disclosure relates to procedures for allowing a UE to identify itself and the presence of the grantless transmissions to an eNB when the UE transmits data in an unscheduled, grantless mode. The UE may generate a DeModulation

Reference Signal (DMRS) in such a way that once the eNB detects the DMRS, the eNB can identify the UE that sent both the DMRS and related data symbols.

Brief Description of the Drawings

[0007] FIG. 1 is a block diagram of a system including an evolved node B (eNB) and a user equipment (UE) that may operate in a wireless telecommunications network according to some embodiments described herein.

[0008] FIG. 2 illustrates an example timing diagram of a non-scheduled, grantless UE transmission on unlicensed spectrum that identifies the UE according to some embodiments.

[0009] FIG. 3 illustrates an interlaced structure for uplink transmissions according to some embodiments.

[0010] FIG. 4 is a block diagram of a User Equipment (UE) in accordance with some embodiments.

[0011] FIG. 5 illustrates a block diagram of a communication device such as an eNB or a UE, in accordance with some embodiments.

Detailed Description

[0012] In Long Term Evolution (LTE) systems, a mobile terminal (referred to as a User Equipment or UE) connects to the cellular network via a base station (referred to as an evolved Node B or eNB). LTE systems usually utilize licensed spectrum for both uplink (UL) and downlink (DL) transmissions between a UE and an eNB. Fig. 1 illustrates an example of the components of a UE 120 and a base station or eNB 100. The eNB 100 includes processing circuitry 101 connected to a radio transceiver 102 for providing an air interface. The UE 120 includes processing circuitry 121 connected to a radio transceiver 122 for providing an air interface over the wireless medium. Each of the transceivers in the devices is connected to antennas 150.

[0013] In various embodiments, the UE 120 may transmit data to the eNB 100 using unlicensed spectrum. For example, the UE 120 may use a MF system to transmit data over the PUSCH to the eNB 100. In this mode, the UE 120 does not request or receive a UL grant from the eNB 100 before transmitting data on the PUSCH. When a UL grant is used, the UL grant provides a time and resources that the UE 120 uses to transmit data to the eNB 100. The eNB 100 knows what UE 120 is transmitting to the eNB 100 based upon the time and resources specified in the UL grant. When the UE 120 transmits without a UL grant, in a nonscheduled, grantless mode, the eNB 100 is unaware that a UE 120 is transmitting data. The eNB 100, therefore, needs a way to identify both a data transmission is occurring and the UE 120 that is transmitting data. In addition, the eNB 100 needs a way to determine when a UL burst has started. In various embodiments, the DMRS is generated by the transmitting UE 120 in a way that identifies the UE 120. Upon detecting the DMRS, the eNB 100 is able to identify the UE 120 and may infer a UL burst has started. The DMRS may also be used by the eNB to identify the number of carriers the UE is using for the UL burst transmission. After the eNB successfully detects a DMRS on multiple carriers, where each DMRS identifies the same UE, the eNB may determine the number of carriers being used by the UE.

[0014] FIG. 2 illustrates an example timing diagram 200 of a non-scheduled, grantless UE transmission on unlicensed spectrum that identifies the UE according to some embodiments. Using downlink signaling, an eNB 202 provides a UE 204 with a UE identity 210. In some embodiments, the UE identity uniquely identifies each UE that is communicating with the eNB 202. The eNB 202 may keep a mapping between the UE identity and the corresponding UE. For example, the eNB 202 may map the UE identity to another identifier that uniquely identifies the UE within the system or between two or more eNBs. The eNB 202 may use a radio network temporary identifier (RNTI) such as a cell RNTI (C-RNTI) as the UE identity. In other embodiments, the UE identity may be set by the UE rather than the eNB. For example, the UE identity can be an identity that is assigned to the SIM card used by the UE.

[0015] In some embodiments, the mapping of the DMRS sequence to a UE identity is unique, such that the DMRS uniquely identifies a single UE. In other embodiments, a DMRS can be mapped to two or more UEs. Mapping multiple UEs to a single DMRS reduces the collision probability among UEs transmitting grantless UL transmissions simultaneously on the same resources. In these embodiments, the eNB may use information from control information that is part of the data transmission to determine the UE. For example, the control information can include the UE identity.

[0016] When the UE 204 wants to send data to the eNB 202 in a grantless, unscheduled mode, the eNB 202 will not have advanced knowledge of the transmission. The eNB 202, therefore, needs to detect the presence of a transmission and identify the UE that is transmitting. Any sequence with a constant amplitude zero autocorrelation property can be used to identify the presence of a transmission, reduce collisions amount UEs and may provide information on the UE identity. For example, a DMRS uses a Zadoff-Chu (ZC) sequence. The DMRS, therefore, can be used to detect the presence of PUSCH data transmissions, to estimate the channel, and provide the identity information of the UE transmitting the data.

[0017] In various embodiments, the UE 204 may generate a DMRS in a way that indicates or provides some information on the UE's identity. There are three aspects of the DMRS that may be used. A root index determines the base sequence of the DMRS. A cyclic shift (CS) is used to make the DMRS orthogonal in the frequency domain. An orthogonal cover code (OCC) may be applied in the time domain and/or frequency domain to make the DMRS signal orthogonal to other DMRSs. When the DMRS is detected by the eNB 202, the eNB 202 determines the root index, CS, and OCC that were used to generate the DMRS. Not all three aspects, however, are required for generating/detecting the DMRS. For example, just the root index, or the root index and CS may be used to generate the DMRS. In addition, not all three aspects are required for identifying a PUSCH transmission and/or UE identity. For example, just the root index may be used to identify the presence of the transmission and to provide information on the UE identity. In other embodiments, the CS and OCC together may be used to generate the DMRS and identify the presence of the PUSCH transmission and the transmitting UE's identity.

[0018] Before transmitting data on unlicensed spectrum, the UE performs a successful LBT procedure 214 on one or more carriers. Once the LBT procedure indicates that the one or more carriers are available, the UE 204 transmits both data and one or more DMRSs 216 to the eNB 202 on the available carrier(s). Because the eNB 202 does not have knowledge that the UE is transmitting data, the eNB may blindly detect if there is any grantless transmission on the available resources. For example, the eNB may correlate received signals on any resource used for grantless, unscheduled UE transmissions with the set of DMRS sequences that are used to detect the presence of grantless transmissions. When the eNB 202 detects a specific DMRS sequence, the eNB 202 determines the parameters, such as the root index, CS, and OCC, used by the UE to generate the DMRS. Using one or more of the root index, CS, and OCC, the eNB 202 is able to determine the presence of a grantless transmission and some information on the UE identity of the UE that transmitted the DMRS. In some embodiments, the information on the UE identity identifies the transmitting UE. If a one-to-one mapping is used, the eNB 202 is able to determine the UE itself 218. If there is a one-to-many mapping, the eNB is able to select a set of UEs who share the received DMRS sequence. The UE identity can be decoded from the data portion of the grantless transmission and matched to one of the set of UEs.

[0019] Selecting the root index, CS, and OCC may be done in various ways. In some embodiments, the eNB can signal the root index, CS, and/or OCC via radio resource control (RRC) signaling or other high layer signaling. In other embodiments, the selection of the root index, CS, and OCC can be a function of the UE identity. For example, the root index may be selected using a modulo operation. For example, mod(UE identity, N) where N is the number of available root indexes that can be used for grantless, non-scheduled transmissions. The selection of the CS and OCC may be done is a similar way. The CS may be selected as mod(UE identity, N), where N is the number of available CS, *e.g.*, 12. The OCC can be selected as mod(UE identity, N) where N is the number of available OCCs. In some embodiments the UE identity is a radio network temporary identifier (RNTI) such as a cell RNTI (C-RNTI).

[0020] The number of available root indexes used for grantless, non-scheduled transmission may be determined to integrate with legacy LTE systems. For root index selection, the length of the ZC sequence used for DMRS generation is the largest prime number that is smaller than the number of Resource Elements (REs) that is used for the grantless transmission, denoted by M, e.g. M=113 if one interlace is used and M=1193 if ten interlaces are used for grantless transmission, such that there are a total of 113 possible ZC sequences that could be used. When the length of DMRS is larger than the length of ZC sequence M, the ZC sequence is extended to the length of DMRS by copying the first (length of DMRS-M) elements to the end of the ZC sequence. For example, when DMRS length is 120, it includes the 113 ZC sequence with elements 0-6 added at the end of the ZC sequence. The number of root indexes used in legacy LTE systems defined to generate an UL DMRS is 60, leaving M-60 unused but available ZC sequences that may be used to generate M-60 root indexes. In some embodiments, M is equal 113 leading to 53 root indexes that can be used for grantless transmissions. In some embodiments, some or all of the defined 60 root indexes may be allocated to scheduled UEs. A function, such as those defined above, may be used to map a root index to a particular UE. The remaining and unused 53 root indexes may be used for non-scheduled, grantless UEs. A function, such as those defined above, may be used to map a root index to a particular UE. Different functions may be used for the two groups of root indexes. In other embodiments, two separate sets of root indexes are defined, with one set being used by scheduled UL transmissions and the other set being used by non-scheduled, grantless UL transmissions. In these embodiments, a part of the 60 DMRS sequences may be assigned to scheduled UL transmissions while another part of the 60 DMRS sequences may be assigned to grantless transmission.

[0021] In some embodiments, the eNB may provide the set of available root indexes to the UE via downlink signaling. The UE may then select the root index to use based upon its UE identity. In these embodiments, the eNB may know the UE identity and the function used by the UE to select a root index, allowing the eNB to map a root index to a UE identity. In other embodiments, the UE may receive the available root indexes as part of a system information or received from an eNB but indicated as being used across multiple eNBs or the entire system. Yet, in other embodiments, the eNB provides the root index that a particular UE should use via downlink signaling. The other aspects of an DMRS, *e.g.*, CS and OCC, may be provided/determined in similar ways.

[0022] Once the DMRS is generated as described above, the UE transmits the DMRS to the eNB. The DMRS allows the eNB to identify the presence of a

UL transmission and determine the identity of the UE that is transmitting the data as described above. FIG. 3 illustrates an interlaced structure for uplink transmissions according to some embodiments. A first graph 302 illustrates various interlaces, where the y-axes may represent resource block (RB) indexes and the x-axes may represent symbols. In some embodiments, each interlace includes ten physical resource blocks (PRBs). Each interlace is shown in Figure 3 as rows with different shading to differentiate different interlaces. In some embodiments, the system bandwidth may be 20MHz, with a total of one hundred PRBs and ten interlaces. The distance between PRBs in the same interlace is a multiple of 10. For example, interlace 0 has PRB0, PRB10, PRB20, and up through PRB90. Interlace 1 has PRB1, PRB11, PRB21, and up through PRB91. In other embodiments, the system bandwidth may be 10MHz. In these embodiments, there may be 50 PRBs and 5 interlaces, each of which still has 10 PRBs.

[0023] Each RB may have 12 subcarriers, which are illustrated in a second graph 304. The symbols illustrated in graphs 302 and 304 may be symbols that are transmitted on the PUSCH. Transmission of resource blocks can be interlaced with other resource blocks as shown, similar to the PUSCH and short physical uplink control channel (sPUCCH) transmissions in MF systems. Multiple interlaces can be allocated to different UEs or to the same UE.

[0024] In some embodiments, the DMRS may be transmitted at the center symbol of a slot within an UL transmission. This is similar to where the DMRS is transmitted in PUSCH transmissions in legacy LTE systems. For example, two slots 310 and 312 may be defined. Each illustrated slot includes seven symbols. The DMRS may be transmitted as the center symbol of each slot, illustrated as symbol 320 for slot 310 and 322 for slot 312. The other symbols 330 may be used to transmit data from the UE.

[0025] The DMRS may also be transmitted at the start of a UL burst. This allows the DMRS to be used as an initial signal to indicate to the eNB that a UL burst from a particular UE is starting. As the eNB does not know when and exactly where a grantless, non-scheduled UE transmission will arrive, a successful detected DMRS may indicate that a UL burst follows the DMRS.

[0026] As part of using unlicensed spectrum, a UE completes a LBT procedure prior to transmitting data. In addition, due to the nature of unlicensed spectrum, various devices may transmit at any time within the same unlicensed spectrum. A UE may complete a LBT procedure at any time but be unable to start transmitting data due to the subframe or slot boundary alignment requirement of PUSCH transmissions. For example, the LBT procedure may complete in the middle of a subframe, slot, and/or symbol, such that the UE needs to wait for the next subframe, slot, and/or symbol boundary before transmitting data. If the UE, however, does not start transmitting some data another device could complete its LBT procedure and start transmitting, thus, grabbing the channel and blocking the transmission of the UE. In some embodiments, after the LBT procedure the UE may repeatedly transmit a DMRS to reserve the spectrum. In these embodiments, the eNB can use this leading DMRS to determine that the UE will soon begin a non-scheduled, grantless data transmission. In some embodiments, the DMRS is transmitted at the start of a UL transmission after the end of a successful LBT and before the following slot or subframe boundary where a PUSCH transmission can start. The DMRS may still be transmitted at the center symbol in each slot of the PUSCH transmission. In some embodiments, the DMRS sequence transmitted before the start of PUSCH transmission and the DMRS sequence transmitted within PUSCH subframes may be different.

[0027] When the DMRS is used at the start of a UL burst or as a reservation signal, the eNB is able to detect the UL transmission earlier than if the DMRS is only transmitted in the center symbol of each slot of the PUSCH transmission. In addition, the DMRS transmitted at the start of a UL burst may indicate, to the eNB, the start of a UL burst. This allows the UE to start a UL burst within a partial subframe or slot, where the UL burst is not aligned with the subframe or slot boundary. The DMRS may also provide an automatic gain control (AGC) setting for each UL burst transmission.

[0028] As used herein, the term "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.

[0029] Embodiments described herein may be implemented into a system using any suitably configured hardware and/or software. Fig. 4 illustrates, for one embodiment, example components of a User Equipment (UE) device 400. The example components may also be used in an eNB. In some embodiments, the UE device 400 may include application circuitry 402, baseband circuitry 404, Radio Frequency (RF) circuitry 406, front-end module (FEM) circuitry 408 and one or more antennas 410, coupled together at least as shown.

[0030] The application circuitry 402 may include one or more application processors. For example, the application circuitry 402 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 and/or may include memory/storage and may be configured to execute instructions stored in the memory/storage to enable various applications and/or operating systems to run on the system.

[0031] The baseband circuitry 404 may include circuitry such as, but not limited to, one or more single-core or multi-core processors. The baseband circuitry 404 may include one or more baseband processors and/or control logic to process baseband signals received from a receive signal path of the RF circuitry 406 and to generate baseband signals for a transmit signal path of the RF circuitry 406. Baseband processing circuity 404 may interface with the application circuitry 402 for generation and processing of the baseband signals and for controlling operations of the RF circuitry 406. For example, in some embodiments, the baseband circuitry 404 may include a second generation (2G) baseband processor 404a, third generation (3G) baseband processor 404b, fourth generation (4G) baseband processor 404c, and/or other baseband processor(s) 404d for other existing generations, generations in development or to be developed in the future (e.g., fifth generation (5G), 6G, etc.). The baseband circuitry 404 (e.g., one or more of baseband processors 404a-d) may handle various radio control functions that enable communication with one or more radio networks via the RF circuitry 406. 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 404 may include Fast-Fourier Transform (FFT), precoding, and/or constellation mapping/demapping functionality. In some embodiments, encoding/decoding circuitry of the baseband circuitry 404 may include convolution, tail-biting convolution, turbo, Viterbi, and/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.

[0032] In some embodiments, the baseband circuitry 404 may include elements of a protocol stack such as, for example, elements of an evolved universal terrestrial radio access network (EUTRAN) protocol including, for example, physical (PHY), media access control (MAC), radio link control (RLC), packet data convergence protocol (PDCP), and/or radio resource control (RRC) elements. A central processing unit (CPU) 404e of the baseband circuitry 404 may be configured to run elements of the protocol stack for signaling of the PHY, MAC, RLC, PDCP and/or RRC layers. In some embodiments, the baseband circuitry may include one or more audio digital signal processor(s) (DSP) 404f. The audio DSP(s) 404f 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 404 and the application circuitry 402 may be implemented together such as, for example, on a system on a chip (SOC).

[0033] In some embodiments, the baseband circuitry 404 may provide for communication compatible with one or more radio technologies. For example, in some embodiments, the baseband circuitry 404 may support communication with an evolved universal terrestrial radio access network (EUTRAN) and/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 404 is configured to support radio communications of more than one wireless protocol may be referred to as multi-mode baseband circuitry.

[0034] RF circuitry 406 may enable communication with wireless networks using modulated electromagnetic radiation through a non-solid medium. In various embodiments, the RF circuitry 406 may include switches, filters, amplifiers, etc. to facilitate the communication with the wireless network. RF circuitry 406 may include a receive signal path which may include circuitry to down-convert RF signals received from the FEM circuitry 408 and provide baseband signals to the baseband circuitry 404. RF circuitry 406 may also include a transmit signal path which may include circuitry to up-convert baseband signals provided by the baseband circuitry 404 and provide RF output signals to the FEM circuitry 408 for transmission.

[0035] In some embodiments, the RF circuitry 406 may include a receive signal path and a transmit signal path. The receive signal path of the RF circuitry 406 may include mixer circuitry 406a, amplifier circuitry 406b and filter circuitry 406c. The transmit signal path of the RF circuitry 406 may include filter circuitry 406c and mixer circuitry 406a. RF circuitry 406 may also include synthesizer circuitry 406d for synthesizing a frequency for use by the mixer circuitry 406a of the receive signal path and the transmit signal path. In some embodiments, the mixer circuitry 406a of the receive signal path may be configured to down-convert RF signals received from the FEM circuitry 408 based on the synthesized frequency provided by synthesizer circuitry 406d. The amplifier circuitry 406b may be configured to amplify the down-converted signals and the filter circuitry 406c 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 404 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 406a of the receive signal path may comprise passive mixers, although the scope of the embodiments is not limited in this respect.

[0036] In some embodiments, the mixer circuitry 406a of the transmit signal path may be configured to up-convert input baseband signals based on the synthesized frequency provided by the synthesizer circuitry 406d to generate RF output signals for the FEM circuitry 408. The baseband signals may be provided by the baseband circuitry 404 and may be filtered by filter circuitry 406c. The filter circuitry 406c may include a low-pass filter (LPF), although the scope of the embodiments is not limited in this respect.

[0037] In some embodiments, the mixer circuitry 406a of the receive signal path and the mixer circuitry 406a of the transmit signal path may include two or more mixers and may be arranged for quadrature downconversion and/or upconversion respectively. In some embodiments, the mixer circuitry 406a of the receive signal path and the mixer circuitry 406a 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 406a of the receive signal path and the mixer circuitry 406a may be arranged for direct downconversion and/or direct upconversion, respectively. In some embodiments, the mixer circuitry 406a of the receive signal path and the mixer circuitry 406a of the transmit signal path may be configured for super-heterodyne operation.

[0038] 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 406 may include analog-to-digital converter (ADC) and digital-to-analog converter (DAC) circuitry and the baseband circuitry 404 may include a digital baseband interface to communicate with the RF circuitry 406.

[0039] 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.

[0040] In some embodiments, the synthesizer circuitry 406d may be a fractional-N synthesizer or a fractional N/N+1 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 406d may be a delta-sigma synthesizer, a frequency multiplier, or a synthesizer comprising a phase-locked loop with a frequency divider.

[0041] The synthesizer circuitry 406d may be configured to synthesize an output frequency for use by the mixer circuitry 406a of the RF circuitry 406 based on a frequency input and a divider control input. In some embodiments, the synthesizer circuitry 406d may be a fractional N/N+1 synthesizer.

[0042] 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 404 or the applications processor 402 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 402.

[0043] Synthesizer circuitry 406d of the RF circuitry 406 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+1 (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.

[0044] In some embodiments, synthesizer circuitry 406d 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 (f_{LO}). In some embodiments, the RF circuitry 406 may include an IQ/polar converter.

[0045] FEM circuitry 408 may include a receive signal path which may include circuitry configured to operate on RF signals received from one or more antennas 410, amplify the received signals and provide the amplified versions of the received signals to the RF circuitry 406 for further processing. FEM circuitry 408 may also include a transmit signal path which may include circuitry configured to amplify signals for transmission provided by the RF circuitry 406 for transmission by one or more of the one or more antennas 410.

[0046] In some embodiments, the FEM circuitry 408 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 a low-noise amplifier (LNA) to amplify received RF signals and provide the amplified received RF signals as an output (e.g., to the RF circuitry 406). The transmit signal path of the FEM circuitry 408 may include a power amplifier (PA) to amplify input RF signals (e.g., provided by RF circuitry 406), and one or more filters to generate RF signals for subsequent transmission (e.g., by one or more of the one or more antennas 410.

[0047] In some embodiments, the UE device 400 may include additional elements such as, for example, memory/storage, display, camera, sensor, and/or input/output (I/O) interface.

[0048] <u>Example Machine Description</u>

[0049] Fig. 5 illustrates a block diagram of an example machine 500 upon which any one or more of the techniques (e.g., methodologies) discussed herein may perform. In alternative embodiments, the machine 500 may operate as a standalone device or may be connected (e.g., networked) to other machines. In a networked deployment, the machine 500 may operate in the capacity of a server machine, a client machine, or both in server-client network environments. In an example, the machine 500 may act as a peer machine in peer-to-peer (P2P) (or other distributed) network environment. The machine 500 may be a user equipment (UE), evolved Node B (eNB), Wi-Fi access point (AP), Wi-Fi station (STA), personal computer (PC), a tablet PC, a set-top box (STB), a personal digital assistant (PDA), a mobile telephone, a smart phone, a web appliance, a network router, switch or bridge, or any machine capable of executing instructions (sequential or otherwise) that specify actions to be taken by that machine. Further, while only a single machine is illustrated, the term "machine" shall also be taken to include any collection of machines that individually or jointly execute a set (or multiple sets) of instructions to perform any one or more of the methodologies discussed herein, such as cloud computing, software as a service (SaaS), other computer cluster configurations.

[0050] Examples, as described herein, may include, or may operate on, logic or a number of components, modules, or mechanisms. Modules are tangible entities (e.g., hardware) capable of performing specified operations and may be configured or arranged in a certain manner. In an example, circuits may be arranged (e.g., internally or with respect to external entities such as other circuits) in a specified manner as a module. In an example, the whole or part of one or more computer systems (e.g., a standalone, client or server computer system) or one or more hardware processors may be configured by firmware or software (e.g., instructions, an application portion, or an application) as a module that operates to perform specified operations. In an example, the software may reside on a machine readable medium. In an example, the software, when executed by the underlying hardware of the module, causes the hardware to perform the specified operations.

[0051] Accordingly, the term "module" is understood to encompass a tangible entity, be that an entity that is physically constructed, specifically configured (e.g., hardwired), or temporarily (e.g., transitorily) configured (e.g., programmed) to operate in a specified manner or to perform part or all of any operation described herein. Considering examples in which modules are temporarily configured, each of the modules need not be instantiated at any one moment in time. For example, where the modules comprise a general-purpose hardware processor configured using software, the general-purpose hardware processor may be configured as respective different modules at different times. Software may accordingly configure a hardware processor, for example, to constitute a particular module at one instance of time and to constitute a different module at a different instance of time.

[0052] Machine (e.g., computer system) 500 may include a hardware processor 502 (e.g., a central processing unit (CPU), a graphics processing unit (GPU), a hardware processor core, or any combination thereof), a main memory 504 and a static memory 506, some or all of which may communicate with each other via an interlink (e.g., bus) 508. The machine 500 may further include a display unit 510, an alphanumeric input device 512 (e.g., a keyboard), and a user interface (UI) navigation device 514 (e.g., a mouse). In an example, the display unit 510, input device 512 and UI navigation device 514 may be a touch screen display. The machine 500 may additionally include a storage device (e.g., drive unit) 516, a signal generation device 518 (e.g., a speaker), a network interface device 520, and one or more sensors, such as a global positioning system (GPS) sensor, compass, accelerometer, or other sensor. The machine 500 may include an output controller 528, such as a serial (e.g., universal serial bus (USB), parallel, or other wired or wireless (e.g., infrared (IR), near field communication (NFC), etc.) connection to communicate or control one or more peripheral devices (e.g., a printer, card reader, etc.).

[0053] The storage device 516 may include a machine readable medium 522 on which is stored one or more sets of data structures or instructions 524 (e.g., software) embodying or utilized by any one or more of the techniques or functions described herein. The instructions 524 may also reside, completely or at least partially, within the main memory 504, within static memory 506, or within the hardware processor 502 during execution thereof by the machine 500. In an example, one or any combination of the hardware processor 502, the main memory 504, the static memory 506, or the storage device 516 may constitute machine readable media.

[0054] While the machine readable medium 522 is illustrated as a single medium, the term "machine readable medium" may include a single medium or multiple media (e.g., a centralized or distributed database, and/or associated caches and servers) configured to store the one or more instructions 524.

[0055] The term “machine readable medium” may include any medium that is capable of storing, encoding, or carrying instructions for execution by the machine 500 and that cause the machine 500 to perform any one or more of the techniques of the present disclosure, or that is capable of storing, encoding or carrying data structures used by or associated with such instructions. Non-limiting machine readable medium examples may include solid-state memories, and optical and magnetic media. Specific examples of machine readable media may include: non-volatile memory, such as semiconductor memory devices (e.g., Electrically Programmable Read-Only Memory (EPROM), Electrically Erasable Programmable Read-Only Memory (EEPROM)) and flash memory devices; magnetic disks, such as internal hard disks and removable disks; magneto-optical disks; Random Access Memory (RAM); and CD-ROM and DVD-ROM disks. In some examples, machine readable media may include non-transitory machine readable media. In some examples, machine readable media may include machine readable media that is not a transitory propagating signal.

[0056] The instructions 524 may further be transmitted or received over a communications network 526 using a transmission medium via the network interface device 520 utilizing any one of a number of transfer protocols (e.g., frame relay, internet protocol (IP), transmission control protocol (TCP), user datagram protocol (UDP), hypertext transfer protocol (HTTP), etc.). Example communication networks may include a local area network (LAN), a wide area network (WAN), a packet data network (e.g., the Internet), mobile telephone networks (e.g., cellular networks), Plain Old Telephone (POTS) networks, and wireless data networks (e.g., Institute of Electrical and Electronics Engineers (IEEE) 802.11 family of standards known as Wi-Fi®, IEEE 802.16 family of standards known as WiMax®), IEEE 802.15.4 family of standards, a Long Term Evolution (LTE) family of standards, a Universal Mobile Telecommunications System (UMTS) family of standards, peer-to-peer (P2P) networks, among others. In an example, the network interface device 520 may include one or more physical jacks (e.g., Ethernet, coaxial, or phone jacks) or one or more antennas to connect to the communications network 526. In an example, the network interface device 520 may include a plurality of antennas to wirelessly communicate using at least one of single-input multiple-output (SIMO), multiple-input multiple-output (MIMO), or multiple-input single-output (MISO) techniques. In some examples, the network interface device 520 may wirelessly communicate using Multiple User MIMO techniques. The term "transmission medium" shall be taken to include any intangible medium that is capable of storing, encoding or carrying instructions for execution by the machine 500, and includes digital or analog communications signals or other intangible medium to facilitate communication of such software.

[0057] Additional notes and examples:

[0058] Example 1 is an apparatus of an evolved Node B (eNB), the apparatus comprising: memory and processing circuitry configured to: map a user equipment (UE) identity to a UE; correlate a DeModulation Reference Signal (DMRS), received on unlicensed spectrum on a physical uplink shared channel (PUSCH) from an unidentified UE, across a plurality of possible root indexes to determine a root index used to generate the DMRS, and wherein the DMRS was transmitted as part of a grant-less, unscheduled transmission unassociated with an uplink grant; determine a UE identity of the unidentified UE based upon at least the root index; and identify the UE mapped to the UE identity, wherein the UE transmitted the DMRS.

[0059] In Example 2, the subject matter of Example 1 optionally includes wherein data is transmitted on the one or more channels using a frame structure comprised of slots, each slot comprising seven symbols, and wherein the DMRS is received at a center of each slot.

[0060] In Example 3, the subject matter of any one or more of Examples 1–2 optionally include wherein the DMRS is received at a start of an uplink burst.

[0061] In Example 4, the subject matter of any one or more of Examples 1–3 optionally include wherein the DMRS is received after a start and before an end of an uplink (UL) subframe, the processing circuitry is further configured to: receive additional DMRSs up to an end of the UL subframe; and decode PUSCH data from the UE as part of a UL burst starting in a next UL subframe after the UL subframe.

[0062] In Example 5, the subject matter of any one or more of Examples 1–4 optionally include wherein the processing circuity is further configured to encode an indication of a set of DMRS sequences that can be used for grantless transmissions in radio resource control (RRC) signaling for the UE.

[0063] In Example 6, the subject matter of any one or more of Examples 1–5 optionally include wherein the processing circuitry is further configured to decode the UE identity from PUSCH data from the UE.

[0064] In Example 7, the subject matter of any one or more of Examples 1–6 optionally include root indexes to identify unscheduled, grantless UEs, wherein M is the total number of root indexes that can be used to generate DMRS.

[0065] In Example 8, the subject matter of any one or more of Examples 1–7 optionally include wherein the processing circuitry is further configured to select a root index for the UE based upon the UE identity and a set of root indexes available to identify grantless transmissions.

[0066] In Example 9, the subject matter of Example 8 optionally includes wherein the processing circuitry is further configured to: correlate the DMRS received on the unlicensed spectrum across a plurality of possible cyclic shift (CS) and a plurality of possible orthogonal cover codes (OCC) to determine a CS and an OCC used to generate the DMRS; and determine the UE identity of the unidentified UE based upon at least the CS and the OCC.

[0067] In Example 10, the subject matter of Example 9 optionally includes wherein the processing circuitry is further configured select a CS for the UE based upon the UE identity and a set of cyclic shifts available.

[0068] In Example 11, the subject matter of Example 10 optionally includes wherein the processing circuitry is further configured to select an OCC for the UE based upon the UE identity and a set of OCCs available.

[0069] In Example 12, the subject matter of any one or more of Examples 1–11 optionally include wherein the UE identity is a Cell Radio Network Temporary Identifier (C-RNTI).

[0070] Example 13 is an apparatus of an evolved Node B (eNB), the apparatus comprising: memory and processing circuitry configured to: map a user equipment (UE) identity to a UE; correlate a DeModulation Reference Signal (DMRS), received on unlicensed spectrum on a physical uplink shared channel (PUSCH) from an unidentified UE, across a plurality of possible cyclic shift (CS) and orthogonal cover codes (OCC) to determine a CS and an OCC used to generate the DMRS, and wherein the DMRS was transmitted as part of a grant-less, unscheduled transmission unassociated with an uplink grant; determine a UE identity of the unidentified UE based upon at least the CS and OCC; and identify the UE mapped to the UE identity, wherein the UE transmitted the DMRS.

[0071] In Example 14, the subject matter of Example 13 optionally includes wherein the DMRS is received at a start of an uplink burst.

[0072] In Example 15, the subject matter of any one or more of Examples 13–14 optionally include wherein data is transmitted on the one or more channels using a frame structure comprised of slots, each slot comprising seven symbols, and wherein the DMRS is received at a center of each slot.

[0073] In Example 16, the subject matter of any one or more of Examples 13–15 optionally include wherein the DMRS is received after a start and before an end of an uplink (UL) subframe, the processing circuitry is further configured to: receive additional DMRSs up to an end of the UL subframe; and decode PUSCH data from the UE as part of a UL burst starting in a next UL subframe after the UL subframe.

[0074] In Example 17, the subject matter of any one or more of Examples 14–16 optionally include wherein the processing circuitry is further configured to encode a set of CSs, and OCCs that can be used to identify a presence of grantless transmissions in radio resource control (RRC) signaling for the UE, wherein the CS and the OCC are in the set of CSs and OCCs.

[0075] In Example 18, the subject matter of any one or more of Examples 14–17 optionally include wherein the processing circuitry is further configured to decode the UE identity from PUSCH data from the UE.

[0076] In Example 19, the subject matter of any one or more of Examples 14–18 optionally include root indexes to identify unscheduled, grantless UEs, wherein M is the total number of root indexes that can be used to generate DMRS.

[0077] In Example 20, the subject matter of any one or more of Examples 14–19 optionally include wherein the processing circuitry is further configured to select a CS for the UE based upon the UE identity and a set of cyclic shifts available.

[0078] In Example 21, the subject matter of Example 20 optionally includes wherein the processing circuitry is further configured to select an OCC for the UE based upon the UE identity and a set of OCCs available.

[0079] In Example 22, the subject matter of Example 21 optionally includes wherein the processing circuitry is further configured to: correlate the DMRS received on the unlicensed spectrum across a plurality of possible root indexes to determine a root index used to generate the DMRS; and select the root index for the UE based upon the UE identity and a set of root indexes available to identify UEs; and determine the UE identity of the unidentified UE based upon at least the root index.

[0080] In Example 23, the subject matter of any one or more of Examples 14–22 optionally include wherein the UE identity is a Cell Radio Network Temporary Identifier (C-RNTI).

[0081] Example 24 is an apparatus of user equipment (UE), the apparatus comprising: memory and processing circuitry configured to: select a root index to generate a DeModulation Reference Signal (DMRS) based upon the UE identity, wherein the root index is associated with the UE; perform a listen-before-talk (LBT) procedure on one or more channels on unlicensed spectrum; generate the DMRS for transmission, after the LBT procedure, to an evolved node B (eNB) on the one or more channels on a physical uplink shared channel (PUSCH) using the root index, wherein the DMRS is transmitted as part of a grant-less, unscheduled transmissions unassociated with an uplink grant, and wherein the root index is an indication of an identity of the UE.

[0082] In Example 25, the subject matter of Example 24 optionally includes wherein data is transmitted on the one or more channels using a frame structure comprised of slots, each slot comprising seven symbols, and wherein the DMRS is transmitted at a center of each slot.

[0083] In Example 26, the subject matter of any one or more of Examples 24–25 optionally include wherein the DMRS is transmitted at a start of an uplink burst.

[0084] In Example 27, the subject matter of any one or more of Examples 24–26 optionally include wherein the DMRS is repeatedly transmitted starting in a partial uplink (UL) subframe through an end of the UL subframe to indicate a start of a grantless UL transmission in a next UL subframe after the partial UL subframe.

[0085] In Example 28, the subject matter of any one or more of Examples 24–27 optionally include wherein the processing circuity is further configured to decode an indication of a set of DMRS sequences that can be used for grantless transmissions from radio resource control (RRC) signaling.

[0086] In Example 29, the subject matter of any one or more of Examples 24–28 optionally include wherein the processing circuitry is further configured to encode the UE identity in PUSCH data for transmission to the eNB.

[0087] In Example 30, the subject matter of any one or more of Examples 24–29 optionally include wherein the processing circuitry is further configured to select a root index based upon the UE identity and a set of root indexes available to identify UEs.

[0088] In Example 31, the subject matter of Example 30 optionally includes wherein the processing circuitry is further configured to: select a cyclic shift (CS) based upon the UE identity and a set of cyclic shifts available; and generate the DMRS with the selected CS.

[0089] In Example 32, the subject matter of Example 31 optionally includes wherein the processing circuitry is further configured to: select an orthogonal cover code (OCC) based upon the UE identity and a set of OCCs available; and generate the DMRS with the selected OCC.

[0090] In Example 33, the subject matter of any one or more of Examples 24–32 optionally include wherein the UE identity is a Cell Radio Network Temporary Identifier (C-RNTI).

[0091] Example 34 is an apparatus of user equipment (UE), the apparatus comprising: memory and processing circuitry configured to: select a cyclic shift (CS) to generate a DeModulation Reference Signal (DMRS) based upon the UE identity, wherein the CS is associated with the UE; select an orthogonal cover code (OCC) to generate the DMRS based upon the UE identity, wherein the OCC is associated with the UE; perform a listen-before-talk (LBT) procedure on one or more channels on unlicensed spectrum; encode the DMRS for transmission, after the LBT procedure, to an evolved node B (eNB) on the one or more channels on a physical uplink shared channel (PUSCH) using the CS and the OCC, wherein the DMRS is transmitted as part of a grant-less, unscheduled transmission unassociated with an uplink grant, and wherein the CS and OCC are an indication of an identity of the UE.

[0092] In Example 35, the subject matter of Example 34 optionally includes wherein data is transmitted on the one or more channels using a frame structure comprised of slots, each slot comprising seven symbols, and wherein the DMRS is transmitted at a center of each slot.

[0093] In Example 36, the subject matter of any one or more of Examples 34–35 optionally include wherein the DMRS is transmitted at a start of an uplink burst.

[0094] In Example 37, the subject matter of any one or more of Examples 34–36 optionally include wherein the DMRS is repeatedly transmitted starting in a partial uplink (UL) subframe through an end of the UL subframe to indicate a start of a UL burst in a next UL subframe after the partial UL subframe.

[0095] In Example 38, the subject matter of any one or more of Examples 34–37 optionally include wherein the processing circuity is further configured to decode a set of CSs, and OCCs that can be used to identify a presence of grantless transmissions in radio resource control (RRC) signaling for the UE, wherein the selected CS and the selected OCC are in the set of CSs and OCCs.

[0096] In Example 39, the subject matter of any one or more of Examples 34–38 optionally include wherein the processing circuitry is further configured to encode the UE identity in PUSCH data for transmission to the eNB.

[0097] In Example 40, the subject matter of any one or more of Examples 34–39 optionally include wherein the processing circuitry is further configured to: select a root index based upon the UE identity and a set of root indexes available to identify UEs; and generate the DMRS with the selected root index.

[0098] In Example 41, the subject matter of Example 40 optionally includes wherein the processing circuitry is further configured to select a cyclic shift (CS) based upon the UE identity and a set of cyclic shifts available.

[0099] In Example 42, the subject matter of Example 41 optionally includes wherein the processing circuitry is further configured to select an orthogonal cover code (OCC) based upon the UE identity and a set of OCCs available.

[00100] In Example 43, the subject matter of any one or more of Examples 34–42 optionally include wherein the UE identity is a Cell Radio Network Temporary Identifier (C-RNTI).

[00101] Example 44 is a computer-readable medium comprising instructions to cause an evolved Node B (eNB), upon execution of the instructions by processing circuitry of the eNB, to: map a user equipment (UE) identity to a UE; correlate a DeModulation Reference Signal (DMRS), received on unlicensed spectrum on a physical uplink shared channel (PUSCH) from an unidentified UE, across a plurality of possible root indexes to determine a root index used to generate the DMRS, and wherein the DMRS was transmitted as part of a grant-less, unscheduled transmission unassociated with an uplink grant; determine a UE identity of the unidentified UE based upon at least the root index; and identify the UE mapped to the UE identity, wherein the UE transmitted the DMRS.

[00102] In Example 45, the subject matter of Example 44 optionally includes wherein data is transmitted on the one or more channels using a frame structure comprised of slots, each slot comprising seven symbols, and wherein the DMRS is received at a center of each slot.

[00103] In Example 46, the subject matter of any one or more of Examples 44–45 optionally include wherein the DMRS is received at a start of an uplink burst.

[00104] In Example 47, the subject matter of any one or more of Examples 44–46 optionally include wherein the DMRS is received after a start and before an end of an uplink (UL) subframe, the instructions further comprising instructions to: receive additional DMRSs up to an end of the UL subframe; and decode PUSCH data from the UE as part of a UL burst starting in a next UL subframe after the UL subframe.

[00105] In Example 48, the subject matter of any one or more of Examples 44–47 optionally include instructions to encode an indication of a set of DMRS

sequences that can be used for grantless transmissions in radio resource control (RRC) signaling for the UE.

[00106] In Example 49, the subject matter of any one or more of Examples 44–48 optionally include wherein the processing circuitry is further configured to decode the UE identity from PUSCH data from the UE.

[00107] In Example 50, the subject matter of any one or more of Examples 44–49 optionally include root indexes to identify unscheduled, grantless UEs, wherein M is the total number of root indexes that can be used to generate DMRS.

[00108] In Example 51, the subject matter of any one or more of Examples 44–50 optionally include instructions to select a root index for the UE based upon the UE identity and a set of root indexes available to identify UEs.

[00109] In Example 52, the subject matter of Example 51 optionally includes instructions to: correlate the DMRS received on the unlicensed spectrum across a plurality of possible cyclic shift (CS) and orthogonal cover codes (OCC) to determine a CS and an OCC used to generate the DMRS; and determine the UE identity of the unidentified UE based upon at least the CS and the OCC.

[00110] In Example 53, the subject matter of Example 52 optionally includes instructions to select a CS for the UE based upon the UE identity and a set of cyclic shifts available.

[00111] In Example 54, the subject matter of Example 53 optionally includes instructions to select an OCC for the UE based upon the UE identity and a set of OCCs available.

[00112] In Example 55, the subject matter of any one or more of Examples 44–54 optionally include wherein the UE identity is a Cell Radio Network Temporary Identifier (C-RNTI).

[00113] Example 56 is a computer-readable medium comprising instructions to cause an evolved Node B (eNB), upon execution of the instructions by processing circuitry of the eNB, to: map a user equipment (UE) identity to a UE; correlate a DeModulation Reference Signal (DMRS), received on unlicensed spectrum on a physical uplink shared channel (PUSCH) from an unidentified UE, across a plurality of possible cyclic shift (CS) and orthogonal cover codes (OCC) to determine a CS and an OCC used to generate the DMRS, and wherein the DMRS was transmitted as part of a grant-less, unscheduled transmission unassociated with an uplink grant; determine a UE identity of the unidentified UE based upon at least the CS and OCC; and identify the UE mapped to the UE identity, wherein the UE transmitted the DMRS.

[00114] In Example 57, the subject matter of Example 56 optionally includes wherein the DMRS is received at a start of an uplink burst.

[00115] In Example 58, the subject matter of any one or more of Examples 56–57 optionally include wherein data is transmitted on the one or more channels using a frame structure comprised of slots, each slot comprising seven symbols, and wherein the DMRS is received at a center of each slot.

[00116] In Example 59, the subject matter of any one or more of Examples 56–58 optionally include wherein the DMRS is received after a start and before an end of an uplink (UL) subframe, the instructions further comprising instructions to: receive additional DMRSs up to an end of the UL subframe; and decode PUSCH data from the UE as part of a UL burst starting in a next UL subframe after the subframe.

[00117] In Example 60, the subject matter of any one or more of Examples 56–59 optionally include instructions to encode an indication of a set of DMRS sequences that can be used for grantless transmissions in radio resource control (RRC) signaling for the UE.

[00118] In Example 61, the subject matter of any one or more of Examples 56–60 optionally include instructions to decode the UE identity from PUSCH data from the UE.

[00119] In Example 62, the subject matter of any one or more of Examples 56–61 optionally include root indexes to identify unscheduled, grantless UEs, wherein M is the total number of root indexes that can be used to generate DMRS.

[00120] In Example 63, the subject matter of any one or more of Examples 56–62 optionally include instructions to select a CS for the UE based upon the UE identity and a set of cyclic shifts available.

[00121] In Example 64, the subject matter of Example 63 optionally includes instructions to select an OCC for the UE based upon the UE identity and a set of OCCs available.

[00122] In Example 65, the subject matter of Example 64 optionally includes instructions to: correlate the DMRS received on the unlicensed spectrum across a plurality of possible root indexes to determine a root index used to generate the DMRS; and determine the UE identity of the unidentified UE based upon at least the root index.

[00123] In Example 66, the subject matter of any one or more of Examples 56–65 optionally include wherein the UE identity is a Cell Radio Network Temporary Identifier (C-RNTI).

[00124] Example 67 is a computer-readable medium comprising instructions to cause user equipment (UE), upon execution of the instructions by processing circuitry of the UE, to: select a root index to generate a DeModulation Reference Signal (DMRS) based upon the UE identity, wherein the root index is associated with the UE; perform a listen-before-talk (LBT) procedure on one or more channels on unlicensed spectrum; encode the DMRS for transmission, after the LBT procedure, to an evolved node B (eNB) on the one or more channels on a physical uplink shared channel (PUSCH) using the root index, wherein the DMRS is transmitted as part of a grant-less, unscheduled transmission unassociated with a uplink grant, and wherein the root index is an indication of an identity of the UE.

[00125] In Example 68, the subject matter of Example 67 optionally includes wherein data is transmitted on the one or more channels using a frame structure comprised of slots, each slot comprising seven symbols, and wherein the DMRS is transmitted at a center of each slot.

[00126] In Example 69, the subject matter of any one or more of Examples 67–68 optionally include wherein the DMRS is transmitted at a start of an uplink burst.

[00127] In Example 70, the subject matter of any one or more of Examples 67–69 optionally include wherein the DMRS is repeatedly transmitted starting in a partial uplink (UL) subframe through an end of the UL subframe to indicate a start of a UL burst in a next UL subframe after the partial UL subframe.

[00128] In Example 71, the subject matter of any one or more of Examples 67–70 optionally include instructions to decode an indication of a set of DMRS sequences that can be used for grantless transmissions from radio resource control (RRC) signaling for the UE.

[00129] In Example 72, the subject matter of any one or more of Examples 67–71 optionally include instructions to encode the UE identity in PUSCH data for transmission to the eNB.

[00130] In Example 73, the subject matter of any one or more of Examples 67–72 optionally include instructions to select a root index based upon the UE identity and a set of root indexes available to identify UEs.

[00131] In Example 74, the subject matter of Example 73 optionally includes instructions to: select a cyclic shift (CS) based upon the UE identity and a set of cyclic shifts available; and generate the DMRS with the selected CS.

[00132] In Example 75, the subject matter of Example 74 optionally includes instructions to: select an orthogonal cover code (OCC) based upon the UE identity and a set of OCCs available; and generate the DMRS with the selected OCC.

[00133] In Example 76, the subject matter of any one or more of Examples 67–75 optionally include wherein the UE identity is a Cell Radio Network Temporary Identifier (C-RNTI).

[00134] Example 77 is a computer-readable medium comprising instructions to cause user equipment (UE), upon execution of the instructions by processing circuitry of the UE, to: select a cyclic shift (CS) to generate a DeModulation Reference Signal (DMRS) based upon the UE identity, wherein the CS is associated with the UE; select an orthogonal cover code (OCC) to generate the DMRS based upon the UE identity, wherein the OCC is associated with the UE; perform a listen-before-talk (LBT) procedure on one or more channels on unlicensed spectrum; encode the DMRS for transmission, after the LBT procedure, to an evolved node B (eNB) on the one or more channels on a physical uplink shared channel (PUSCH) using the CS and the OCC, wherein the DMRS is transmitted as part of a grant-less, unscheduled transmission unassociated with a uplink grant, and wherein the CS and OCC are an indication of an identity of the UE.

[00135] In Example 78, the subject matter of Example 77 optionally includes wherein data is transmitted on the one or more channels using a frame structure comprised of slots, each slot comprising seven symbols, and wherein the DMRS is transmitted at a center of each slot.

[00136] In Example 79, the subject matter of any one or more of Examples 77–78 optionally include wherein the DMRS is transmitted at a start of an uplink burst.

[00137] In Example 80, the subject matter of any one or more of Examples 77–79 optionally include wherein the DMRS is repeatedly transmitted starting in a partial uplink (UL) subframe through an end of the UL subframe to indicate a start of a UL burst in a next UL subframe.

[00138] In Example 81, the subject matter of any one or more of Examples 77–80 optionally include instructions to decode an indication of a set of DMRS sequences that can be used for grantless transmissions from radio resource control (RRC) signaling for the UE.

[00139] In Example 82, the subject matter of any one or more of Examples 77–81 optionally include instructions to encode the UE identity in PUSCH data for transmission to the eNB.

[00140] In Example 83, the subject matter of any one or more of Examples 77–82 optionally include instructions to: select a root index based upon the UE identity and a set of root indexes available to identify UEs; and generate the DMRS with the selected root index.

[00141] In Example 84, the subject matter of Example 83 optionally includes instructions to select a cyclic shift (CS) based upon the UE identity and a set of cyclic shifts available.

[00142] In Example 85, the subject matter of Example 84 optionally includes instructions to select an orthogonal cover code (OCC) based upon the UE identity and a set of OCCs available.

[00143] In Example 86, the subject matter of any one or more of Examples 77–85 optionally include wherein the UE identity is a Cell Radio Network Temporary Identifier (C-RNTI).

[00144] Example 87 is an apparatus of an evolved Node B (eNB), comprising means for performing the functions performed by the memory and processing circuitry of any of Examples 1 through 23.

[00145] Example 88 is an apparatus of user equipment (UE), comprising means for performing the functions performed by the memory and processing circuitry of any of Examples 24 through 43.

[00146] Example 89 is a method comprising performing the functions performed by the memory and processing circuitry of any of Examples 1 through 23.

[00147] Example 90 is a method comprising performing the functions performed by the memory and processing circuitry of any of Examples 24 through 43.

[00148] The above detailed description includes references to the accompanying drawings, which form a part of the detailed description. The drawings show, by way of illustration, specific embodiments that may be practiced. These embodiments are also referred to herein as "examples." Such examples may include elements in addition to those shown or described. However, also contemplated are examples that include the elements shown or described. Moreover, also contemplate are examples using any combination or permutation of those elements shown or described (or one or more aspects thereof), either with respect to a particular example (or one or more aspects thereof), or with respect to other examples (or one or more aspects thereof) shown or described herein.

[00149] Publications, patents, and patent documents referred to in this document are incorporated by reference herein in their entirety, as though individually incorporated by reference. In the event of inconsistent usages between this document and those documents so incorporated by reference, the usage in the incorporated reference(s) are supplementary to that of this document; for irreconcilable inconsistencies, the usage in this document controls.

[00150] In this document, the terms "a" or "an" are used, as is common in patent documents, to include one or more than one, independent of any other instances or usages of "at least one" or "one or more." In this document, the term "or" is used to refer to a nonexclusive or, such that "A or B" includes "A but not B," "B but not A," and "A and B," unless otherwise indicated. In the appended claims, the terms "including" and "in which" are used as the plain-English equivalents of the respective terms "comprising" and "wherein." Also, in the following claims, the terms "including" and "comprising" are open-ended, that is, a system, device, article, or process that includes elements in addition to those listed after such a term in a claim are still deemed to fall within the scope of that claim. Moreover, in the following claims, the terms "first," "second," and "third," etc. are used merely as labels, and are not intended to suggest a numerical order for their objects.

[00151] The embodiments as described above may be implemented in various hardware configurations that may include a processor for executing instructions that perform the techniques described. Such instructions may be contained in a machine-readable medium such as a suitable storage medium or a memory or other processor-executable medium.

[00152] The embodiments as described herein may be implemented in a number of environments such as part of a wireless local area network (WLAN), 3rd Generation Partnership Project (3GPP) Universal Terrestrial Radio Access Network (UTRAN), or Long-Term-Evolution (LTE) or a Long-Term-Evolution (LTE) communication system, although the scope of the disclosure is not limited in this respect. An example LTE system includes a number of mobile stations, defined by the LTE specification as User Equipment (UE), communicating with a base station, defined by the LTE specifications as an eNB.

[00153] Antennas referred to herein may comprise one or more directional or omnidirectional antennas, including, for example, dipole antennas, monopole antennas, patch antennas, loop antennas, microstrip antennas or other types of antennas suitable for transmission of RF signals. In some embodiments, instead of two or more antennas, a single antenna with multiple apertures may be used. In these embodiments, each aperture may be considered a separate antenna. In some multiple-input multiple-output (MIMO) embodiments, antennas may be effectively separated to take advantage of spatial diversity and the different channel characteristics that may result between each of antennas and the antennas of a transmitting station. In some MIMO embodiments, antennas may be separated by up to 1/10 of a wavelength or more.

[00154] In some embodiments, a receiver as described herein may be configured to receive signals in accordance with specific communication standards, such as the Institute of Electrical and Electronics Engineers (IEEE) standards including IEEE 802.11 standards and/or proposed specifications for WLANs, although the scope of the disclosure is not limited in this respect as they may also be suitable to transmit and/or receive communications in accordance with other techniques and standards. In some embodiments, the receiver may be configured to receive signals in accordance with the IEEE 802.16-2004, the IEEE 802.16(e) and/or IEEE 802.16(m) standards for wireless metropolitan area networks (WMANs) including variations and evolutions thereof, although the scope of the disclosure is not limited in this respect as they may also be suitable to transmit and/or receive communications in accordance with other techniques and standards. In some embodiments, the receiver may be configured to receive signals in accordance with the Universal Terrestrial Radio Access Network (UTRAN) LTE communication standards. For more information with respect to the IEEE 802.11 and IEEE 802.16 standards, please refer to "IEEE Standards for Information Technology -- Telecommunications and Information Exchange between Systems" - Local Area Networks - Specific Requirements – Part 11 "Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY), ISO/IEC 8802-11: 1999", and Metropolitan Area Networks - Specific Requirements – Part 16: "Air Interface for Fixed Broadband Wireless Access Systems," May 2005 and related amendments/versions. For more information with respect to UTRAN LTE standards, see the 3rd Generation Partnership Project (3GPP) standards for UTRAN-LTE, including variations and evolutions thereof.

[00155] The above description is intended to be illustrative, and not restrictive. For example, the above-described examples (or one or more aspects thereof) may be used in combination with others. Other embodiments may be used, such as by one of ordinary skill in the art upon reviewing the above description. The Abstract is to allow the reader to quickly ascertain the nature of the technical disclosure. It is submitted with the understanding that it will not be used to interpret or limit the scope or meaning of the claims. Also, in the above Detailed Description, various features may be grouped together to streamline the disclosure. However, the claims may not set forth every feature disclosed herein as embodiments may feature a subset of said features. Further, embodiments may include fewer features than those disclosed in a particular example. Thus, the following claims are hereby incorporated into the Detailed Description, with a claim standing on its own as a separate embodiment. The scope of the embodiments disclosed herein is to be determined with reference to the appended claims, along with the full scope of equivalents to which such claims are entitled.

CLAIMS

1. An apparatus of user equipment (UE), the apparatus comprising:

memory; and

processing circuitry configured to:

select a root index to generate a DeModulation Reference Signal (DMRS) based upon an UE identity, wherein the root index is associated with the UE;

perform a listen-before-talk (LBT) procedure on one or more channels on unlicensed spectrum;

generate the DMRS for transmission, after the LBT procedure, to an evolved node B (eNB) on the one or more channels using the root index, wherein the DMRS is transmitted as part of a grant-less, unscheduled transmissions unassociated with an uplink grant, and wherein the root index is an indication of an identity of the UE.

2. The apparatus of claim 1, wherein data is transmitted on the one or more channels using a frame structure comprised of slots, each slot comprising seven symbols, and wherein the DMRS is transmitted at a center of each slot.

3. The apparatus of claim 1, wherein the DMRS is transmitted at a start of an uplink burst.

4. The apparatus of claim 1, wherein the DMRS is repeatedly transmitted starting in a partial uplink (UL) subframe through an end of the UL subframe to indicate a start of a grantless UL transmission in a next UL subframe after the partial UL subframe.

5. The apparatus of claim 1, wherein the processing circuity is further configured to decode an indication of a set of DMRS sequences that can be used for grantless transmissions from radio resource control (RRC) signaling.

6. The apparatus of claim 1, wherein the processing circuitry is further configured to encode the UE identity in data for transmission to the eNB as part of the grant-less, unscheduled transmission.

7. The apparatus of claim 1, wherein the processing circuitry is further configured to select a root index based upon the UE identity and a set of root indexes available to identify UEs.

8. The apparatus of claim 7, wherein the processing circuitry is further configured to:

select a cyclic shift (CS) based upon the UE identity and a set of cyclic shifts available; and

generate the DMRS with the selected CS.

9. The apparatus of claim 8, wherein the processing circuitry is further configured to:

select an orthogonal cover code (OCC) based upon the UE identity and a set of OCCs available; and

generate the DMRS with the selected OCC.

10. The apparatus of claim 1, wherein the UE identity is a Cell Radio Network Temporary Identifier (C-RNTI).

11. An apparatus of user equipment (UE), the apparatus comprising:

memory and processing circuitry configured to:

select a cyclic shift (CS) to generate a DeModulation Reference Signal (DMRS) based upon an UE identity, wherein the CS is associated with the UE;

select an orthogonal cover code (OCC) to generate the DMRS based upon the UE identity, wherein the OCC is associated with the UE;

perform a listen-before-talk (LBT) procedure on one or more channels on unlicensed spectrum;

encode the DMRS for transmission, after the LBT procedure, to an evolved node B (eNB) on the one or more channels on a physical uplink shared channel (PUSCH) using the CS and the OCC, wherein the DMRS is transmitted as part of a grant-less, unscheduled transmission unassociated with an uplink grant, and wherein the CS and OCC are an indication of an identity of the UE.

12. The apparatus of claim 11, wherein data is transmitted on the one or more channels using a frame structure comprised of slots, each slot comprising seven symbols, and wherein the DMRS is transmitted at a center of each slot.

13. The apparatus of claim 11, wherein the DMRS is transmitted at a start of an uplink burst.

14. The apparatus of claim 11, wherein the DMRS is repeatedly transmitted starting in a partial uplink (UL) subframe through an end of the UL subframe to indicate a start of a UL burst in a next UL subframe after the partial UL subframe.

15. The apparatus of claim 11, wherein the processing circuity is further configured to decode a set of CSs, and OCCs that can be used to identify a presence of grantless transmissions in radio resource control (RRC) signaling for the UE, wherein the selected CS and the selected OCC are in the set of CSs and OCCs.

16. The apparatus of claim 11, wherein the processing circuitry is further configured to encode the UE identity in PUSCH data for transmission to the eNB.

17. The apparatus of claim 11, wherein the processing circuitry is further configured to:

select a root index based upon the UE identity and a set of root indexes available for grantless unscheduled transmissions; and

generate the DMRS with the selected root index.

18. The apparatus of claim 17, wherein the processing circuitry is further configured to select a cyclic shift (CS) based upon the UE identity and a set of cyclic shifts available.

19. The apparatus of claim 18, wherein the processing circuitry is further configured to select an orthogonal cover code (OCC) based upon the UE identity and a set of OCCs available.

20. The apparatus of claim 11, wherein the UE identity is a Cell Radio Network Temporary Identifier (C-RNTI).

21. A computer-readable medium comprising instructions to cause user equipment (UE), upon execution of the instructions by processing circuitry of the UE, to:

select a root index to generate a DeModulation Reference Signal (DMRS) based upon an UE identity, wherein the root index is associated with the UE;

perform a listen-before-talk (LBT) procedure on one or more channels on unlicensed spectrum;

encode the DMRS for transmission, after the LBT procedure, to an evolved node B (eNB) on the one or more channels using the root index, wherein the DMRS is transmitted as part of a grant-less, unscheduled transmission unassociated with a uplink grant, and wherein the root index is an indication of an identity of the UE.

22. The medium of claim 21, wherein data is transmitted on the one or more channels using a frame structure comprised of slots, each slot comprising seven symbols, and wherein the DMRS is transmitted at a center of each slot.

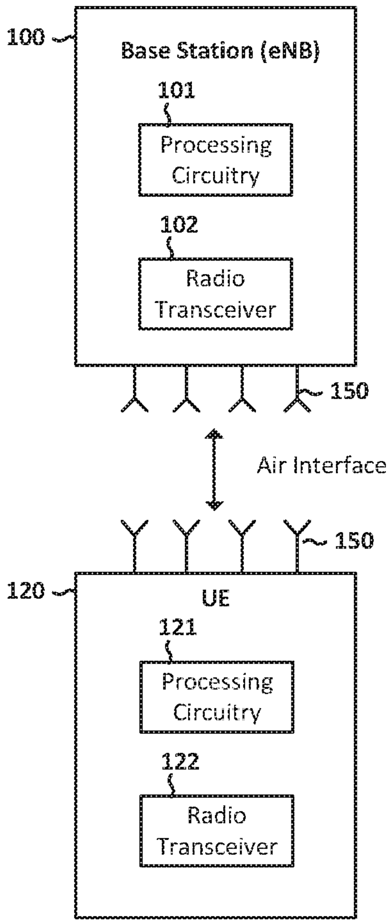
23. The medium of claim 21, wherein the DMRS is repeatedly transmitted starting in a partial uplink (UL) subframe through an end of the UL subframe to indicate a start of a UL burst.

24. The medium of claim 21, further comprising instructions to select a root index based upon the UE identity and a set of root indexes available for grantless, unscheduled transmissions.

25. The medium of claim 24, further comprising instructions to:

select a cyclic shift (CS) based upon the UE identity and a set of cyclic shifts available; and

generate the DMRS with the selected CS.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Base Station (eNB)
101
Processing Circuitry
102
Radio Transceiver
150
Air Interface
150
120
UE
121
Processing Circuitry
122
Radio Transceiver

FIG. 1

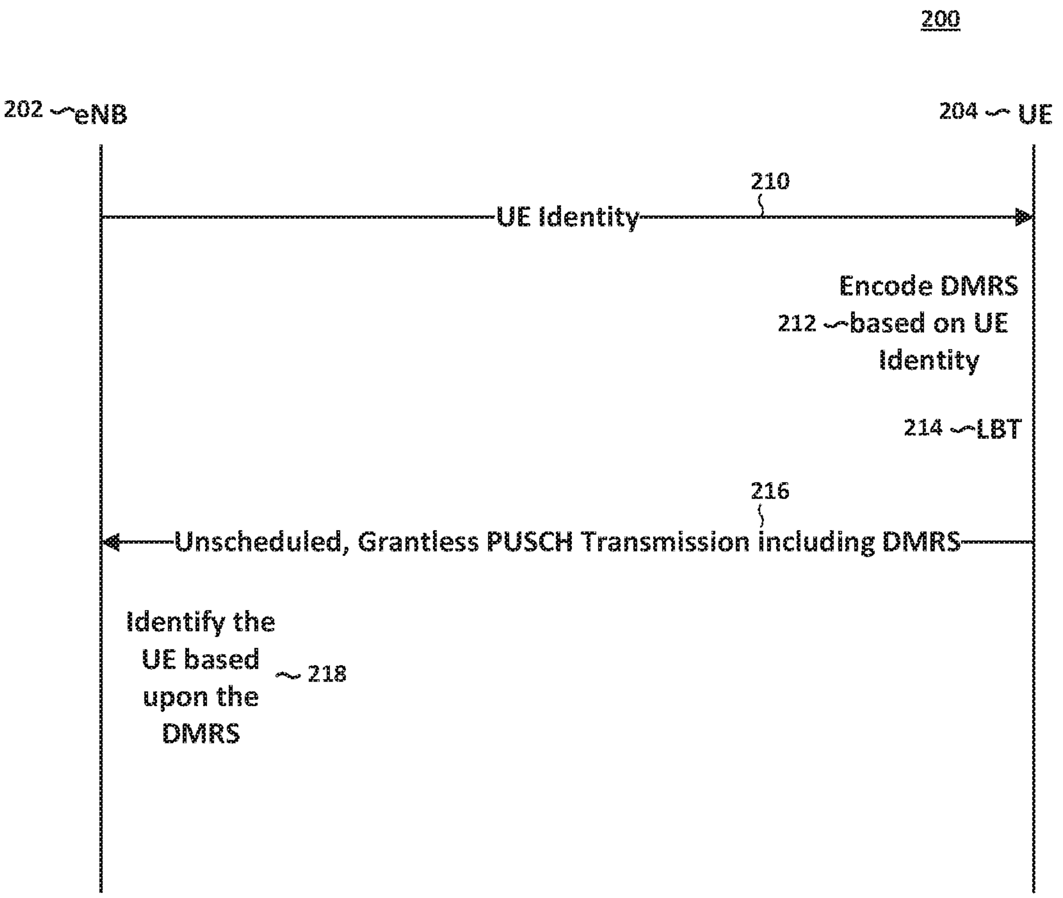
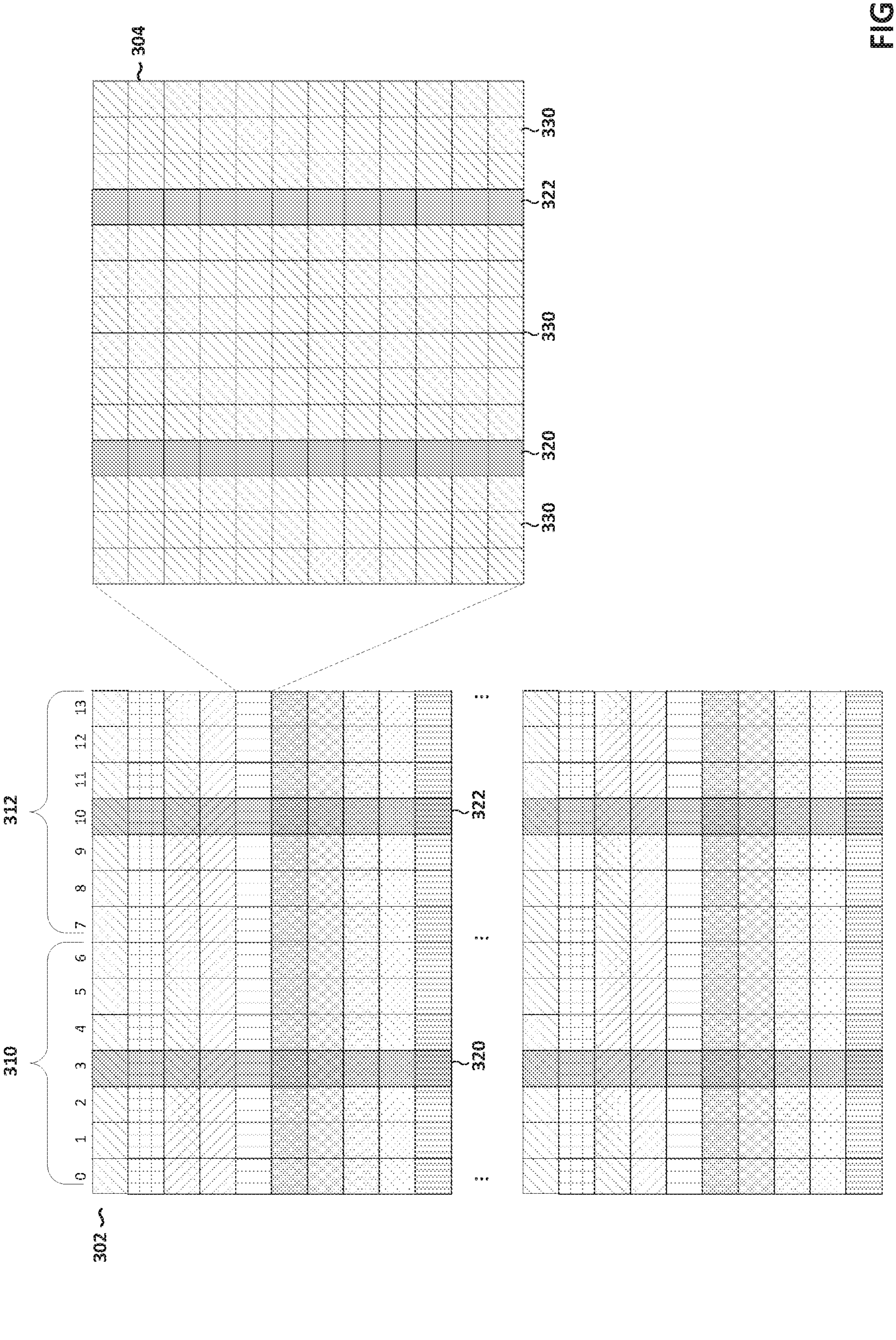

200
202 eNB
204 UE
UE Identity
210
Encode DMRS
212 based on UE
Identity
214 LBT
216
Unscheduled, Grantless PUSCH Transmission including DMRS
Identify the
UE based
upon the
DMRS
218

FIG. 2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330
322
330
320
330
312
310
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1
2
3
4
5
6
7
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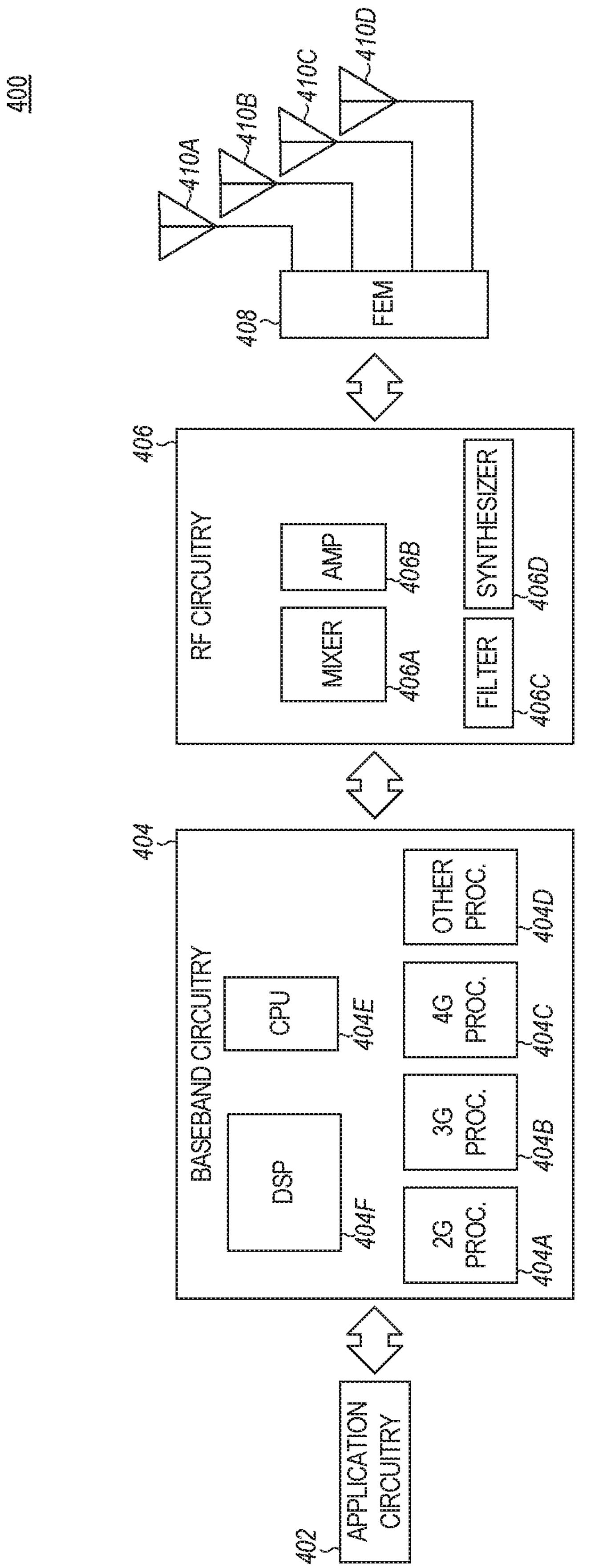
13
322
320
302

FIG. 3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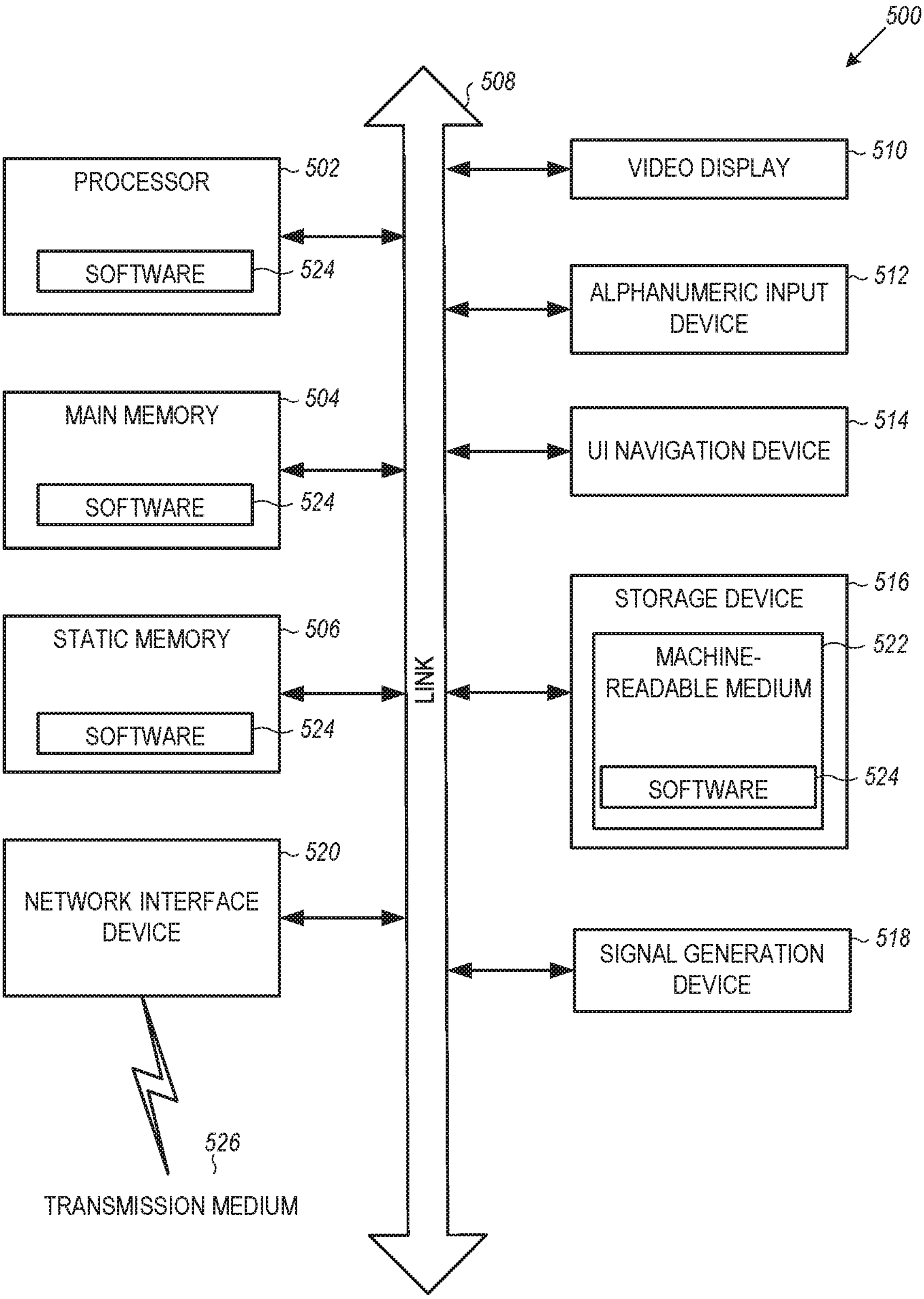
410A
410B
410C
410D
408
FEM
406
RF CIRCUITRY
MIXER
406A
AMP
406B
FILTER
406C
SYNTHESIZER
406D
404
BASEBAND CIRCUITRY
DSP
404F
CPU
404E
2G PROC.
404A
3G PROC.
404B
4G PROC.
404C
OTHER PROC.
404D
402
APPLICATION CIRCUITRY

FIG. 4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508
LINK
PROCESSOR
502
SOFTWARE
524
MAIN MEMORY
504
SOFTWARE
524
STATIC MEMORY
506
SOFTWARE
524
NETWORK INTERFACE DEVICE
520
526
TRANSMISSION MEDIUM
VIDEO DISPLAY
510
ALPHANUMERIC INPUT DEVICE
512
UI NAVIGATION DEVICE
514
STORAGE DEVICE
516
MACHINE-READABLE MEDIUM
522
SOFTWARE
524
SIGNAL GENERATION DEVICE
518

FIG. 5

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2017/019487

A. CLASSIFICATION OF SUBJECT MATTER

H04L 5/00(2006.01)i, H04L 27/26(2006.01)i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H04L 5/00; H04W 56/00; H04B 1/10; H04W 72/08; H04W 72/04; H04L 27/26

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Korean utility models and applications for utility models
Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
eKOMPASS(KIPO internal) & keywords: root index, DMRS(DeModulation Reference Signal), UE identity, LBT(Listen-before-talk), unlicensed spectrum, grant-less, cyclic shift(CS)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2014-0348063 A1 (JI WON KANG et al.) 27 November 2014 See paragraphs [0108]-[0112]; and figure 9.	1-25
A	US 2015-0092702 A1 (QUALCOMM INCORPORATED) 02 April 2015 See paragraph [0052]; claims 24, 25; and figures 9A, 9B.	1-25
A	US 2014-0036850 A1 (YOSUKE AKIMOTO et al.) 06 February 2014 See paragraphs [0073]-[0078]; and figure 5.	1-25
A	US 2015-0270938 A1 (LG ELECTRONICS INC.) 24 September 2015 See paragraphs [0126]-[0136]; and figure 15.	1-25
A	FUJITSU, `UL LBT and PUSCH Design for LAA', R1-160489, 3GPP TSG RAN WG1 Meeting #84, 05 February 2016. See section 2.	1-25

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

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

Date of the actual completion of the international search	Date of mailing of the international search report
22 May 2017 (22.05.2017)	**24 May 2017 (24.05.2017)**

Name and mailing address of the ISA/KR	Authorized officer
International Application Division Korean Intellectual Property Office 189 Cheongsa-ro, Seo-gu, Daejeon, 35208, Republic of Korea	Lee, Eun Kyu
Facsimile No. +82-42-481-8578	Telephone No. +82-42-481-3580

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2017/019487

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