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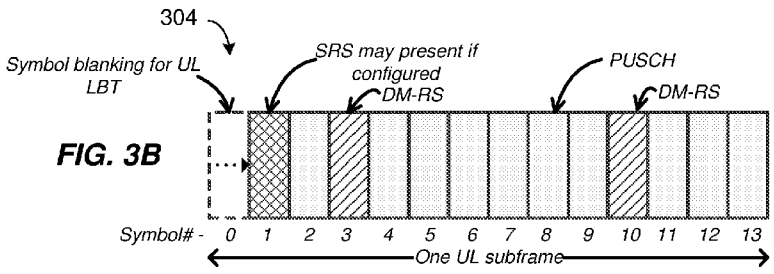


FIG. 3B

(57) Abstract: An apparatus of a user equipment is described. The apparatus may comprise at least one memory, and logic, at least a portion of which is implemented in circuitry coupled to the at least one memory. The logic to receive a configuration broadcast communication from an infrastructure station of a radio access network over a downlink (DL) channel of a long term evolution in unlicensed spectrum (LTE-U) system. The logic to identify a format of an uplink (UL) signal in the configuration broadcast communication for an UL channel of the LTE-U system. The logic to generate the UL signal according to the identified format, the UL signal to include a sounding reference signal (SRS) at a first portion of a subframe for the UL signal. Other embodiments are described and claimed.

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SOUNDING REFERENCE SIGNAL IN CELLULAR SYSTEMS

RELATED CASES

This application claims the benefit of priority under 35 U.S.C. §119(e) to United States Provisional Patent Application Number 62/291,840, filed February 5, 2016, the entirety of which is hereby incorporated by reference.

TECHNICAL FIELD

Embodiments herein generally relate to communications between devices in broadband wireless communications networks.

BACKGROUND

A wireless communications system may communicate information using allocated portions of radio-frequency (RF) spectrum. The allocated RF spectrum may comprise licensed RF spectrum or unlicensed RF spectrum. Licensed RF spectrum is regulated by the Federal Communications Commission (FCC) and assigned to specific communication system providers for exclusive use by that provider. For instance, long term evolution (LTE) is a standard for high-speed wireless communications used by cellular systems. In North America, LTE systems may use licensed RF spectrum such as 700, 750, 800, 850, 1900, 1700/2100, 2300, 2500 and 2600 MHz. Unlicensed RF spectrum is also regulated by the FCC. However, unlicensed spectrum is non-exclusive, and it may be used by any communication system providers. For instance, wireless local area network (WLAN) systems may use unlicensed RF spectrum such as 5 GHz.

Wireless communication systems are attempting to utilize any available radio-frequency (RF) spectrum to meet the increasing demand for higher data rates over wireless systems. Given the ever-increasing need for bandwidth, some communication systems are designed to utilize both licensed RF spectrum and unlicensed RF spectrum. For instance, cellular systems using licensed RF spectrum for LTE may be designed to also use unlicensed RF spectrum for WLANs. This creates potential conflicts with WLAN systems. Techniques for improved co-existence are therefore needed to provide fair use between competing communication systems.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 illustrates an example heterogeneous network with wireless access provided through a radio access network in accordance with one embodiment.

FIG. 2 illustrates an example cell architecture for a radio access network in accordance with one embodiment.

FIG. 3A illustrates a first uplink subframe structure in accordance with one embodiment.

FIG. 3B illustrates a second uplink subframe structure in accordance with one embodiment.

FIG. 3C illustrates a third uplink subframe structure in accordance with one embodiment.

FIG. 4 illustrates example components of an electronic device in accordance with one embodiment.

FIG. 5 illustrates an example of a storage medium in accordance with one embodiment.

FIG. 6 illustrates a first logic flow in accordance with one embodiment.

FIG. 7 illustrates a second logic flow in accordance with one embodiment.

DETAILED DESCRIPTION

Various embodiments may comprise one or more elements. An element may comprise any structure arranged to perform certain operations. Each element may be implemented as hardware, software, or any combination thereof, as desired for a given set of design parameters or performance constraints. Although an embodiment may be described with a limited number of elements in a certain topology by way of example, the embodiment may include more or less elements in alternate topologies as desired for a given implementation. It is worthy to note that any reference to "one embodiment" or "an embodiment" means that a particular feature, structure, or characteristic described in connection with the embodiment is included in at least one embodiment. The appearances of the phrases "in one embodiment," "in some embodiments," and "in various embodiments" in various places in the specification are not necessarily all referring to the same embodiment.

Various embodiments herein generally relate to communications between devices in broadband wireless communications networks. Some embodiments are particularly directed to wireless communication systems capable of using licensed RF spectrum, unlicensed RF spectrum, or a combination of both licensed RF spectrum and unlicensed RF spectrum. Some embodiments may implement techniques for improved sounding reference signal (SRS) operations and/or listen before talk (LBT) operations for user equipment and/or infrastructure equipment for improved performance of electronic devices within a wireless communications network.

In one embodiment, for example, an apparatus of a user equipment (UE) may comprise at least one memory, and logic, at least a portion of which is implemented in circuitry coupled to the at least one memory. The logic may be arranged to receive a configuration broadcast communication from an infrastructure station of a radio access network over a downlink (DL) channel of a long term evolution in unlicensed spectrum (LTE-U) system. The logic

may be arranged to identify a format of an uplink (UL) signal in the configuration broadcast communication for an UL channel of the LTE-U system. The logic may be arranged to generate the UL signal according to the identified format, the UL signal to include a sounding reference signal (SRS) at a first portion of a subframe for the UL signal. In this manner, user equipment and/or infrastructure equipment may more efficiently utilize or allocate UL and DL communication resources within a LTE-U system.

Embodiments are generally directed to wireless communication systems capable of using both licensed RF spectrum and unlicensed RF spectrum. More particularly, embodiments are directed to 3rd Generation Partnership Project (3GPP) long term evolution (LTE) systems, such as LTE in unlicensed spectrum (LTE-U) systems, as defined by 3GPP LTE series of standards, which include without limitation 3GPP Technical Specification (TS) 21.101 V12.0.2 (2016-12) titled "Technical Specification Group Services and System Aspects; Technical Specifications and Technical Reports for a UTRAN-based 3GPP system (Release 12)," dated December 2016; 3GPP TS 21.101 V13.0.0 (2016-12) titled "Technical Specification Group Services and System Aspects; Technical Specifications and Technical Reports for a UTRAN-based 3GPP system (Release 13)," dated December 2016; 3GPP TS 22.011 V14.4.0 (2016-12) titled "Technical Specification Group Services and System Aspects; Service accessibility (Release 14)," dated December 2016; 3GPP TS 22.115 V15.0.0 (2016-12) titled "Technical Specification Group Services and System Aspects; Service aspects; Charging and billing (Release 15)," dated December 2016; including their revisions, progeny and variants. It may be appreciated, however, that embodiments may be applicable to other wireless communication systems utilizing licensed RF spectrum and/or unlicensed RF spectrum as well. Embodiments are not limited in this context.

The 3GPP organization has attempted to increase network capacity by improving the spectral efficiency of LTE systems through introduction of such techniques as higher order modulations, advanced multi-input multi-output (MIMO) antenna technologies, and multi-cell coordination techniques. Another way to improve network capacity is to expand system bandwidth. However, newly available spectrum in the lower frequency bands is very scarce. This is the main rationale behind 3GPP Release 12 and Release 13, which is designed to enable operation of LTE-U systems using unlicensed RF spectrum. A next step evolution of LTE-U systems and 3GPP Release 13 is referred to as a Licensed-Assisted Access (LAA) system. A LAA system meets region-specific regulations to allow for mobile operator deployments worldwide. LAA is an important part of the 3GPP Release 13 standard. 3GPP Release 14 defines another type of LAA, referred to as an "eLAA." Another standard is referred to as

MulteFire™. MulteFire is an LTE-based technology that, unlike LTE-U and LAA, operates exclusively in unlicensed spectrum.

One important consideration for operating LTE in unlicensed spectrum is to ensure fair coexistence with the incumbent systems such as a Wireless Local Area Network (WLAN). The unlicensed RF spectrum of interest in LTE-U is the 5 GHz band, which has wide spectrum with global common availability. The 5 GHz band is governed by the FCC in the United States and European Telecommunications Standards Institute (ETSI) in the Europe Union (EU). The main incumbent system in the 5 GHz band is the WLAN system, specifically WLAN systems based on the Institute of Electrical and Electronics Engineers (IEEE) 802.11 series of standards (collectively referred to as "Wi-Fi"). Since WLAN systems are widely deployed both by individuals and operators for carrier-grade access service and data offloading, sufficient care must be taken before any LTE-U deployment in order to avoid unacceptable levels of conflict with WLAN users.

To facilitated fair co-existence with incumbent systems, LTE-U systems implement a listen before talk (LBT) feature. LBT is a procedure whereby radio transmitters first sense the medium, and transmit only if the medium is sensed to be idle, which is also called clear channel assessment (CCA). The CCA utilizes energy detection to determine presence of signals on a channel. Some regulatory regions, such as the EU and Japan, definitively require unlicensed spectrum users to use LBT for accessing certain spectrum bands. It is worthy to note that Wi-Fi has its own version of LBT called the Distributed Coordination Function (DCF) or Enhanced Distributed Channel Access (EDCA).

LTE-U systems, such as the 3GPP Release 13 LAA system, mainly focused on enabling downlink (DL) access via carrier aggregation. However, uplink (UL) LBT was also partly considered for forward compatibility with 3GPP Release 14 License-Assisted Access (eLAA). One main design goal of Release 14 eLAA systems is to specify UL support for LAA secondary cell (SCell) operation in unlicensed RF spectrum. The UL support for LAA SCell includes definitions for a sounding reference signal (SRS), Physical Uplink Shared Channel (PUSCH), Physical Uplink Control Channel (PUCCH), and Physical Random Access Channel (PRACH).

One major design consideration for LTE-U systems is use of SRS. A SRS is typically used for channel estimation. Channel estimation is important since it enables frequency-selective resource scheduling. The SRS also supports various start-up operations for a UE which has not been recently scheduled. When operating in unlicensed RF spectrum, transmission of a SRS must also use LBT.

Embodiments attempt to improve channel estimation for wireless communication

systems. More particularly, some embodiments utilize techniques to improve SRS use in LTE-U systems. For instance, improved SRS techniques may include SRS transmission details including symbol positions and LBT, support for narrowband SRS, support for wideband SRS, SRS symbol structure, SRS triggering mechanisms, and other improved SRS techniques. The improved SRS techniques may improve channel estimation in LTE-U systems, which result in more efficient allocation of RF spectrum resources, fair use among competing systems, greater throughput, lower latency, efficient power use, lower compute cycles, and other significant technical effects and improvements.

FIG. 1 shows a heterogeneous network with wireless access provided through a radio access network (RAN) 101. The RAN 101 itself may be implemented as a homogeneous network, using a single wireless technology (e.g., LTE or LTE-A), or more typically, as a heterogeneous network using a combination of different wireless technologies (e.g., LTE-U). The RAN 101 allows wireless communication devices (e.g., UEs) to access multiple different networks 108 through one or more network switches 106. The network switches 106 generally refer to switches (e.g., circuit and/or soft switches) used to find and/or connect a client device to a desired target within the networks 108. The network switches 106 may also include gateway interfaces and any other server components for performing a desired level of connectivity. The networks 108 may include any networks including but not limited to voice and/or data networks such as the Internet, the public switch telephone network (PSTN), subscriber based voice/data networks, and other types of networks.

The RAN 101 may implement various techniques that involve transmission of data over one or more wireless connections using one or more wireless mobile broadband technologies. For example, various embodiments may involve transmissions over one or more wireless connections according to one or more 3rd Generation Partnership Project (3GPP) technologies and/or standards, such as 3GPP Long Term Evolution (LTE), 3GPP LTE-Advanced (LTE-A), and/or 3GPP LTE-U, including their revisions, progeny and variants. Various embodiments may additionally or alternatively involve transmissions according to one or more Global System for Mobile Communications (GSM)/Enhanced Data Rates for GSM Evolution (EDGE), Universal Mobile Telecommunications System (UMTS)/High Speed Packet Access (HSPA), and/or GSM with General Packet Radio Service (GPRS) system (GSM/GPRS) technologies and/or standards, including their revisions, progeny and variants.

Examples of wireless mobile broadband technologies and/or standards may also include, without limitation, any of the Institute of Electrical and Electronics Engineers (IEEE) 802.16 wireless broadband standards such as IEEE 802.16m and/or 802.16p, International Mobile

Telecommunications Advanced (IMT-ADV), Worldwide Interoperability for Microwave Access (WiMAX) and/or WiMAX II, Code Division Multiple Access (CDMA) 2000 (e.g., CDMA2000 1xRTT, CDMA2000 EV-DO, CDMA EV-DV, and so forth), High Performance Radio Metropolitan Area Network (HIPERMAN), Wireless Broadband (WiBro), High Speed Downlink Packet Access (HSDPA), High Speed Orthogonal Frequency-Division Multiplexing (OFDM) Packet Access (HSOPA), High-Speed Uplink Packet Access (HSUPA) technologies and/or standards, including their revisions, progeny and variants.

Some embodiments may additionally or alternatively involve wireless communications according to other wireless communications technologies and/or standards. Examples of other wireless communications technologies and/or standards that may be used in various embodiments may include, without limitation, other IEEE wireless communication standards such as the IEEE 802.11, IEEE 802.11a, IEEE 802.11b, IEEE 802.11g, IEEE 802.11n, IEEE 802.11u, IEEE 802.11ac, IEEE 802.11ad, IEEE 802.11af, and/or IEEE 802.11ah standards, High-Efficiency Wi-Fi standards developed by the IEEE 802.11 High Efficiency WLAN (HEW) Study Group, Wi-Fi Alliance (WFA) wireless communication standards such as Wi-Fi, Wi-Fi Direct, Wi-Fi Direct Services, Wireless Gigabit (WiGig), WiGig Display Extension (WDE), WiGig Bus Extension (WBE), WiGig Serial Extension (WSE) standards and/or standards developed by the WFA Neighbor Awareness Networking (NAN) Task Group, machine-type communications (MTC) standards such as those embodied in 3GPP Technical Report (TR) 23.887, 3GPP Technical Specification (TS) 22.368, and/or 3GPP TS 23.682, and/or near-field communication (NFC) standards such as standards developed by the NFC Forum, including any revisions, progeny, and/or variants of any of the above. The embodiments are not limited to these examples.

In addition to transmission over one or more wireless connections, the techniques disclosed herein may involve transmission of content over one or more wired connections through one or more wired communications media. Examples of wired communications media may include a wire, cable, metal leads, printed circuit board (PCB), backplane, switch fabric, semiconductor material, twisted-pair wire, co-axial cable, fiber optics, and so forth. The embodiments are not limited in this context.

Referring again to FIG. 1, the RAN 101 includes multiple infrastructure stations 102, 103. Due to different nomenclatures used for different wireless standards, the term "infrastructure station" may generally refer to any electronic device that provides connection between a wireless UE and the network 108 within the RAN 101. Examples of infrastructure stations may include without limitation a base station, a node, a transceiver station, an access

point, an evolved Node B (eNodeB or eNB), and so forth. Embodiments are not limited in this context.

The infrastructure stations 102, 103 generally provide an air interface for transmitting and receiving signals to/from multiple wireless clients such as UEs 88, 90. The infrastructure stations 102, 103 may also communicate with each other through wireless or wired connections. The infrastructure stations 102, 103 may facilitate various infrastructure operations, such as modulation / demodulation, physical channel coding, micro diversity, error handling, closed loop power control, and/or other RAN operations. In one embodiment, the infrastructure stations 102 may represent fixed communication equipment installed and maintained by various cellular service carriers (e.g., Verizon™, AT&T™, and Sprint™). In one embodiment, the infrastructure station 103 may represent fixed communication equipment installed and maintained by a user, such as a wireless access point (WAP) or router installed in a home residence or office.

In one embodiment, an infrastructure station 102 may be implemented as an eNB for a LTE-U system. The infrastructure stations 102 may be arranged to communicate with either UE 88 or UE 90 over a communications channel 92, which utilizes licensed radio-frequency (RF) spectrum (e.g., 2600 MHz). In one embodiment, the infrastructure station 103 may be implemented as an access point (AP) for a WLAN. The infrastructure station 103 may be arranged to communicate with UE 90 over a communications channel 94, which comprises unlicensed RF spectrum (e.g., 5 GHz). Although certain embodiments are described with reference to LTE-U systems, it may be appreciated that embodiments may be implemented for other wireless communication systems, such as LAA systems, eLAA systems, integrated wireless network for railways (LTE-R), and other wireless communication systems arranged for use with unlicensed RF spectrum. Embodiments are not limited to these examples.

The infrastructure stations 102, 103 may each have one more transceivers capable of communicatively coupling to one or more radio network controllers (RNC) 104. A RNC 104 controls client access through the RAN 101 to one or more of the networks 108 or to another wireless UE in the RAN 101. The RNC 104 may operate to control radio resources and admission, allocate channels, control power settings, control handover, and/or control macro diversity, ciphering, segmentation/reassembly, broadcast signaling, open loop power control, and other RNC operations. In some embodiments, RNC 104 may also perform at least some of the location services (e.g., using global positioning satellite systems) for position and/or route assisted cell management, such as controlling and/or assisting in handover, scanning, and download decisions.

The infrastructure stations 102, 103 may communicate with one or more wireless

communication devices, such as UE 88, 90. In one embodiment, the UE 88 is designed to communicate with only the infrastructure stations 102 over the communication channel 92. In one embodiment, the UE 90 is arranged to communicate with either or both of the infrastructure stations 102, 103 over the communication channels 92, 94, respectively. It may be appreciated that the RAN 101 may include multiple UE of multiple types, and embodiments are not limited to these examples. Examples of wireless communication devices are described in more detail with reference to FIG. 8.

Channel Estimation

As previously discussed, SRS is typically used for channel estimation. Channel estimation is important since it enables frequency-selective resource scheduling. The SRS also supports various start-up operations for a UE which has not been recently scheduled. When operating in unlicensed RF spectrum, transmission of a SRS must also use LBT. Various embodiments, as illustrated and described with reference to FIGS. 2, 3A-C, provide an example of how enhanced SRS and/or LBT signaling may be implemented for LTE-U systems to perform improved channel estimation.

FIG. 2 illustrates an exemplary cell architecture 200 suitable for use with RAN 101. In one embodiment, the cell architecture 200 may utilize a point-to-multipoint (PMP) cellular architecture. It may be appreciated, however, that other types of architectures may be used as well, such as a mesh broadband wireless topology. Embodiments are not limited in this context.

As shown in FIG. 2, the cell architecture 200 illustrates two types of wireless cells. A first type of wireless cell comprises a set of larger wireless cells 204-*a*, sometimes referred to as "macrocells." A macrocell provides radio coverage served by a higher power cellular base station or tower, such as an eNB in a LTE, LTE-A or LTE-U system. A second type of wireless cell comprises a set of smaller wireless cells 206-*b*, sometimes referred to as "microcells." A microcell provides radio coverage served by a lower power WLAN access point, such as an 802.11 wireless access point. Generally, a macrocell provides coverage larger than a microcell.

In this depiction, a single RAN 101 representation is shown for simplicity with wireless cells 204-*a* enumerated as C_1 through C_N and wireless cells 206-*b* enumerated as cells S_{x1} to S_{X7}, with the macrocells and microcells each being implemented via use of one or more infrastructure stations 102, 103. As non-limiting examples, each of the macro cells C_1 through C_N may be implemented via use of a licensed spectrum operating infrastructure stations such as the infrastructure station 102 (e.g., a LTE eNB), whereas each of the micro cells S_{x1} to S_{X7} may be implemented via use of an unlicensed (e.g., 5 GHz) spectrum operating infrastructure stations, such as the infrastructure station 103 (e.g., a WLAN AP).

In FIG. 2, the UE 90 is initially shown at an intermediate position within the cell architecture 200, somewhere between cells C_3, C_5 and C_6. The illustration further shows two example route plans (R_A, R_B) that the UE 90 may possibly follow. Assume the UE 90 travels along example route R_B. While traveling, the UE 90 may interact with various infrastructure stations 102, such as found in various macrocells C_5, C_8 and C_{11}. The UE 90 may also interact with various infrastructure stations 103, such as found in microcells S_{x3}, S_{x4}. As the UE 90 travels in proximity to a given macrocell and/or microcell, the infrastructure station 102 (e.g., an eNB) will dynamically schedule an UL window of time to the UE 90. The UE 90 may use the scheduled UL window to perform an UL transmission.

To dynamically schedule UL windows for the UE 90, an infrastructure station 102 (e.g., an eNB) transmits control information in each DL subframe to the UE 90. For example, layer 1 or layer 2 signaling may be used to transmit the control information. The control information indicates when the UE 90 should transmit data to the infrastructure station 102 in subsequent subframes. The control information also indicates which resource blocks (RB) are to be used for the UL transmissions.

In addition to transmitting control information for UL windows for the UE 90, the infrastructure station 102 may also communicate other types of control information associated with a UL resource grid to the UE 90. A UL resource grid includes, for example, data and uplink control information for Physical Uplink Shared Channel (PUSCH) transmissions, and includes UL control information for PUCCH transmissions, along with various reference signals. The reference signals may include, for example, a demodulation reference signal (DM-RS) and SRS. A DM-RS is generally used for coherent demodulation of PUSCH and PUCCH data. A SRS is generally used to estimate the uplink channel quality for purposes of frequency-selective scheduling. This infrastructure station 102 may communicate the control information using a configuration broadcast communication. Examples of a configuration broadcast communication may include by way of example and not limitation an information element (IE) of a master information broadcasting (MIB), system information broadcasting (SIB), or radio resource configuration (RRC) signaling, among other types of signaling.

FIGS. 3A-3C illustrate exemplary UL subframe structures 302, 304 and 306. Each UL subframe structure 302, 304 and 306 may include multiple symbols. A symbol is a transmission construct (e.g., a waveform) that represents an integer number of bits.

FIG. 3A illustrates an example UL subframe structure 302 typically used for LTE-U operations. As shown in FIG. 3A, the UL subframe structure 302 comprises 14 symbols (symbols 0-13). As shown in FIG. 3A, information associated with a SRS may be included at a

symbol 13 position, information associated with a Physical Uplink Shared Channel (PUSCH) signal may be included at a symbol 8 position, and information associated with DM-RS signals may be included at symbols 3, 10 positions.

The UL subframe structure 302 may cause problems for a LTE-U system. In order to use the UL subframe structure 302 for a communications channel 94 (e.g., unlicensed RF spectrum), a LBT operation is needed in a subframe before the transmission of the UL subframe 302. As previously described, a LBT operation is needed for fair co-existence with the incumbent systems operating on an unlicensed spectrum. LBT is a procedure whereby the UE 90 must first sense the medium, and transmit only if the medium is idle. However, the UE 90 is given a finite amount of time (e.g., detection time) to perform LBT operations. Since the SRS is included in the last symbol position (symbol 13) of the UL subframe structure 302, the UE 90 may not be able to perform LBT operations within the finite amount of time without additional operations. For instance, the SRS transmission may need to be restricted to only those scheduled UEs transmitting PUSCH in the preceding symbols or additional symbol puncturing may be needed before SRS transmission to accommodate those UEs not transmitting PUSCH in the preceding symbols.

FIG. 3B illustrates an example UL subframe structure 304 for use in an LTE-U system. The UL subframe structure 304 is arranged in a manner that solves the problems associated with the UL subframe structure 302. More particularly, the UL subframe structure 304 punctures symbol 0 for LBT, and moves the SRS from the symbol 13 position in the UL subframe structure 302 to the symbol 1 position following punctured symbol 0 for LBT in the UL subframe structure 304. Similar to the UL subframe structure 302, the UL subframe structure 304 may include the PUSCH signal at a symbol 8 position, and the DM-RS signals at symbol 3, 10 positions.

In the UL subframe structure 304, the time period associated with symbol 0 is not used to provide a viable symbol. Instead, the time period associated with symbol 0 is used to perform LBT operations of unlicensed spectrum. When LBT operations are not needed, all 14 symbols (0-13) are available for use as viable symbols. When LBT operations are needed, however, only 13 symbols (1-13) are available for use as viable symbols. In the latter case, the UE 90 may puncture or blank out the symbol 0 of the UL subframe structure 304. To perform puncturing, the UE 90 may encode symbol 0 with a particular or predetermined symbol. To perform blanking, the UE 90 may avoid transmitting symbol 0 to the serving infrastructure station. In this case, the serving infrastructure may treat symbol 0 as a lost symbol. When performing blanking operations, the UE 90 may take into consideration that a symbol is missing from the UL

subframe structure 304, and may perform rate matching to a subframe having less than the normal 14 symbols (e.g., 0-13). This may be performed before or during transmission of the UL subframe structure 304. Since the UL will have been scheduled in advance by the serving infrastructure station, it would recognize the received subframe as an UL subframe structure 304.

When the UE 90 performs LBT sensing operations and senses that the unlicensed spectrum is not idle at a scheduled UL window of time, then the UL subframe structure 304 would not be transmitted at the scheduled UL window. Instead, the UE 90 would have to wait for the serving infrastructure station to reschedule another UL window in order to perform LBT operations to sense idle unlicensed spectrum.

The use of the time period associated with symbol 0 for LBT operations solves conflict problems on the unlicensed spectrum. In a situation where an uploading UE 90 and a competing WLAN device simultaneously start transmitting at a same time (e.g., scheduled subframe symbol 0), then such simultaneous transmissions would instantly conflict and abort procedures would have to be conducted by both the UE 90 and the WLAN device. Both devices would need to retry transmission again at a later time. For both the LTE-U system and the WLAN system, the conflicted transmission time on the unlicensed spectrum is forever lost, and additional system resources would have to be consumed to attempt later retransmission. For the UE 90, the entire UL window of the scheduled UL on the unlicensed spectrum is entirely lost.

In contrast, if the WLAN device starts transmission some time during the symbol 0 time period while the UE 90 is conducting LBT operations during the symbol 0 time period, the UE 90 would detect a non-idleness (e.g., use) of the unlicensed spectrum. The UE 90 would then inhibit itself from starting transmission from the symbol 1 time period, thus avoiding conflict with the WLAN device. As a result, the WLAN device would make use of the unlicensed spectrum during at least part of the scheduled UL window. This results in increased usage of the unlicensed spectrum. This also would enhance a level of cooperation between the UE 90 access and WLAN device access of the shared unlicensed spectrum. For the UE 90, the penalty would be loss of use of the shared unlicensed spectrum for the entire UL window which was scheduled, as well as the use of additional UE system resources to reschedule the UL.

The use of the time period associated with symbol 0 for LBT operations provides further advantages as well. By blanking or puncturing the first symbol of a subframe, the LBT and the PUSCH may be contained within one subframe rather than multiple subframes. This can reduce scheduling complexity for the serving infrastructure station, relative to an arrangement which blanks or punctures the last symbol of a subframe. For instance, if the last symbol of a subframe is to be blanked or punctured, additional complexity may be encountered in that the serving

infrastructure station may need to look one subframe ahead to decide if the symbol is needed to be blanked or punctured, or not. That is, a last symbol punctured or blanked would result in 13 symbols which may warrant rate matching, and for rate matching to be conducted for a subject subframe, the UE would have to know the content of the subframe in advance so that the rate matching may be conducted ahead of (e.g., one subframe in advance) the time when the subject subframe is to begin transmission.

FIG. 3C shows an example UL subframe structure 306. As with the UL subframe structures 302, 304, the UL subframe structure 306 has 14 symbols (0-13). Further, the UL subframe structure 306 may include the PUSCH signal at a symbol 8 position, and the DM-RS signals at symbol 3, 10 positions. Unlike the UL subframe structures 302, 304, however, the UL subframe structure 306 also includes a reservation signal at symbol 2.

Within a 20MHz frame spectrum there may be other UEs scheduled only for PUSCH transmission and not for SRS transmission. These UEs are sometimes referred to as "non-SRS UEs." Non-SRS UEs may transmit a reservation signal after the successful completion of LBT. In order to avoid interference, a predetermined cyclic shift version of SRS sequence (as one example) can be reserved for use by the other UEs, for the purpose of a common reservation signal. In other words, the UEs scheduled for PUSCH but not for SRS, can transmit the common reservation signal, which (in one example) is one reserved cyclic shift version, during the SRS symbol.

The UL subframe structure 306 includes a reservation signal. In one embodiment, the reservation signal may be a predetermined (e.g., single symbol) cyclic shift of SRS included at a symbol 2 position. However, implementation is not limited to a single symbol cyclic shift of SRS at symbol 2 position for the reservation signal. Alternatively, for example, a cyclic shift at any of symbols 4, 5, 6, 7, 9 and 11 positions may be equally useable (e.g., selected) as the common reservation symbol.

Wideband Channel Estimation

As previously described, a SRS is typically used for channel estimation. Channel estimation is important since it enables frequency-selective resource scheduling. The SRS also supports various start-up operations for a UE which has not been recently scheduled. When operating in unlicensed RF spectrum, transmission of a SRS must also use LBT.

Various embodiments, as illustrated and described with reference to FIGS. 2, 3A-C, provide an example of how enhanced SRS and/or LBT signaling may be implemented for LTE-U systems to perform improved channel estimation. These techniques can be used for either

narrowband channel estimation or wideband channel estimation.

With respect to wideband channel estimation, the UE 90 may sometimes transmit information over the entire available bandwidth in an interlaced manner. This may occur, for example, with certain multiple access schemes. For instance, a relatively new multiple access scheme denoted as Block-Interleaved Frequency Division Multiple Access (B-IFDMA) is a variant of LTE-U systems. In a B-IFDMA system, the transmission by a UE 90 is spread over an entire operational bandwidth via interlaced RB assignments. Since transmissions of a UE 90 takes place over the entire bandwidth in an interlaced manner, wideband channel quality estimation becomes increasingly important. Conversely, narrowband channel estimation on a limited portion of the full available bandwidth has limited use. Therefore, depending on a particular UL waveform adopted for a given wireless communication system, wideband channel estimation and wideband SRS could be a desirable feature of such systems (e.g., LTE-U systems, B-IFDMA systems, and analogous systems) to ensure improved UL and DL resource allocation in such systems.

Nonetheless, it may be desirable to redesign a SRS symbol structure regardless of a particular UL waveform is adopted for a given wireless communication system. Current SRS symbol structures are based on interleaved FDMA (IFDMA), where a SRS signal occupies every alternate subcarrier in a comb-like pattern. As multiple access schemes evolve, such as B-IFDMA systems, the IFDMA-based SRS symbol structure may need to evolve as well. This may become particularly important if B-IFDMA is adopted as a eLAA UL waveform. For instance, a modified SRS symbol structure may be used where a SRS signal occupies all subcarriers of the assigned interlaced RBs. One potential design challenge of this approach, however, is that an amount of interference over each interlace can be very localized, thereby making an accurate wideband channel estimation difficult to obtain. For instance, one interlace can be heavily used by neighboring cells, whereas another interlace could be lightly used. In this case, a wideband channel estimation based on one interlace may not effectively represent the overall wideband channel quality. Therefore, it may be a design choice to reuse a SRS symbol structure regardless of an adopted UL waveform for eLAA.

SRS Triggering

The 3GPP LTE series of standards define at least 3 techniques to initiate or trigger SRS in a LTE-U system. These 3 techniques include a single SRS, periodic SRS, and aperiodic SRS. A radio resource control (RCC) configures the single SRS and periodic SRS. The RCC also configures the aperiodic SRS. However, the aperiodic SRS is triggered by downlink control information (DCI). Since unlicensed RF spectrum is shared between heterogeneous systems, the

use of the unlicensed RF spectrum is highly unpredictable. As such, eLAA systems may benefit from implementing aperiodic SRS, which can dynamically trigger SRS by setting a "SRS Request Flag" in the DCI.

FIG. 4 illustrates example components of an electronic device 400. In embodiments, the electronic device 400 may, implement, be incorporated into, or otherwise be a part of a UE, a node such as the infrastructure stations 102, 103, an eNB, some other equipment capable of performing similar operations, or some combination thereof. In some embodiments, the electronic 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.

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. Embodiments described herein may be implemented into a system using any suitably configured hardware and/or software.

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 (e.g., memory/storage 404g or 406e) 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.

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.

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).

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.

The baseband circuitry 404 may be coupled with and/or may include memory/storage (e.g., memory/storage 404g) and may be configured to execute instructions stored in the memory/storage to enable various, processes, applications to run.

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.

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.

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.

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.

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.

In some dual-mode embodiments, a separate radio IC circuitry may be provided for processing signals for each spectrum, although the scope of the embodiments is not limited in this respect.

In some embodiments, the synthesizer circuitry 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.

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.

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.

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.

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 (fLO). In some embodiments, the RF circuitry 406 may include an IQ/polar converter.

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.

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.

In some embodiments, the electronic device 400 may include additional elements such as, for example, memory/storage, display, camera, sensor, and/or input/output (I/O) interface. For example, the RF circuitry 406 may be coupled with and/or may include memory/storage

(e.g., memory/storage 406e) and may be configured to execute instructions stored in the memory/storage.

In embodiments where the electronic device 400 is, implements, is incorporated into, or is otherwise part of a UE, the RF circuitry 406 may receive a long term evolution (LTE) subframe that includes a BRRS. The baseband circuitry 404 may be to determine a value of the BRRS and switch a DL Tx beam based on the value of the BRRS.

In embodiments where the electronic device 400 is, implements, is incorporated into, or is otherwise part of a eNodeB (eNB), network node, or cellular base station, RF circuitry 406 may receive a LTE subframe that includes extended (e.g, 5G) xSRS. The baseband circuitry 404 may be to determine a value of the xSRS within the LTE subframe and refine UL Rx beam based on the value of the xSRS.

Various embodiments of the invention may be implemented fully or partially in software and/or firmware. This software and/or firmware may take the form of instructions contained in or on a non-transitory computer-readable storage medium. Those instructions may then be read and executed by one or more processors to enable performance of the operations described herein. The instructions may be in any suitable form, such as but not limited to source code, compiled code, interpreted code, executable code, static code, dynamic code, and the like. Such a computer-readable medium may include any tangible non-transitory medium for storing information in a form readable by one or more computers, such as – but not limited to – read only memory (ROM), random access memory (RAM), magnetic disk storage media, optical storage media, semiconductor storage media, flash memory, etc.

FIG. 5 illustrates an embodiment of a storage medium 500. The storage medium 500 may comprise an article of manufacture. In one embodiment, the storage medium 500 may comprise any non-transitory computer readable medium or machine readable medium, such as an optical, magnetic or semiconductor storage. The storage medium may store various types of computer executable instructions, such as instructions 502 to implement one or more of logic flows described herein. Examples of a computer readable or machine readable storage medium may include any tangible media capable of storing electronic data, including volatile memory or non-volatile memory, removable or non-removable memory, erasable or non-erasable memory, writeable or re-writeable memory, and so forth. Examples of computer executable instructions may include any suitable type of code, such as source code, compiled code, interpreted code, executable code, static code, dynamic code, object-oriented code, visual code, and the like. The embodiments are not limited in this context.

In some embodiments, the storage medium 500 may be configured to perform one or

more logic flows, processes, techniques, and/or methods as described herein, or portions thereof. For instance, the storage medium 500 may store instructions 502 arranged to perform logic flows as described with reference to FIGS. 6, 7.

Operations for the above embodiments may be further described with reference to the following figures and accompanying examples. Some of the figures may include a logic flow. Although such figures presented herein may include a particular logic flow, it can be appreciated that the logic flow merely provides an example of how the general functionality as described herein can be implemented. Further, the given logic flow does not necessarily have to be executed in the order presented unless otherwise indicated. In addition, the given logic flow may be implemented by a hardware element, a software element executed by a processor, or any combination thereof. The embodiments are not limited in this context.

FIG. 6 illustrates an embodiment of a logic flow 600, which may be representative of the operations executed by one or more embodiments described herein. For example, logic flow 600 may be representative of operations that may be performed in some embodiments by the UE 90 in the RAN 101 of FIG. 1 and/or the cellular architecture 200 of FIG. 2. Embodiments are not limited in this context.

As shown in FIG. 6, the logic flow 600 may receive a configuration broadcast communication from an infrastructure station of a radio access network over a downlink (DL) channel of a long term evolution in unlicensed spectrum (LTE-U) system at block 602. For example, the UE 90 may receive a configuration broadcast communication from an infrastructure station 102 of a RAN 101 over a DL channel of a LTE-U system. The configuration broadcast message can be any control message from the infrastructure station 102, such as an information element (IE) of a master information broadcasting (MIB), system information broadcasting (SIB), or radio resource configuration (RRC) signaling, among other types of signaling.

The logic flow 600 may identify a format of an uplink (UL) signal in the configuration broadcast communication for an UL channel of the LTE-U system at block 604. For example, the UE 90 may identify a format of an UL signal in the configuration broadcast communication for an UL channel of the LTE-U system. The format of the UL signal may comprise, for example, the UL subframe structure 304.

The logic flow 600 may generate the UL signal according to the identified format, the UL signal to include a sounding reference signal (SRS) at a first portion of a subframe for the UL signal, at block 606. For example, the UE 90 may generate the UL subframe structure 304 with a SRS at a first portion of a subframe. A first portion of a subframe may refer to a lower range

of symbols for a given subframe. A second portion of a subframe may refer to a higher range of symbols for a given subframe. A particular number of symbols for a given first portion or second portion may be modified for a particular implementation. In various embodiments, for instance, the first portion may comprise any of symbols 0 to 7 of the UL subframe structure 304, and the second portion may comprise any of symbols 8 to 14 of the UL subframe structure 304. In one embodiment, for example, the SRS may be positioned at a second symbol of the UL subframe structure 304, which is designated as symbol 1 in FIG. 3B.

FIG. 7 illustrates an embodiment of a logic flow 700, which may be representative of the operations executed by one or more embodiments described herein. For example, logic flow 700 may be representative of operations that may be performed in some embodiments by the infrastructure station 102 (or 103) in the RAN 101 of FIG. 1 and/or the cellular architecture 200 of FIG. 2. Additionally or alternatively, the logic flow 700 may be implemented as part of another infrastructure device, such as a server implementing a soft radio located within a network accessible by the infrastructure station 102 (or 103). Embodiments are not limited in this context.

As shown in FIG. 7, the logic flow 700 may configure a format of an uplink (UL) signal for an UL channel of a long term evolution in unlicensed spectrum (LTE-U) system, the UL signal to include an indication that a sounding reference signal (SRS) is to be positioned at a first portion of a subframe at block 702. For example, the infrastructure station 102 (or 103) may configure a format of an UL signal for an UL channel of a LTE-U system. The format of the UL signal may comprise, for example, the UL subframe structure 304. The format may indicate that a SRS is positioned at a first portion of a subframe. A first portion of a subframe may refer to a lower range of symbols for a given subframe. A second portion of a subframe may refer to a higher range of symbols for a given subframe. A particular number of symbols for a given first portion or second portion may be modified for a particular implementation. In various embodiments, for instance, the first portion may comprise any of symbols 0 to 7 of the UL subframe structure 304, and the second portion may comprise any of symbols 8 to 14 of the UL subframe structure 304. In one embodiment, for example, the SRS may be positioned at a second symbol of the UL subframe structure 304, which is designated as symbol 1 in FIG. 3B.

The logic flow 700 may associate the format of the UL signal with a configuration broadcast communication at block 704. For example, the infrastructure station 102 (or 103) may associate the UL subframe structure 304 with a configuration broadcast communication. The configuration broadcast message can be any control message from the

infrastructure station 102, such as an information element (IE) of a master information broadcasting (MIB), system information broadcasting (SIB), or radio resource configuration (RRC) signaling, among other types of signaling.

The logic flow 700 may encode the configuration broadcast communication for transmission over a downlink (DL) channel of the LTE-U system at block 706. For example, the infrastructure station 102 (or 103) may encode the configuration broadcast communication for transmission over a DL channel of the LTE-U system for receipt by the UE 90. The UE 90 may then perform UL transmissions in accordance with the UL subframe structure 304, as described with reference to FIGS. 3B, 6.

Various embodiments may be implemented using hardware elements, software elements, or a combination of both. Examples of hardware elements may include processors, microprocessors, circuits, circuit elements (e.g., transistors, resistors, capacitors, inductors, and so forth), integrated circuits, application specific integrated circuits (ASIC), programmable logic devices (PLD), digital signal processors (DSP), field programmable gate array (FPGA), logic gates, registers, semiconductor device, chips, microchips, chip sets, and so forth. Examples of software may include software components, programs, applications, computer programs, application programs, system programs, machine programs, operating system software, middleware, firmware, software modules, routines, subroutines, functions, methods, procedures, software interfaces, application program interfaces (API), instruction sets, computing code, computer code, code segments, computer code segments, words, values, symbols, or any combination thereof. Determining whether an embodiment is implemented using hardware elements and/or software elements may vary in accordance with any number of factors, such as desired computational rate, power levels, heat tolerances, processing cycle budget, input data rates, output data rates, memory resources, data bus speeds and other design or performance constraints.

One or more aspects of at least one embodiment may be implemented by representative instructions stored on a machine-readable medium which represents various logic within the processor, which when read by a machine causes the machine to fabricate logic to perform the techniques described herein. Such representations, known as "IP cores" may be stored on a tangible, machine readable medium and supplied to various customers or manufacturing facilities to load into the fabrication machines that actually make the logic or processor. Some embodiments may be implemented, for example, using a machine-readable medium or article which may store an instruction or a set of instructions that, if executed by a machine, may cause the machine to perform a method and/or operations in accordance with the embodiments. Such a

machine may include, for example, any suitable processing platform, computing platform, computing device, processing device, computing system, processing system, computer, processor, or the like, and may be implemented using any suitable combination of hardware and/or software. The machine-readable medium or article may include, for example, any suitable type of memory unit, memory device, memory article, memory medium, storage device, storage article, storage medium and/or storage unit, for example, memory, removable or non-removable media, erasable or non-erasable media, writeable or re-writeable media, digital or analog media, hard disk, floppy disk, Compact Disk Read Only Memory (CD-ROM), Compact Disk Recordable (CD-R), Compact Disk Rewriteable (CD-RW), optical disk, magnetic media, magneto-optical media, removable memory cards or disks, various types of Digital Versatile Disk (DVD), a tape, a cassette, or the like. The instructions may include any suitable type of code, such as source code, compiled code, interpreted code, executable code, static code, dynamic code, encrypted code, and the like, implemented using any suitable high-level, low-level, object-oriented, visual, compiled and/or interpreted programming language.

The following examples pertain to further embodiments:

In a first example, an apparatus of a user equipment may comprise at least one memory; and logic, at least a portion of which is implemented in circuitry coupled to the at least one memory, the logic to: receive a configuration broadcast communication from an infrastructure station of a radio access network over a downlink (DL) channel of a long term evolution in unlicensed spectrum (LTE-U) system; identify a format of an uplink (UL) signal in the configuration broadcast communication for an UL channel of the LTE-U system; and generate the UL signal according to the identified format, the UL signal to include a sounding reference signal (SRS) at a first portion of a subframe for the UL signal.

Further to the first example, the UL signal to include the SRS at a second symbol of the first portion of the subframe.

Further to the first example, the logic to generate the UL signal with a punctured first symbol of the subframe.

Further to the first example, the logic to generate the UL signal with a punctured first symbol of the subframe, the punctured first symbol to include a predetermined symbol.

Further to the first example, the logic to generate the UL signal with a punctured first symbol of the subframe, the punctured first symbol to include a blank symbol.

Further to the first example, the configuration broadcast communication comprising downlink control information (DCI), master information broadcasting (MIB), system information broadcasting (SIB), or radio resource control (RRC) signaling.

Further to the first example, the logic to generate the UL signal with a demodulation reference signal (DM-RS) in a symbol of the subframe.

Further to the first example, the logic to generate the UL signal with multiple demodulation reference signals (DM-RS), with a DM-RS in a fourth symbol and a DM-RS in an eleventh symbol.

Further to the first example, the logic to generate the UL signal with a Physical Uplink Shared Channel (PUSCH) signal in a symbol of the subframe.

Further to the first example, the logic to generate the UL signal with a Physical Uplink Shared Channel (PUSCH) signal in a ninth symbol of the subframe.

Further to the first example, the apparatus comprising a radio-frequency (RF) transceiver communicatively coupled to the circuitry, the RF transceiver to transmit the UL signal as RF signals over the UL channel of the LTE-U system.

Further to the first example, the apparatus comprising a memory controller communicatively coupled to the at least one memory to control memory operations for the at least one memory, and an input/output (I/O) controller communicatively coupled to the circuitry to control I/O operations for the circuitry.

In a second example, a method may comprise receiving a configuration broadcast communication from an infrastructure station of a radio access network over a downlink (DL) channel of a long term evolution in unlicensed spectrum (LTE-U) system; identifying a format of an uplink (UL) signal in the configuration broadcast communication for an UL channel of the LTE-U system; and generating the UL signal according to the identified format, the UL signal to include a sounding reference signal (SRS) at a first portion of a subframe for the UL signal.

Further to the second example, the method comprising generating the UL signal to include the SRS at a second symbol of the first portion of the subframe.

Further to the second example, the method comprising generating the UL signal with a punctured first symbol of the subframe.

Further to the second example, the method comprising generating the UL signal with a punctured first symbol of the subframe, the punctured first symbol to include a predetermined symbol.

Further to the second example, the method comprising generating the UL signal with a punctured first symbol of the subframe, the punctured first symbol to include a blank symbol.

Further to the second example, the configuration broadcast communication comprising downlink control information (DCI), master information broadcasting (MIB), system

information broadcasting (SIB), or radio resource control (RRC) signaling.

Further to the second example, the method comprising generating the UL signal with a demodulation reference signal (DM-RS) in a symbol of the subframe.

Further to the second example, the method comprising generating the UL signal with multiple demodulation reference signals (DM-RS), with a DM-RS in a fourth symbol and a DM-RS in an eleventh symbol.

Further to the second example, the method comprising generating the UL signal with a Physical Uplink Shared Channel (PUSCH) signal in a symbol of the subframe.

Further to the second example, the method comprising generating the UL signal with a Physical Uplink Shared Channel (PUSCH) signal in a ninth symbol of the subframe.

Further to the second example, the method comprising transmitting the UL signal as RF signals over the UL channel of the LTE-U system.

In a third example, at least one machine-readable storage medium may comprise instructions that when executed by a computing device, cause the computing device to: receive a configuration broadcast communication from an infrastructure station of a radio access network over a downlink (DL) channel of a long term evolution in unlicensed spectrum (LTE-U) system; identify a format of an uplink (UL) signal in the configuration broadcast communication for an UL channel of the LTE-U system; and generate the UL signal according to the identified format, the UL signal to include a sounding reference signal (SRS) at a first portion of a subframe for the UL signal.

Further to the third example, the storage medium comprising instructions to generate the UL signal with the SRS at a second symbol of the first portion of the subframe.

Further to the third example, the storage medium comprising instructions to generate the UL signal with a punctured first symbol of the subframe.

Further to the third example, the storage medium comprising instructions to generate the UL signal with a punctured first symbol of the subframe, the punctured first symbol to include a predetermined symbol.

Further to the third example, the storage medium comprising instructions to generate the UL signal with a punctured first symbol of the subframe, the punctured first symbol to include a blank symbol.

Further to the third example, the configuration broadcast communication to comprise a downlink control information (DCI), master information broadcasting (MIB), system information broadcasting (SIB), or radio resource control (RRC) signaling.

Further to the third example, the storage medium comprising instructions to generate the

UL signal with a demodulation reference signal (DM-RS) in a symbol of the subframe.

Further to the third example, the storage medium comprising instructions to generate the UL signal with multiple demodulation reference signals (DM-RS), with a DM-RS in a fourth symbol and a DM-RS in an eleventh symbol.

Further to the third example, the storage medium comprising instructions to generate the UL signal with a Physical Uplink Shared Channel (PUSCH) signal in a symbol of the subframe.

Further to the third example, the storage medium comprising instructions to generate the UL signal with a Physical Uplink Shared Channel (PUSCH) signal in a ninth symbol of the subframe.

Further to the third example, the storage medium comprising instructions to transmit the UL signal as RF signals over the UL channel of the LTE-U system.

In a fourth example, an apparatus of a user equipment may comprise means for receiving a configuration broadcast communication from an infrastructure station of a radio access network over a downlink (DL) channel of a long term evolution in unlicensed spectrum (LTE-U) system; means for identifying a format of an uplink (UL) signal in the configuration broadcast communication for an UL channel of the LTE-U system; and means for generating the UL signal according to the identified format, the UL signal to include a sounding reference signal (SRS) at a first portion of a subframe for the UL signal.

Further to the fourth example, the apparatus comprising means for generating the UL signal to include the SRS at a second symbol of the first portion of the subframe.

Further to the fourth example, the apparatus comprising means for generating the UL signal with a punctured first symbol of the subframe.

Further to the fourth example, the apparatus comprising means for generating the UL signal with a punctured first symbol of the subframe, the punctured first symbol to include a predetermined symbol.

Further to the fourth example, the apparatus comprising means for generating the UL signal with a punctured first symbol of the subframe, the punctured first symbol to include a blank symbol.

Further to the fourth example, the configuration broadcast communication comprising downlink control information (DCI), master information broadcasting (MIB), system information broadcasting (SIB), or radio resource control (RRC) signaling.

Further to the fourth example, the apparatus comprising means for generating the UL signal with a demodulation reference signal (DM-RS) in a symbol of the subframe.

Further to the fourth example, the apparatus comprising means for generating the UL

signal with multiple demodulation reference signals (DM-RS), with a DM-RS in a fourth symbol and a DM-RS in an eleventh symbol.

Further to the fourth example, the apparatus comprising means for generating the UL signal with a Physical Uplink Shared Channel (PUSCH) signal in a symbol of the subframe.

Further to the fourth example, the apparatus comprising means for generating the UL signal with a Physical Uplink Shared Channel (PUSCH) signal in a ninth symbol of the subframe.

Further to the fourth example, the apparatus comprising means for transmitting the UL signal as RF signals over the UL channel of the LTE-U system.

In a fifth example, an apparatus of an infrastructure station may comprise at least one memory; and logic, at least a portion of which is implemented in circuitry coupled to the at least one memory, the logic to: configure a format of an uplink (UL) signal for an UL channel of a long term evolution in unlicensed spectrum (LTE-U) system, the UL signal to include an indication that a sounding reference signal (SRS) is to be positioned at a first portion of a subframe; associate the format of the UL sounding signal with a configuration broadcast communication; and encode the configuration broadcast communication for transmission over a downlink (DL) channel of the LTE-U system.

Further to the fifth example, the logic to configure the format of the UL signal to include the SRS at a second symbol of the first portion of the subframe.

Further to the fifth example, the logic to configure the format of the UL signal to include a punctured first symbol of the subframe.

Further to the fifth example, the logic to configure the format of the UL signal to include a punctured first symbol of the subframe, the punctured first symbol to include a predetermined symbol.

Further to the fifth example, the logic to configure the format of the UL signal to include a punctured first symbol of the subframe, the punctured first symbol to include a blank symbol.

Further to the fifth example, the configuration broadcast communication comprising downlink control information (DCI), master information broadcasting (MIB), system information broadcasting (SIB), or radio resource control (RRC) signaling.

Further to the fifth example, the logic to configure the format of the UL signal to include a demodulation reference signal (DM-RS) in a symbol of the subframe.

Further to the fifth example, the logic to configure the format of the UL signal to include multiple demodulation reference signals (DM-RS), with a DM-RS in a fourth symbol and a DM-RS in an eleventh symbol.

Further to the fifth example, the logic to configure the format of the UL signal to include a Physical Uplink Shared Channel (PUSCH) signal in a symbol of the subframe.

Further to the fifth example, the logic to configure the format of the UL signal to include a Physical Uplink Shared Channel (PUSCH) signal in a ninth symbol of the subframe.

Further to the fifth example, the apparatus comprising a radio-frequency (RF) transceiver communicatively coupled to the circuitry, the RF transceiver to transmit the configuration broadcast communication as RF signals over the DL channel of the LTE-U system.

Further to the fifth example, the apparatus comprising a memory controller communicatively coupled to the at least one memory to control memory operations for the at least one memory, and an input/output (I/O) controller communicatively coupled to the circuitry to control I/O operations for the circuitry.

In a sixth example, a method may comprise configuring a format of an uplink (UL) signal for an UL channel of a long term evolution in unlicensed spectrum (LTE-U) system, the UL signal to include an indication that a sounding reference signal (SRS) is to be positioned at a first portion of a subframe; associating the format of the UL sounding signal with a configuration broadcast communication; and encoding the configuration broadcast communication for transmission over a downlink (DL) channel of the LTE-U system.

Further to the sixth example, the method comprising configuring the format of the UL signal to include the SRS at a second symbol of the first portion of the subframe.

Further to the sixth example, the method comprising configuring the format of the UL signal to include a punctured first symbol of the subframe.

Further to the sixth example, the method comprising configuring the format of the UL signal to include a punctured first symbol of the subframe, the punctured first symbol to include a predetermined symbol.

Further to the sixth example, the method comprising configuring the format of the UL signal to include a punctured first symbol of the subframe, the punctured first symbol to include a blank symbol.

Further to the sixth example, the configuration broadcast communication comprising downlink control information (DCI), master information broadcasting (MIB), system information broadcasting (SIB), or radio resource control (RRC) signaling.

Further to the sixth example, the method comprising configuring the format of the UL signal to include a demodulation reference signal (DM-RS) in a symbol of the subframe.

Further to the sixth example, the method comprising configuring the format of the UL

signal to include multiple demodulation reference signals (DM-RS), with a DM-RS in a fourth symbol and a DM-RS in an eleventh symbol.

Further to the sixth example, the method comprising configuring the format of the UL signal to include a Physical Uplink Shared Channel (PUSCH) signal in a symbol of the subframe.

Further to the sixth example, the method comprising configuring the format of the UL signal to include a Physical Uplink Shared Channel (PUSCH) signal in a ninth symbol of the subframe.

Further to the sixth example, the method comprising transmitting the configuration broadcast communication as RF signals over the DL channel of the LTE-U system.

In a seventh example, at least one machine-readable storage medium may comprise instructions that when executed by a computing device, cause the computing device to: configure a format of an uplink (UL) signal for an UL channel of a long term evolution in unlicensed spectrum (LTE-U) system, the UL signal to include an indication that a sounding reference signal (SRS) is to be positioned at a first portion of a subframe; associate the format of the UL sounding signal with a configuration broadcast communication; and encode the configuration broadcast communication for transmission over a downlink (DL) channel of the LTE-U system.

Further to the seventh example, the storage medium comprising instructions to configure the format of the UL signal to include the SRS at a second symbol of the first portion of the subframe.

Further to the seventh example, the storage medium comprising instructions to configure the format of the UL signal to include a punctured first symbol of the subframe.

Further to the seventh example, the storage medium comprising instructions to configure the format of the UL signal to include a punctured first symbol of the subframe, the punctured first symbol to include a predetermined symbol.

Further to the seventh example, the storage medium comprising instructions to configure the format of the UL signal to include a punctured first symbol of the subframe, the punctured first symbol to include a blank symbol.

Further to the seventh example, the configuration broadcast communication comprising downlink control information (DCI), master information broadcasting (MIB), system information broadcasting (SIB), or radio resource control (RRC) signaling.

Further to the seventh example, the storage medium comprising instructions to configure the format of the UL signal to include a demodulation reference signal (DM-RS) in a

symbol of the subframe.

Further to the seventh example, the storage medium comprising instructions to configure the format of the UL signal to include multiple demodulation reference signals (DM-RS), with a DM-RS in a fourth symbol and a DM-RS in an eleventh symbol.

Further to the seventh example, the storage medium comprising instructions to configure the format of the UL signal to include a Physical Uplink Shared Channel (PUSCH) signal in a symbol of the subframe.

Further to the seventh example, the storage medium comprising instructions to configure the format of the UL signal to include a Physical Uplink Shared Channel (PUSCH) signal in a ninth symbol of the subframe.

Further to the seventh example, the storage medium comprising instructions to transmit the configuration broadcast communication as RF signals over the DL channel of the LTE-U system.

In an eighth example, an apparatus for an infrastructure station may comprise means for configuring a format of an uplink (UL) signal for an UL channel of a long term evolution in unlicensed spectrum (LTE-U) system, the UL signal to include an indication that a sounding reference signal (SRS) is to be positioned at a first portion of a subframe; means for associating the format of the UL sounding signal with a configuration broadcast communication; and means for encoding the configuration broadcast communication for transmission over a downlink (DL) channel of the LTE-U system.

Further to the eighth example, the apparatus comprising means for configuring the format of the UL signal to include the SRS at a second symbol of the first portion of the subframe.

Further to the eighth example, the apparatus comprising means for configuring the format of the UL signal to include a punctured first symbol of the subframe.

Further to the eighth example, the apparatus comprising means for configuring the format of the UL signal to include a punctured first symbol of the subframe, the punctured first symbol to include a predetermined symbol.

Further to the eighth example, the apparatus comprising means for configuring the format of the UL signal to include a punctured first symbol of the subframe, the punctured first symbol to include a blank symbol.

Further to the eighth example, the configuration broadcast communication comprising downlink control information (DCI), master information broadcasting (MIB), system information broadcasting (SIB), or radio resource control (RRC) signaling.

Further to the eighth example, the apparatus comprising means for configuring the format of the UL signal to include a demodulation reference signal (DM-RS) in a symbol of the subframe.

Further to the eighth example, the apparatus comprising means for configuring the format of the UL signal to include multiple demodulation reference signals (DM-RS), with a DM-RS in a fourth symbol and a DM-RS in an eleventh symbol.

Further to the eighth example, the apparatus comprising means for configuring the format of the UL signal to include a Physical Uplink Shared Channel (PUSCH) signal in a symbol of the subframe.

Further to the eighth example, the apparatus comprising means for configuring the format of the UL signal to include a Physical Uplink Shared Channel (PUSCH) signal in a ninth symbol of the subframe.

Further to the eighth example, the apparatus comprising means for transmitting the configuration broadcast communication as RF signals over the DL channel of the LTE-U system.

Numerous specific details have been set forth herein to provide a thorough understanding of the embodiments. It will be understood by those skilled in the art, however, that the embodiments may be practiced without these specific details. In other instances, well-known operations, components, and circuits have not been described in detail so as not to obscure the embodiments. It can be appreciated that the specific structural and functional details disclosed herein may be representative and do not necessarily limit the scope of the embodiments.

Some embodiments may be described using the expression "coupled" and "connected" along with their derivatives. These terms are not intended as synonyms for each other. For example, some embodiments may be described using the terms “connected” and/or “coupled” to indicate that two or more elements are in direct physical or electrical contact with each other. The term "coupled," however, may also mean that two or more elements are not in direct contact with each other, but yet still co-operate or interact with each other.

Unless specifically stated otherwise, it may be appreciated that terms such as “processing,” “computing,” “calculating,” “determining,” or the like, refer to the action and/or processes of a computer or computing system, or similar electronic computing device, that manipulates and/or transforms data represented as physical quantities (e.g., electronic) within the computing system’s registers and/or memories into other data similarly represented as physical quantities within the computing system’s memories, registers or other such information storage, transmission or display devices. The embodiments are not limited in this context.

It should be noted that the methods described herein do not have to be executed in the order described, or in any particular order. Moreover, various activities described with respect to the methods identified herein can be executed in serial or parallel fashion.

Although specific embodiments have been illustrated and described herein, it should be appreciated that any arrangement calculated to achieve the same purpose may be substituted for the specific embodiments shown. This disclosure is intended to cover any and all adaptations or variations of various embodiments. It is to be understood that the above description has been made in an illustrative fashion, and not a restrictive one. Combinations of the above embodiments, and other embodiments not specifically described herein will be apparent to those of skill in the art upon reviewing the above description. Thus, the scope of various embodiments includes any other applications in which the above compositions, structures, and methods are used.

It is emphasized that the Abstract of the Disclosure is provided to comply with 37 C.F.R. § 1.72(b), requiring an abstract that will 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. In addition, in the foregoing Detailed Description, it can be seen that various features are grouped together in a single embodiment for the purpose of streamlining the disclosure. This method of disclosure is not to be interpreted as reflecting an intention that the claimed embodiments require more features than are expressly recited in each claim. Rather, as the following claims reflect, inventive subject matter lies in less than all features of a single disclosed embodiment. Thus the following claims are hereby incorporated into the Detailed Description, with each claim standing on its own as a separate preferred embodiment. In the appended claims, the terms "including" and "in which" are used as the plain-English equivalents of the respective terms "comprising" and "wherein," respectively. Moreover, the terms "first," "second," and "third," etc. are used merely as labels, and are not intended to impose numerical requirements on their objects.

Although the subject matter has been described in language specific to structural features and/or methodological acts, it is to be understood that the subject matter defined in the appended claims is not necessarily limited to the specific features or acts described above. Rather, the specific features and acts described above are disclosed as example forms of implementing the claims.

CLAIMS

What is claimed is:

1. An apparatus of a user equipment, comprising:

at least one memory; and

logic, at least a portion of which is implemented in circuitry coupled to the at least one memory, the logic to:

receive a configuration broadcast communication from an infrastructure station of a radio access network over a downlink (DL) channel of a long term evolution in unlicensed spectrum (LTE-U) system;

identify a format of an uplink (UL) signal in the configuration broadcast communication for an UL channel of the LTE-U system; and

generate the UL signal according to the identified format, the UL signal to include a sounding reference signal (SRS) at a first portion of a subframe for the UL signal.

2. The apparatus of claim 1, the UL signal to include the SRS at a second symbol of the first portion of the subframe.
3. The apparatus of claim 1 or 2, the logic to generate the UL signal with a punctured first symbol of the subframe.
4. The apparatus of claim 1 or 2, the logic to generate the UL signal with a punctured first symbol of the subframe, the punctured first symbol to include a predetermined symbol.
5. The apparatus of claim 1 or 2, the logic to generate the UL signal with a punctured first symbol of the subframe, the punctured first symbol to include a blank symbol.
6. The apparatus of claim 1, the configuration broadcast communication comprising downlink control information (DCI), master information broadcasting (MIB), system information broadcasting (SIB), or radio resource control (RRC) signaling.
7. The apparatus of claim 1, the logic to generate the UL signal with a demodulation reference signal (DM-RS) in a symbol of the subframe.
8. The apparatus of claim 1, the logic to generate the UL signal with multiple demodulation reference signals (DM-RS), with a DM-RS in a fourth symbol and a DM-RS in an eleventh symbol.
9. The apparatus of claim 1, the logic to generate the UL signal with a Physical Uplink Shared Channel (PUSCH) signal in a symbol of the subframe.
10. The apparatus of claim 1, the logic to generate the UL signal with a Physical Uplink Shared Channel (PUSCH) signal in a ninth symbol of the subframe.
11. The apparatus of claim 1, comprising a radio-frequency (RF) transceiver

communicatively coupled to the circuitry, the RF transceiver to transmit the UL signal as RF signals over the UL channel of the LTE-U system.

12. The apparatus of claim 1, comprising a memory controller communicatively coupled to the at least one memory to control memory operations for the at least one memory, and an input/output (I/O) controller communicatively coupled to the circuitry to control I/O operations for the circuitry.

13. A method, comprising:

receiving a configuration broadcast communication from an infrastructure station of a radio access network over a downlink (DL) channel of a long term evolution in unlicensed spectrum (LTE-U) system;

identifying a format of an uplink (UL) signal in the configuration broadcast communication for an UL channel of the LTE-U system; and

generating the UL signal according to the identified format, the UL signal to include a sounding reference signal (SRS) at a first portion of a subframe for the UL signal.

14. The method of claim 13, comprising generating the UL signal to include the SRS at a second symbol of the first portion of the subframe.

15. The method of claim 13 or 14, comprising generating the UL signal with a punctured first symbol of the subframe.

16. The method of claim 13 or 14, comprising generating the UL signal with a punctured first symbol of the subframe, the punctured first symbol to include a predetermined symbol.

17. The method of claim 13 or 14, comprising generating the UL signal with a punctured first symbol of the subframe, the punctured first symbol to include a blank symbol.

18. The method of claim 13, comprising generating the UL signal with a demodulation reference signal (DM-RS) in a symbol of the subframe.

19. The method of claim 13, comprising generating the UL signal with multiple demodulation reference signals (DM-RS), with a DM-RS in a fourth symbol and a DM-RS in an eleventh symbol.

20. The method of claim 13, comprising generating the UL signal with a Physical Uplink Shared Channel (PUSCH) signal in a symbol of the subframe.

21. The method of claim 13, comprising generating the UL signal with a Physical Uplink Shared Channel (PUSCH) signal in a ninth symbol of the subframe.

22. The method of claim 13, comprising transmitting the UL signal as RF signals over

the UL channel of the LTE-U system.

23. At least one machine-readable storage medium comprising instructions that when executed by a computing device, cause the computing device to:

receive a configuration broadcast communication from an infrastructure station of a radio access network over a downlink (DL) channel of a long term evolution in unlicensed spectrum (LTE-U) system;

identify a format of an uplink (UL) signal in the configuration broadcast communication for an UL channel of the LTE-U system; and

generate the UL signal according to the identified format, the UL signal to include a sounding reference signal (SRS) at a first portion of a subframe for the UL signal.

24. The at least one machine-readable storage medium of claim 23, comprising instructions to generate the UL signal with the SRS at a second symbol of the first portion of the subframe.

25. The at least one machine-readable storage medium of claim 23, comprising instructions to generate the UL signal with a punctured first symbol of the subframe.

26. The at least one machine-readable storage medium of claim 23 or 24, comprising instructions to generate the UL signal with a punctured first symbol of the subframe, the punctured first symbol to include a predetermined symbol.

27. The at least one machine-readable storage medium of claim 23 or 24, comprising instructions to generate the UL signal with a punctured first symbol of the subframe, the punctured first symbol to include a blank symbol.

28. The at least one machine-readable storage medium of claim 23 or 24, the configuration broadcast communication to comprise a downlink control information (DCI), master information broadcasting (MIB), system information broadcasting (SIB), or radio resource control (RRC) signaling.

29. The at least one machine-readable storage medium of claim 23, comprising instructions to generate the UL signal with a demodulation reference signal (DM-RS) in a symbol of the subframe.

30. The at least one machine-readable storage medium of claim 23, comprising instructions to transmit the UL signal as RF signals over the UL channel of the LTE-U system.

FIG. 1

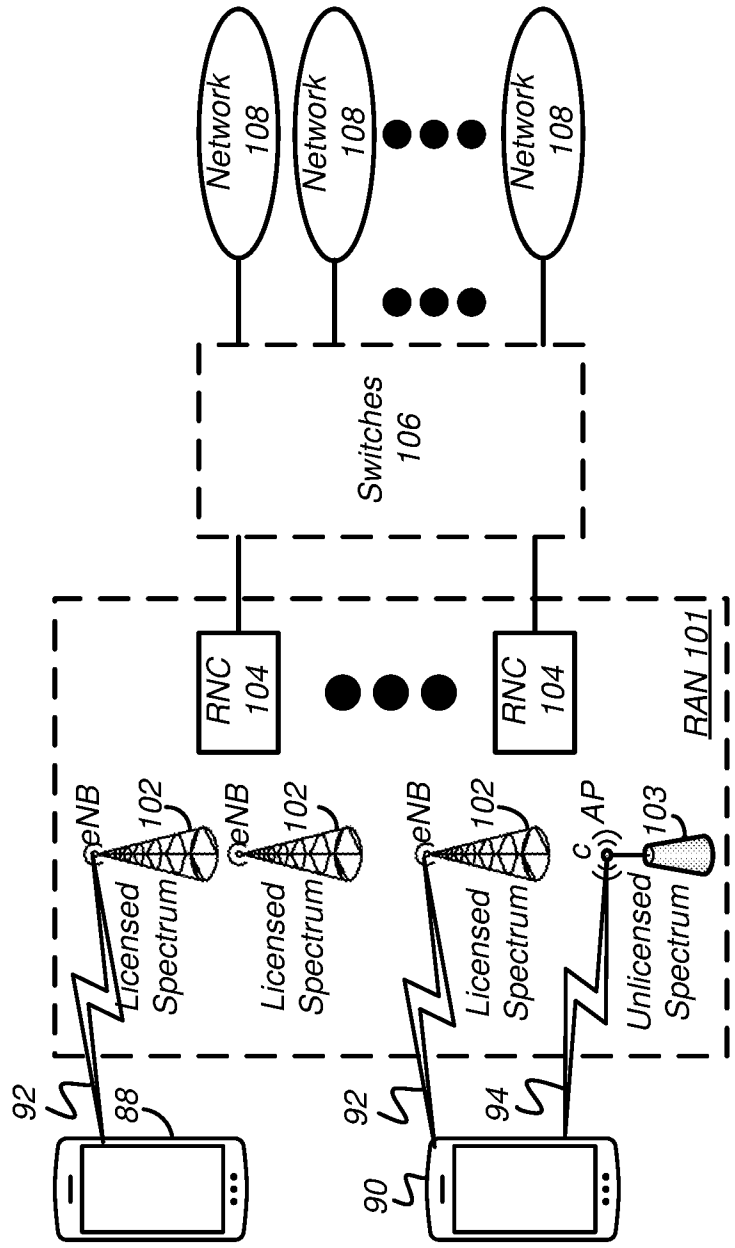
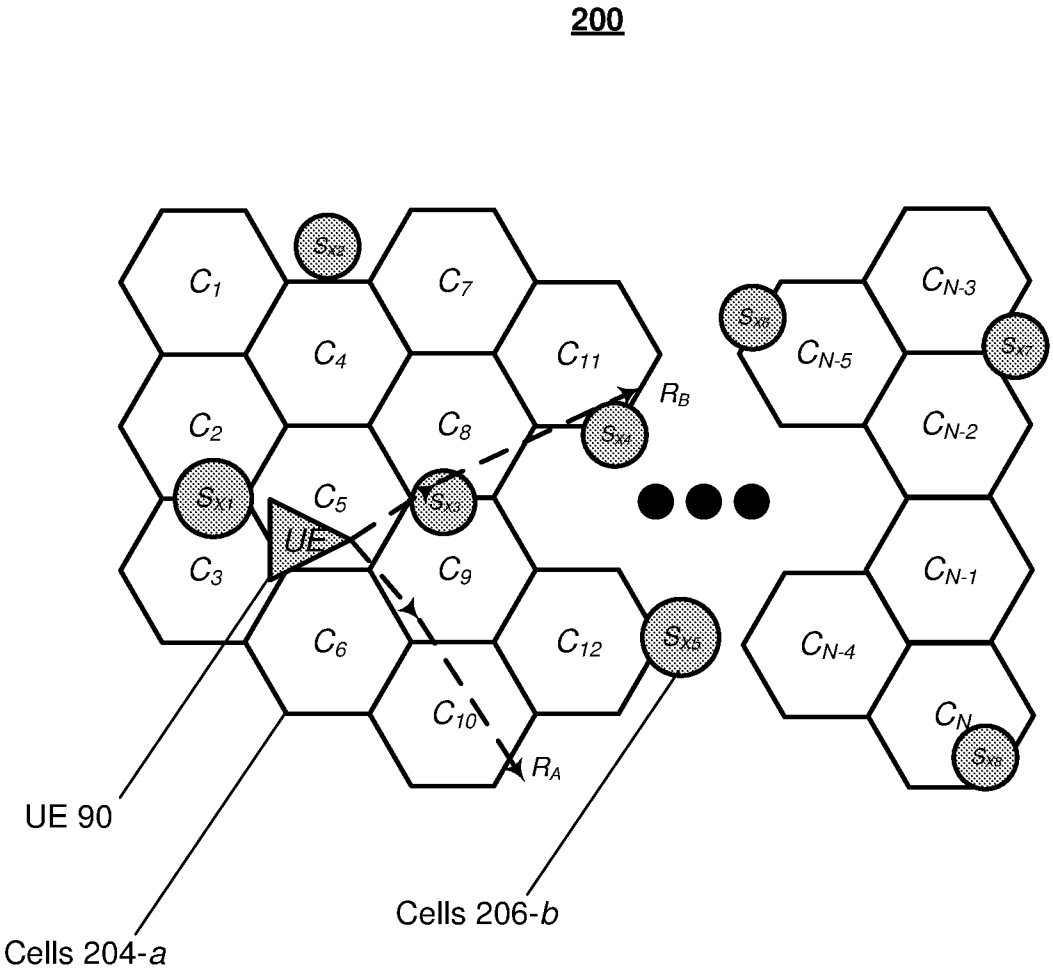

Network 108
Network 108
Network 108
Switches 106
RNC 104
RNC 104
RAN 101
eNB
102
eNB
102
eNB
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AP
103
Licensed Spectrum
Licensed Spectrum
Licensed Spectrum
Unlicensed Spectrum
92
88
92
94
90

FIG. 2


200
C1
C7
C4
C11
C2
C8
C5
C3
C9
C6
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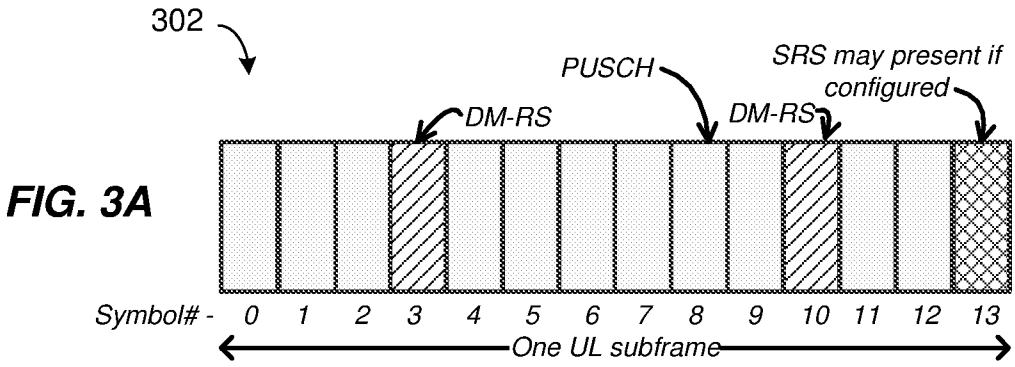


FIG. 3A

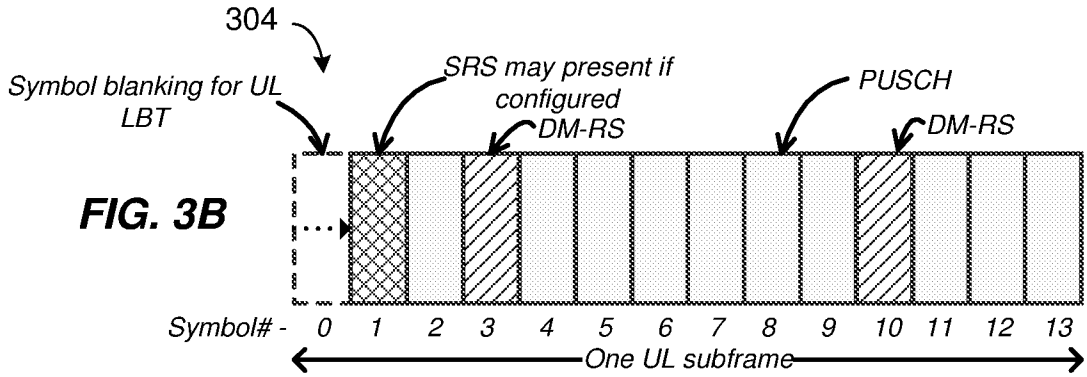


FIG. 3B

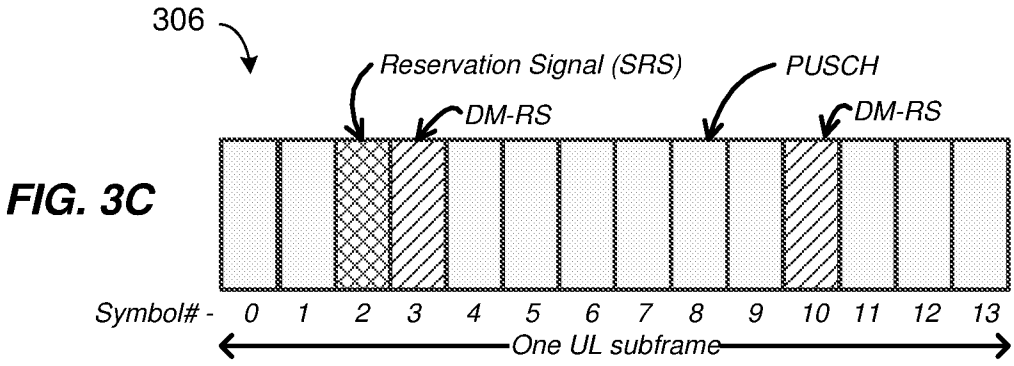


FIG. 3C

FIG. 4

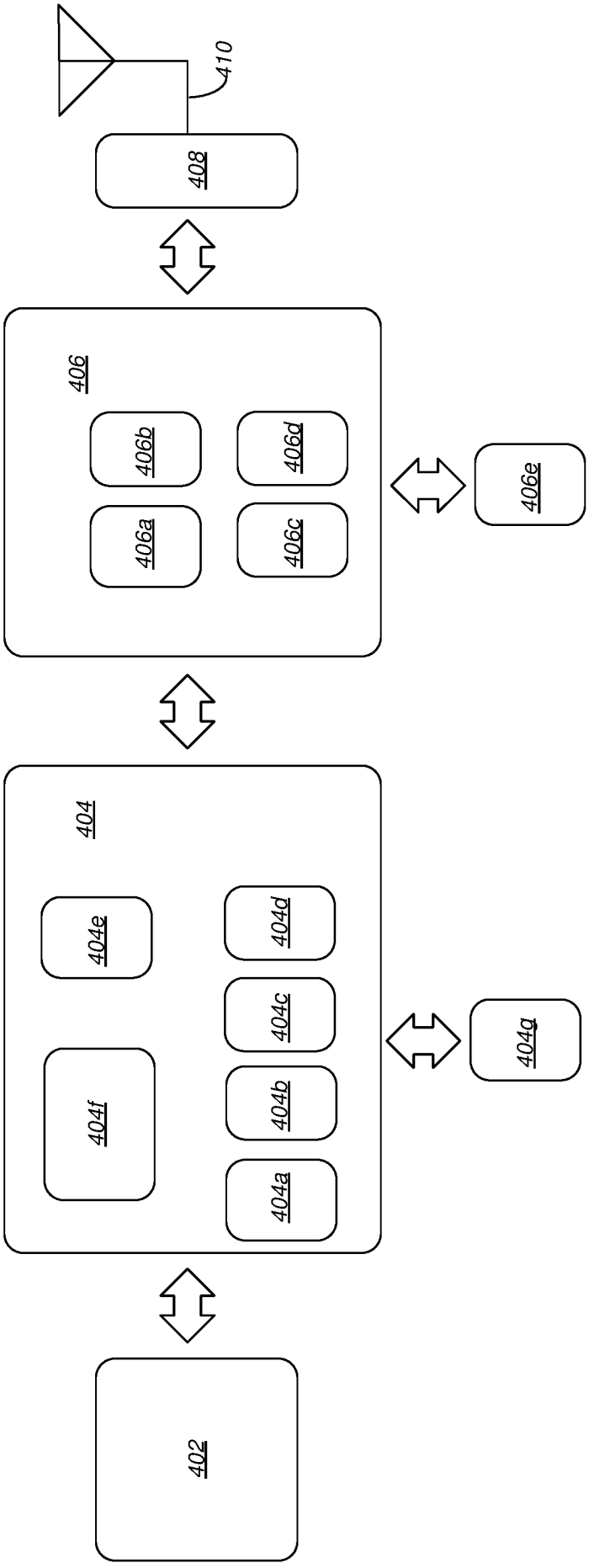

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402
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404a
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FIG. 5

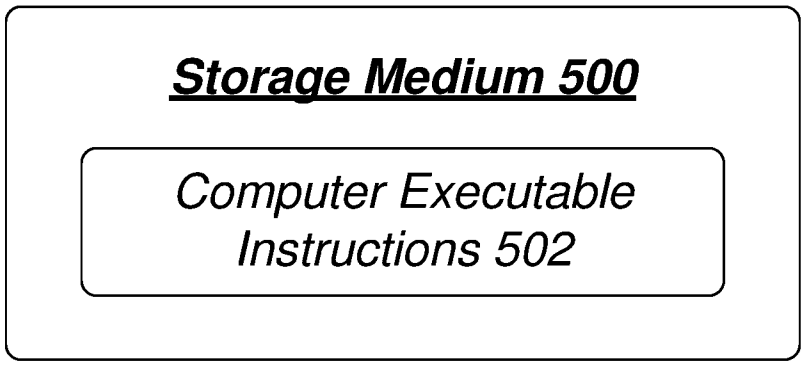


FIG. 6

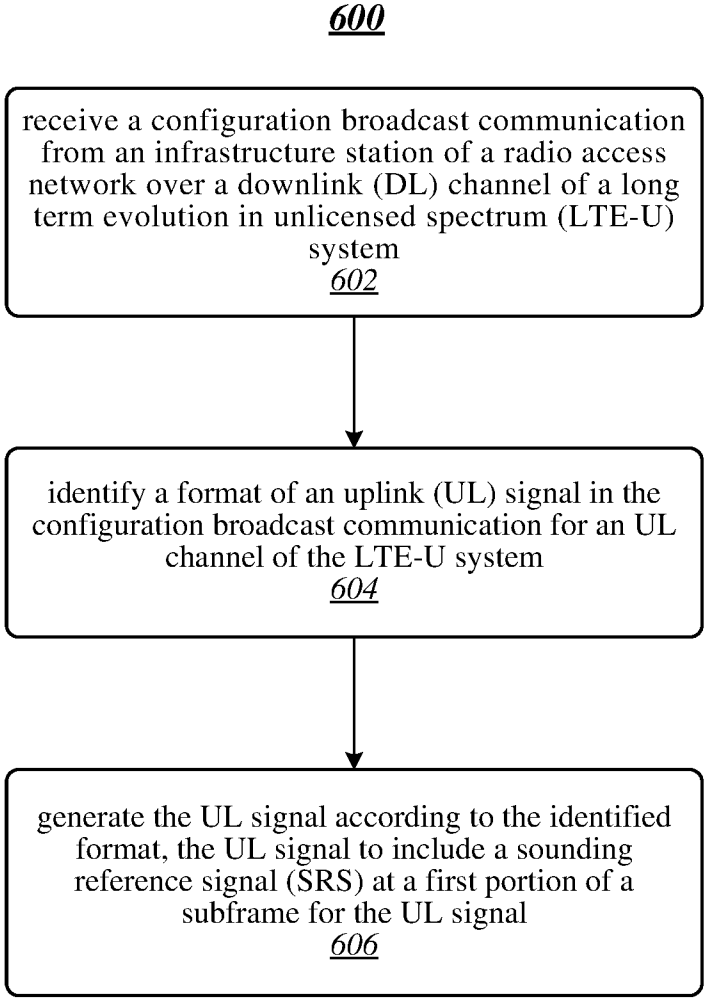
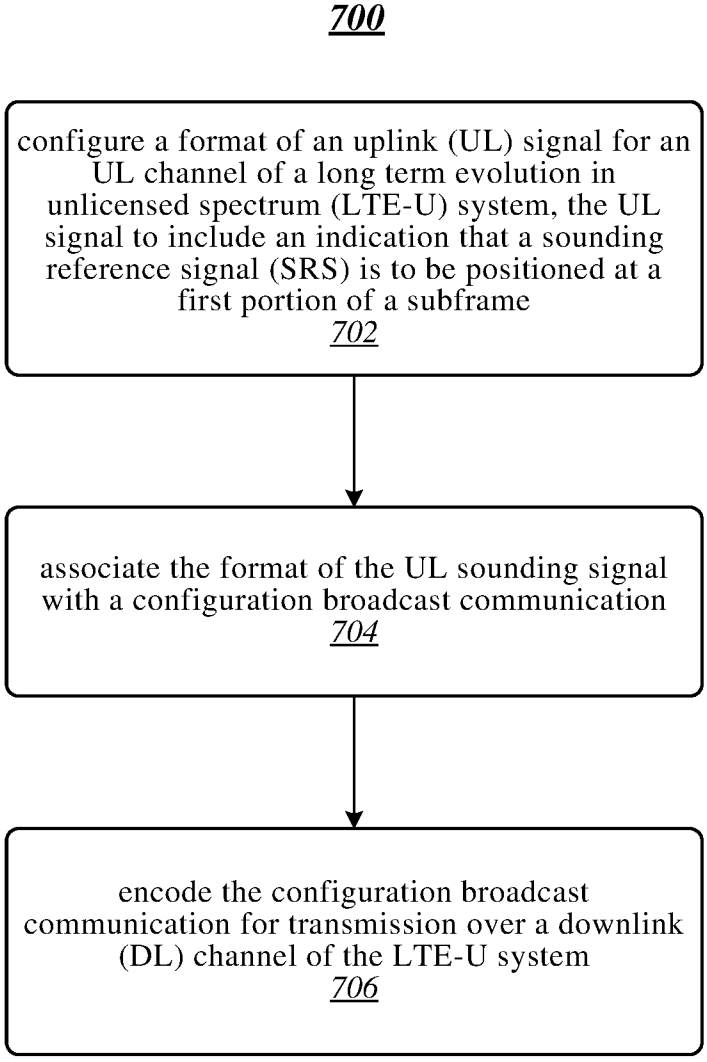

600
receive a configuration broadcast communication from an infrastructure station of a radio access network over a downlink (DL) channel of a long term evolution in unlicensed spectrum (LTE-U) system
602
identify a format of an uplink (UL) signal in the configuration broadcast communication for an UL channel of the LTE-U system
604
generate the UL signal according to the identified format, the UL signal to include a sounding reference signal (SRS) at a first portion of a subframe for the UL signal
606

FIG. 7


700
configure a format of an uplink (UL) signal for an UL channel of a long term evolution in unlicensed spectrum (LTE-U) system, the UL signal to include an indication that a sounding reference signal (SRS) is to be positioned at a first portion of a subframe
702
associate the format of the UL sounding signal with a configuration broadcast communication
704
encode the configuration broadcast communication for transmission over a downlink (DL) channel of the LTE-U system
706

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2016/069635

A. CLASSIFICATION OF SUBJECT MATTER
INV. H04L5/00 H04L12/413 H04L27/00 H04W16/14 H04W74/08
ADD.

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H04L H04W H04B

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

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal, INSPEC, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	LG ELECTRONICS: "DL/UL solutions of LAA with LBT", 3GPP DRAFT; R1-150214 LAA LBT PROPOSAL, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRANCE , vol. RAN WG1, no. Athens, Greece; 20150209 - 20150213 30 January 2015 (2015-01-30), XP050948551, Retrieved from the Internet: URL:http://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_80/Docs/ [retrieved on 2015-01-30]	1,7-13, 18-23, 29,30
A	Sect. 2 figure 4	2-6, 14-17, 24-28

-/--

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

[X] 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
7 April 2017	19/04/2017

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

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Form PCT/ISA/210 (second sheet) (April 2005)

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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