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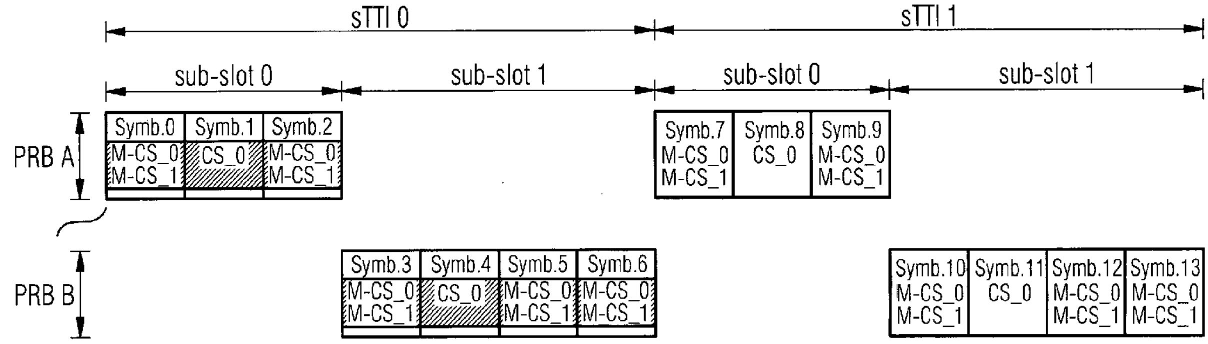
(54) Title: SCALABLE SPUCCH DESIGN FOR LOW LATENCY LTE OPERATION

FIG 4



(57) Abstract: A configuration is received indicating a UE is to operate in a reduced latency mode. The UE determines uplink control information to be reported using a short physical uplink control channel. The UE determines a short physical uplink control channel resource for transmitting the uplink control information. The determined short physical uplink control channel resource is a reduced latency mode physical uplink control channel resource. The short physical uplink control channel resource comprises a first and a second instance of LTE Rel-8 length 12 uplink DMRS sequence transmitted in one or more DFT-S-OFDM symbols on a first physical resource block, followed by a third and a fourth instance of LTE Rel-8 length 12 uplink DMRS sequence transmitted in one or more DFT-S-OFDM symbols on a second physical resource block. The UE transmits the uplink control information on the determined reduced latency mode physical uplink control channel resource.

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DESCRIPTION

TITLE

Scalable sPUCCH Design for Low Latency LTE Operation

TECHNICAL FIELD

[0001] This invention relates generally to reducing air interface latency in a wireless communication system and, more specifically, relates to reducing air interface latency by providing uplink control signaling support for UEs configured to operate in a low-latency configuration.

BACKGROUND

[0002] This section is intended to provide a background or context to the invention disclosed below. The description herein may include concepts that could be pursued, but are not necessarily ones that have been previously conceived, implemented or described. Therefore, unless otherwise explicitly indicated herein, what is described in this section is not prior art to the description in this application and is not admitted to be prior art by inclusion in this section. Abbreviations that may be found in the specification and/or the drawing figures are defined below, after the main part of the detailed description section.

[0003] This invention relates to LTE evolution towards reduced air interface latency, which is part of LTE Rel-13/14. More specifically, the invention provides a needed uplink control signalling support, especially HARQ-ACK channel support, for UEs configured to operate in low-latency configuration.

[0004] A related Rel-13 study item (RP-150465) has been approved at the TSG RAN#67, March 2015. RAN1#83 notes that with regards to TTI shortening and reduced processing times the performance of TTI lengths between 0.5ms and one OFDM symbol should be studied taking into account an impact on reference signals and physical layer control signalling. It is also noted that backwards compatibility shall be preserved to allow normal operation of pre-Rel 13 UEs on the same carrier.

[0005] Usage of PUCCH Format 2/2a/2b channel for conveying HARQ-ACK has been considered. The problem with this approach is that it does not consider some of the important aspects such as frequency hopping and scalability to any TTI length between 0.5ms and one OFDM symbol.

[0006] A solution has been proposed for 1 or 2 bit HARQ ACK transmission utilizing two PUCCH format 2 resources, one on each edge of the spectrum, and applying frequency hopping between those resources. However, while providing a viable solution for signalling of 1 or 2 HARQ-ACK bits, this solution does not cover the cases where larger HARQ-ACK payloads need to be supported.

[0007] In R1-160904, it was proposed that PUCCH with 1-symbol TTI could be constructed by summing a base sequence with a cyclically shifted and QPSK modulated version of the same sequence. Furthermore, it was noted that multiple QPSK symbols could be transmitted by summing to the base sequence multiple modulated and cyclically shifted base sequences. For 2-symbol TTI, it was proposed that the 1-symbol scheme could be applied separately to each of the two symbol in the TTI, which would allow obtaining frequency diversity by making a frequency hop between the symbols.

[0008] There is a problem in how to support current PUCCH functionalities for feedback of a few HARQ-ACK or CSI bits for UEs configured to low latency configuration. The preferred solution should support TTI lengths between 0.5ms and two DFT-S-OFDM symbols, and preserve backwards compatibility. That is, the solution should allow for multiplexing of short TTI and normal TTI UEs on the same physical resource blocks and maximize the performance in considered operation scenarios.

[0009] From the single UE perspective, PUCCH consists of frequency resource of one resource block (12 subcarriers) and time resource of one subframe. To handle coverage-limited situations, the transmission of ACK/NACK spans the full 1 ms subframe.

[0010] FIG. 7 illustrates slot-based (i.e. per 0.5 millisecond) frequency hopping on the band edges symmetrically over the center frequency as is typically used on PUCCH. Frequency hopping provides the necessary frequency diversity needed for delivering critical control signaling.

[0011] There are five different PUCCH formats supported in LTE Release 13:

1) Format 1/1a/1b is used to convey SR and HARQ-ACK. It is based on the combination of CAZAC sequence modulation and block-wise spreading and can carry one information symbol (1 or 2 bits) per slot.
2) Format 2/2a/2b is used to convey periodic CSI (with (2a, 2b) or without (2) HARQ-ACK). It utilizes only CAZAC sequence modulation and is capable of conveying 5 symbols per slot (20 coded bits + 1 or 2 ACK/NACK bits per subframe).
3) Format 3 introduced in Rel-10 is used to convey Carrier Aggregation HARQ-ACK (with and without CQI / SR). Format 3 based on the combination of DFT-S-OFDMA and block-wise spreading and conveys 12 information symbols (24 bits) per slot, i.e. 48 bits per subframe.

4) Format 4 introduced in Rel-13 utilizes DFT-S-OFDMA without any spreading. The bandwidth is configurable and can be up to 10 PRBs. This allows for support of large payloads in the order of hundreds of bits.
5) Format 5 introduced in Rel-13 utilizes 1 PRB and spreading with Orthogonal Cover Codes of length 2 within each DFT-S-OFDM symbol to allow for CDM multiplexing of two users. Format 5 is suitable for payload sizes in the order of 50 bits.

[0012] FIG. 3 shows the logical split between different PUCCH formats and the way in which the PUCCH is configured in the LTE Rel-8 specifications. The number of resource blocks reserved for periodic CQI (i.e., PUCCH Format 2/2a/2b) is configured by a cell-specific parameter, $N_{\mathrm{RB}}^{(2)}$.

[0013] In essence, this parameter defines the starting PRB for PUCCH Format 1/1a/1b. Otherwise, PUCCH Format 2/2a/2b as well as PUCCH Format 3/4/5 resources (not shown) can be assigned anywhere in the UL frequency band.

[0014] The main shortcomings of current HARQ-ACK design are the following:

1) Length of the PUCCH transmission is fixed to 1 subframe, i.e. 1 millisecond.
2) Slot-based (per 0.5 millisecond) frequency hopping is the only way to benefit from frequency diversity.
3) In order to maintain orthogonality between parallel HARQ-ACK (PUCCH Format 1/1a/1b) channels, signals multiplexed within the same PRB must use block-wise spreading in similar manner.

[0015] For these reasons, it is not straightforward to modify the current HARQ-ACK channel to support design criteria for uplink control signaling support, for example, for UEs configured to operate in low-latency configuration.

[0016] Accordingly, solutions are needed for providing control channel support corresponding to TTI lengths between 0.5ms and one OFDM symbol. In accordance with the exemplary embodiments, solutions are provided allowing for feedback of HARQ-ACKs in the carrier aggregation case, when a few carriers with reduced latency operation are configured for the UE, and/or providing support for periodic CSI feedback.

BRIEF SUMMARY

[0017] This section is intended to include examples and is not intended to be limiting. In accordance with a non-limiting exemplary embodiment, a configuration is received indicating a UE is to operate in a reduced latency mode. The UE determines uplink control information to be reported using a short physical uplink control channel. The UE determines a short physical uplink control channel resource for transmitting the uplink control information. The determined short physical uplink control channel resource is a reduced latency mode physical uplink control channel resource. The short physical uplink control channel resource comprises a first and a second instance of LTE Rel-8 length 12 uplink DMRS sequence transmitted in one or more DFT-S-OFDM symbols on a first physical resource block, followed by a third and a fourth instance of LTE Rel-8 length 12 uplink DMRS sequence transmitted in one or more DFT-S-OFDM symbols on a second physical resource block. The UE transmits the uplink control information on the determined reduced latency mode physical uplink control channel resource.

[0018] In accordance with another non-limiting exemplary embodiment, an apparatus, comprises at least one processor; and at least one memory including computer program code, the at least one memory and the computer program code configured to, with the at least one processor, cause the apparatus to perform at least the following: receive a configuration to operate in a reduced latency mode; determine uplink control information to be reported using a short physical uplink control channel; determine a short physical uplink control channel resource for transmitting the uplink control information, wherein the determined short physical uplink control channel resource is a reduced latency mode physical uplink control channel resource, and wherein the short physical uplink control channel resource comprises a first and a second instance of LTE Rel-8 length 12 uplink DMRS sequence transmitted in one or more DFT-S-OFDM symbols on a first physical resource block, followed by a third and a fourth instance of LTE Rel-8 length 12 uplink DMRS sequence transmitted in one or more DFT-S-OFDM symbols on a second physical resource block ; and transmit the uplink control information on the determined reduced latency mode physical uplink control channel resource.

[0019] In accordance with another non-limiting exemplary embodiment, a computer program product comprises a computer-readable medium bearing computer program code embodied therein for use with a computer, the computer program code comprising: code for receiving a configuration to operate in a reduced latency mode; determining uplink control information to be reported using a short physical uplink control channel; determining a short physical uplink control channel resource for transmitting the uplink control information, wherein the determined short physical uplink control channel resource is a reduced latency mode physical uplink control channel resource, and wherein the short physical uplink control channel resource comprises a first and a second instance of LTE Rel-8 length 12 uplink DMRS sequence transmitted in one or more DFT-S-OFDM symbols on a first physical resource block, followed by a third and a fourth instance of LTE Rel-8 length 12 uplink DMRS sequence transmitted in one or more DFT-S-OFDM symbols on a second physical resource block ; and transmitting the uplink control information on the determined reduced latency mode physical uplink control channel resource.

[0020] In accordance with another non-limiting embodiment, a base station determines that a UE will transmit uplink control information in a reduced latency mode. The base station determines a short physical uplink control channel resource for receiving the uplink control information. The determined short physical uplink control channel resource is a reduced latency mode physical uplink control channel resource. The short physical uplink control channel resource comprises a first and a second instance of LTE Rel-8 length 12 uplink DMRS sequence transmitted in one or more DFT-S-OFDM symbols on a first physical resource block, followed by a third and a fourth instance of LTE Rel-8 length 12 uplink DMRS sequence transmitted in one or more DFT-S-OFDM symbols on a second physical resource block. The base station receives the uplink control information on the determined reduced latency mode physical uplink control channel resource.

BRIEF DESCRIPTION OF THE DRAWINGS

[0021] In the attached Drawing FIG.s:

[0022] FIG. 1 is a block diagram of one possible and non-limiting exemplary system in which the exemplary embodiments may be practiced;

[0023] FIG. 2(a) is a logic flow diagram for configuring a UE for reduced latency mode with a scalable sPUCCH design for low latency operation, and illustrates the operation of an exemplary method, a result of execution of computer program instructions embodied on a computer readable memory, functions performed by logic implemented in hardware, and/or interconnected means for performing functions in accordance with exemplary embodiments;

[0024] FIG. 2(b) is a logic flow diagram for a base station communicating with a UE with reduced latency mode with a scalable sPUCCH design for low latency operation, and illustrates the operation of an exemplary method, a result of execution of computer program instructions embodied on a computer readable memory, functions performed by logic implemented in hardware, and/or interconnected means for performing functions in accordance with exemplary embodiments;

[0025] FIG. 3 illustrates a typical PUCCH configuration;

[0026] FIG. 4 illustrates a mapping of un-modulated (CS_0) and modulated (M-CS_0 and M_Cs_1) sequences in two sub-slots of short TTI;

[0027] FIG. 5 shows alternatives for 3 / 4 symbol sTTI configuration;

[0028] FIG. 6 shows BLER vs SNR for sPUCCH with sTTI length of 7-symbols;

[0029] FIG. 7 illustrates a mapping to physical resource blocks for PUCCH; and

[0030] FIG. 8 shows sPUCCH for 1-bit or 2-bit HARQ-ACK.

DETAILED DESCRIPTION OF THE DRAWINGS

[0031] The word “exemplary” is used herein to mean “serving as an example, instance, or illustration.” Any embodiment described herein as “exemplary” is not necessarily to be construed as preferred or advantageous over other embodiments. All of the embodiments described in this Detailed Description are exemplary embodiments provided to enable persons skilled in the art to make or use the invention and not to limit the scope of the invention which is defined by the claims.

[0032] The exemplary embodiments herein describe techniques for scalable sPUCCH design for low latency LTE operation

[0033] Additional description of these techniques is presented after a system into which the exemplary embodiments may be used is described.

[0034] Turning to FIG. 1, this figure shows a block diagram of one possible and non-limiting exemplary system in which the exemplary embodiments may be practiced. In FIG. 1, a user equipment (UE) 110 is in wireless communication with a wireless network 100. A UE is a wireless, typically mobile device that can access a wireless network. The UE 110 includes one or more processors 120, one or more memories 125, and one or more transceivers 130 interconnected through one or more buses 127. Each of the one or more transceivers 130 includes a receiver, Rx, 132 and a transmitter, Tx, 133. The one or more buses 127 may be address, data, or control buses, and may include any interconnection mechanism, such as a series of lines on a motherboard or integrated circuit, fiber optics or other optical communication equipment, and the like. The one or more transceivers 130 are connected to one or more antennas 128. The one or more memories 125 include computer program code 123.

[0035] The UE 110 includes a Reduced Latency Mode (RLM) module 140, comprising one of or both parts 140-1 and/or 140-2, which may be implemented in a number of ways. The RLM module 140 may be implemented in hardware as RLM module 140-1, such as being implemented as part of the one or more processors 120. The RLM module 140-1 may be implemented also as an integrated circuit or through other hardware such as a programmable gate array. In another example, the RLM module 140 may be implemented as RLM module 140-2, which is implemented as computer program code 123 and is executed by the one or more processors 120. For instance, the one or more memories 125 and the computer program code 123 may be configured to, with the one or more processors 120, cause the user equipment 110 to perform one or more of the operations as described herein. The UE 110 communicates with eNB 170 via a wireless link 111.

[0036] The eNB (evolved NodeB) 170 is a base station (e.g., for LTE, long term evolution) that provides access by wireless devices such as the UE 110 to the wireless network 100. The eNB 170 includes one or more processors 152, one or more memories 155, one or more network interfaces (N/W I/F(s)) 161, and one or more transceivers 160 interconnected through one or more buses 157. Each of the one or more transceivers 160 includes a receiver, Rx, 162 and a transmitter, Tx, 163. The one or more transceivers 160 are connected to one or more antennas 158. The one or more memories 155 include computer program code 153.

[0037] The eNB 170 includes a Reduced Latency Mode (RLM) module 150, comprising one of or both parts 150-1 and/or 150-2, which may be implemented in a number of ways. The RLM module 150 may be implemented in hardware as RLM module 150-1, such as being implemented as part of the one or more processors 152. The RLM module 150-1 may be implemented also as an integrated circuit or through other hardware such as a programmable gate array. In another example, the RLM module 150 may be implemented as RLM module 150-2, which is implemented as computer program code 153 and is executed by the one or more processors 152. For instance, the one or more memories 155 and the computer program code 153 are configured to, with the one or more processors 152, cause the eNB 170 to perform one or more of the operations as described herein. The one or more network interfaces 161 communicate over a network such as via the links 176 and 131. Two or more eNBs 170 communicate using, e.g., link 176. The link 176 may be wired or wireless or both and may implement, e.g., an X2 interface.

[0038] The one or more buses 157 may be address, data, or control buses, and may include any interconnection mechanism, such as a series of lines on a motherboard or integrated circuit, fiber optics or other optical communication equipment, wireless channels, and the like. For example, the one or more transceivers 160 may be implemented as a remote radio head (RRH) 195, with the other elements of the eNB 170 being physically in a different location from the RRH, and the one or more buses 157 could be implemented in part as fiber optic cable to connect the other elements of the eNB 170 to the RRH 195.

[0039] The wireless network 100 may include a network control element (NCE) 190 that may include MME (Mobility Management Entity)/SGW (Serving Gateway) functionality, and which provides connectivity with a further network, such as a telephone network and/or a data communications network (e.g., the Internet). The eNB 170 is coupled via a link 131 to the NCE 190. The link 131 may be implemented as, e.g., an S1 interface. The NCE 190 includes one or more processors 175, one or more memories 171, and one or more network interfaces (N/W I/F(s)) 180, interconnected through one or more buses 185. The one or more memories 171 include computer program code 173. The one or more memories 171 and the computer program code 173 are configured to, with the one or more processors 175, cause the NCE 190 to perform one or more operations.

[0040] The computer readable memories 125, 155, and 171 may be of any type suitable to the local technical environment and may be implemented using any suitable data storage technology, such as semiconductor based memory devices, flash memory, magnetic memory devices and systems, optical memory devices and systems, fixed memory and removable memory. The computer readable memories 125, 155, and 171 may be means for performing storage functions. The processors 120, 152, and 175 may be of any type suitable to the local technical environment, and may include one or more of general purpose computers, special purpose computers, microprocessors, digital signal processors (DSPs) and processors based on a multi-core processor architecture, as non-limiting examples. The processors 120, 152, and 175 may be means for performing functions, such as controlling the UE 110, eNB 170, and other functions as described herein.

[0041] In general, the various embodiments of the user equipment 110 can include, but are not limited to, cellular telephones such as smart phones, tablets, personal digital assistants (PDAs) having wireless communication capabilities, portable computers having wireless communication capabilities, image capture devices such as digital cameras having wireless communication capabilities, gaming devices having wireless communication capabilities, music storage and playback appliances having wireless communication capabilities, Internet appliances permitting wireless Internet access and browsing, tablets with wireless communication capabilities, as well as portable units or terminals that incorporate combinations of such functions.

[0042] Having thus introduced one suitable but non-limiting technical context for the practice of the exemplary embodiments of this invention, the exemplary embodiments will now be described with greater specificity.

[0043] FIG. 2(a) is a logic flow diagram for configuring a UE for reduced latency mode. This figure further illustrates the operation of an exemplary method, a result of execution of computer program instructions embodied on a computer readable memory, functions performed by logic implemented in hardware, and/or interconnected means for performing functions in accordance with exemplary embodiments. For instance, the RLM module 140 may include multiples ones of the blocks in FIG. 2(a), where each included block is an interconnected means for performing the function in the block. The blocks in FIG. 2(a) are assumed to be performed by the UE 110, e.g., under control of the RLM module 140 at least in part.

[0044] As shown, a configuration is received indicating a UE is to operate in a reduced latency mode (Step One). The UE determines uplink control information to be reported using a short physical uplink control channel (Step Two). The UE determines a short physical uplink control channel resource for transmitting the uplink control information (Step Three). The determined short physical uplink control channel resource is a reduced latency mode physical uplink control channel resource. The short physical uplink control channel resource comprises a first and a second instance of LTE Rel-8 length 12 uplink DMRS sequence transmitted in one or more DFT-S-OFDM symbols on a first physical resource block, followed by a third and a fourth instance of LTE Rel-8 length 12 uplink DMRS sequence transmitted in one or more DFT-S-OFDM symbols on a second physical resource block. The UE transmits the uplink control information on the determined reduced latency mode physical uplink control channel resource (Step Four).

[0045] FIG. 2(b) is a logic flow diagram for a base station communicating with a UE with reduced latency mode. This figure further illustrates the operation of an exemplary method, a result of execution of computer program instructions embodied on a computer readable memory, functions performed by logic implemented in hardware, and/or interconnected means for performing functions in accordance with exemplary embodiments. For instance, the RLM module 150 may include multiples ones of the blocks in FIG. 2(b), where each included block is an interconnected means for performing the function in the block. The blocks in FIG. 2(b) are assumed to be performed by a base station such as eNB 170, e.g., under control of the RLM module 150 at least in part.

[0046] As shown, a base station determines that a user equipment will transmit uplink control information in a reduced latency mode (Step One). The base station determines a short physical uplink control channel resource for receiving the uplink control information (Step Two). The determined short physical uplink control channel resource is a reduced latency mode physical uplink control channel resource. The short physical uplink control channel resource comprises a first and a second instance of LTE Rel-8 length 12 uplink DMRS sequence transmitted in one or more DFT-S-OFDM symbols on a first physical resource block, followed by a third and a fourth instance of LTE Rel-8 length 12 uplink DMRS sequence transmitted in one or more DFT-S-OFDM symbols on a second physical resource block. The base station receives the uplink control information on the determined reduced latency mode physical uplink control channel resource (Step Three).

[0047] Embodiments herein may be implemented in software (executed by one or more processors), hardware (e.g., an application specific integrated circuit), or a combination of software and hardware. In an example embodiment, the software (e.g., application logic, an instruction set) is maintained on any one of various conventional computer-readable media. In the context of this document, a “computer-readable medium” may be any media or means that can contain, store, communicate, propagate or transport the instructions for use by or in connection with an instruction execution system, apparatus, or device, such as a computer, with one example of a computer described and depicted, e.g., in FIG. 1. A computer-readable medium may comprise a computer-readable storage medium (e.g., memories 125, 155, 171 or other device) that may be any media or means that can contain, store, and/or transport the instructions for use by or in connection with an instruction execution system, apparatus, or device, such as a computer. A computer-readable storage medium does not comprise propagating signals.

[0048] In accordance with a non-limiting exemplary embodiment, a configuration is received indicating a UE is to operate in a reduced latency mode. The UE determines uplink control information to be reported using a short physical uplink control channel. The UE determines a short physical uplink control channel resource for transmitting the uplink control information. The determined short physical uplink control channel resource is a reduced latency mode physical uplink control channel resource. The short physical uplink control channel resource comprises a first and a second instance of LTE Rel-8 length 12 uplink DMRS sequence transmitted in one or more DFT-S-OFDM symbols on a first physical resource block, followed by a third and a fourth instance of LTE Rel-8 length 12 uplink DMRS sequence transmitted in one or more DFT-S-OFDM symbols on a second physical resource block. The UE transmits the uplink control information on the determined reduced latency mode physical uplink control channel resource.

[0049] The uplink control information may include HARQ-ACK for one or more downlink transport block for at least one of one or more downlink carriers and channel state information. The uplink control information may also include a scheduling request indicator. The reduced latency mode may include operation with transmit time intervals shorter than one millisecond. The first and the second physical resource blocks may be located on the opposite edges of the system bandwidth.

[0050] The cyclic shifts applied for the first and the second instances of the LTE Rel-8 length 12 uplink DMRS sequence may be different. The cyclic shift for the second instance may be implicitly derived based on the cyclic shift for the first instance. For example, if the index of the cyclic shift for the first instance is n, the index of the cyclic shift for the second instance may be e.g. n+1 or n+2. The cyclic shifts applied for the said third and the fourth instances of the LTE Rel-8 length 12 uplink DMRS sequence may be different. The cyclic shift for the fourth instance may be implicitly derived based on the cyclic shift for the first or the third instance.

[0051] At least one of the first or the second instances of LTE Rel-8 length 12 uplink DMRS sequence may be un-modulated and may be used as a demodulation reference signal by the eNodeB. At least one of the said third or the fourth instances of LTE Rel-8 length 12 uplink DMRS sequence may be un-modulated and may be used as a demodulation reference signal by the eNodeB.

[0052] At least one of the said first, the second, the third, and the fourth LTE Rel-8 length 12 uplink DMRS sequence may be modulated and carry uplink control information including at least one of a HARQ-ACK, channel state information and scheduling request indicator. The modulation may be at least one of quadrature phase shift key modulation and multi-sequence modulation.

[0053] At least some of the demodulation reference signals for two subsequent short physical uplink control channel resources may be located on the same DFT-S-OFDM symbol on the same physical resource block and have different cyclic shifts. The short physical uplink control channel resource may include at least a portion of four LTE PUCCH format 2 resources.

[0054] In accordance with another non-limiting embodiment, a base station determines that a UE will transmit uplink control information in a reduced latency mode. The base station determines a short physical uplink control channel resource for receiving the uplink control information. The determined short physical uplink control channel resource is a reduced latency mode physical uplink control channel resource. The short physical uplink control channel resource comprises a first and a second instance of LTE Rel-8 length 12 uplink DMRS sequence transmitted in one or more DFT-S-OFDM symbols on a first physical resource block, followed by a third and a fourth instance of LTE Rel-8 length 12 uplink DMRS sequence transmitted in one or more DFT-S-OFDM symbols on a second physical resource block. The base station receives the uplink control information on the determined reduced latency mode physical uplink control channel resource.

[0055] In accordance with an exemplary embodiment, a sPUCCH is built for a low-latency use case using four instances of a predetermined UL demodulation reference Signal sequence (DM-RS), occupying at least partially four PUCCH format 2 resources. The instances of the DM-RS sequence are grouped so that they form two pairs, and the instances of the DM-RS sequence in each pair are transmitted on the same PRB. Within the PRB, the two DMRS sequences are separated by applying a different cyclic shift (CS) for each one.

[0056] In order to maximize frequency diversity, the different pairs of DM-RS sequences are transmitted on different PRBs on the different sides of the system bandwidth (defined by the PRB index m). Moreover, for a given DFT-S-OFDMA symbol, only one of the pairs of DM-RS sequences is transmitted.

[0057] In accordance with an exemplary embodiment, the instances of DM-RS sequences are further divided into two categories:

1) Some of the DM-RS instances are transmitted as such and are used as demodulation reference signals
2) Some of the DM-RS instances are QPSK modulated and carry uplink control information such as: HARQ-ACKs for one or more data transport blocks on one or more carriers, Channel State Information (CSI) including one or more of CQI, PMI, and RI, and Scheduling request indicator (SRI)

[0058] FIG. 4 shows the basic principle of an exemplary embodiment. Each short TTI (sTTI) is split (in time) into two parts (denoted as sub-slots) and frequency hopping takes place at the sub-slot boundary between two PRBs. In the figure, the short TTI length is 7 DFT-S-OFDM symbols and the two sub-slots are 3 and 4 DFT-S-OFDM symbols long. In each sub-slot, one of the instances of the DM-RS sequence is transmitted un-modulated, and can hence be used as a reference signal by the eNodeB when receiving the uplink control information. As shown in FIG. 4, the transmission of these un-modulated sequences in symbols 1 and 4 of sTTI 0 and in symbols 8 and 11 in sTTI 1 are marked with CS_0 (Cyclic Shift index 0). The other DM-RS instances are QPSK modulated and can be used for transmission of UCI. As shown in FIG. 4, the other DM-RS instances are marked with M-CS_0 and M-CS_1 (Modulated Cyclic Shift index 0 and 1). Also here, Rel-8 length-12 UL DM-RS sequences are applied, with a distinct cyclic shift assigned for each sequence. In the DM-RS symbols (i.e. symbol #1, #4), one un-modulated DM-RS sequence is transmitted (e.g. CS_0), whereas in data symbols two QPSK-modulated sequences are transmitted in parallel (e.g. M-CS_0, M-CS_1), separated with cyclic shifts. Frequency hopping is applied between “short slots” hence maintaining frequency diversity similarly as the legacy PUCCH formats. The described arrangement results in having 20 uncoded bits in a 0.5 ms TTI, i.e. the same number as with the current LTE PUCCH format 2. This allows for directly reusing the PUCCH Format 2 Reed-Muller channel coding scheme. Similarly as with the 1/ 2 bit design, also in this case legacy PUCCH format 2 users - as well as sPUCCH Format 1 users – can be multiplexed on the same PRB(s). The design principle scales also to shorter TTI lengths, although at the cost of supported payloads.

[0059] The exemplary embodiment illustrated in FIG. 4 allows transmission of 10 QPSK modulated DFT-S-OFDM symbols (20 coded bits) which means that the existing coding scheme of Format 2 can be utilized. In another configuration alternative, symbols 1 and 4 (8 and 11) would also carry a modulated sequence in addition to the un-modulated sequence. This would allow a capacity of 12 QPSK symbols (24 coded bits) but with reduced maximum reference signal power as the power in symbols 1 and 4 would need to be split between the modulated and reference sequences. Furthermore, the exemplary embodiment illustrated in FIG. 4 means favorable single carrier transmission of the reference signals while also transmitting modulated sequences in addition to the reference sequences with an increase PAPR (Peak to Average Power Ratio) and a required larger power back-off.

[0060] Other configurations with reference sequences transmitted in more than one DFT-S-OFDM symbol of a sub-slot can be designed for increased reference signal power.

[0061] Although in Figure 4 the cyclic shifts applied are the same in different symbols, it should be noted that this does not need to be the case. For example, cyclic shift hopping (i.e. randomization) can be applied between adjacent DFT-S-OFDM symbols and / or short-slots. In an exemplary embodiment, the cyclic shifts for each modulated or un-modulated DMRS sequence is determined the same way as for PUCCH format 2/2a/2b resources on the same physical resource block, as defined in 3GPP TS 36.211, version 8.9.0 in Section 5.4 and 5.4.2.

[0062] FIG. 5 illustrates three alternative configurations with alternating 3 and 4 symbols sTTI lengths. In Alternative 1 the number of modulation symbols in the consecutive sTTIs is fairly uneven (4 versus 6) while in Alternative 2 all sTTIs carry 5 modulation symbols. In Alternative 3, the numbers of modulation symbols are 5 and 6. In alternatives 2 and 3 the second sub-slot is in a sense overlapping with the first sub-slot of the following sTTI as there are transmissions belonging to two sTTIs in symbols 3 and 10. The Alternatives 2 and 3 are drawn for the case that different UEs transmit in the consecutive sTTIs. If a single UE transmits, only one reference sequence (CS_0) is transmitted in symbols 3 and 10 because that leads to smaller PAPR.

[0063] FIG. 6 shows the BLER performance for new sPUCCH format options for 7-symbol sTTI length and also shows a comparison with existing legacy formats. The exemplary embodiment shown in FIG. 4 is denoted by format-2 like in FIG. 6. The performance is compared with other possible options as well. Format 3-like and format 4-like are other possible options that are mainly based on the existing legacy format 3 and legacy format 5, respectively. It is seen that the format-2 like option that is based on the proposed invention gives the best performance in comparison to other alternatives for both the low speed and high speed scenarios. For reference, legacy format 2 and legacy format 3 are also shown here. Because the legacy formats are for the full subframe and hop over 1-slot, their energy per bit is higher and they perform better than shorter formats.

[0064] PUCCH design is one of the key aspects in facilitating latency reduction. Latency reduction components are TTI shortening and processing time reduction. In order to be able to reduce HARQ round-trip time, the UL control channel conveying HARQ-ACK needs to be shortened similarly as the related PDSCH carrying the data transport block(s). Therefore, a shortened PUCCH will need to be specified to carry at least HARQ-ACK. The same design may be applied for conveying Scheduling Request as well, which in turn may provide a minor decrease in the observed latency.

[0065] The primary contents for sTTI PUCCH are HARQ-ACK (+SR) and the need for supporting periodic CSI transmission over shortened PUCCH is unclear. As for the PUCCH supported payload, the baseline design should provide support for single-CC case (i.e. 1 or 2 bit HARQ-ACK + possibly SR) with a robust performance as well as for moderate carrier aggregation configurations should be considered as well, so that ~10 bits can be supported.

[0066] When it comes to shortened PUCCH design, a few requirements need to be considered. In LTE, the coverage of the whole system is often limited by the PUCCH. In order to mitigate this, various means have been specified including e.g. PUCCH repetition to enhance HARQ-ACK coverage. Obviously, for shorter TTI operation to make sense, the impact on coverage should be minimized. On the other hand, shorter TTI means that the energy per bit for, for example, HARQ-ACK transmission is inevitably reduced, and hence there will be some penalty in terms of cell coverage. This issue is more pronounced with TTI lengths less than 0.5 ms and may easily end up limiting the coverage of sTTI feature as a whole.

[0067] PUCCH coverage may easily become a bottleneck for sTTI, especially if sTTI length of less than 0.5 is considered. In order to make shorter TTI operation an attractive feature, special attention needs to be put on PUCCH coverage. As a start, one needs to keep the basic design properties of 1-ms PUCCH, namely frequency hopping to achieve frequency diversity. Furthermore, sPUCCH waveform should have low cubic metric to guarantee uncompromised operation at maximum TX power.

[0068] The sTTI PUCCH should aim for as large a coverage as possible, retain support for frequency diversity (i.e. hopping across band edges), and have low cubic metric similar or close to that of SC-FDMA. Another key design target for LTE PUCCH has been low overhead, which has been achieved with high multiplexing capability. Depending on the PUCCH format (and correspondingly payload), more than 10 UEs can share the same PUCCH PRB. The same design target is equally important with shorter TTIs as well, and efficient multiplexing of different sPUCCH UEs. Also, both sPUCCH and legacy PUCCH UEs should be supported within a PRB. In addition, any increase in UL control overhead due to sTTI should be minimized, multiplexing of sPUCCHs should be supported within the same PRB, and multiplexing of sPUCCH and legacy PUCCH should be supported within the same PRB.

[0069] In accordance with non-limiting exemplary embodiments, sPUCCH designs meet these target criteria. The designs target 0.5 ms TTI, and support payload sizes similar to legacy PUCCH Formats 1b and 2, respectively. However, the exemplary embodiments are also scalable and applicable with shorter TTI lengths.

[0070] FIG. 8 shows the design for a PUCCH Format 1b-like design is capable of supporting 1 or 2 bit HARQ-ACK transmission, as well as SR transmission through channel selection as in LTE Rel-8. The design is based on QPSK-modulated length-12 UL DM-RS sequences. Similarly as with legacy PUCCH format 2, user multiplexing with cyclic shifts can be performed, allowing for six simultaneous UEs on a single PUCCH PRB. Furthermore, it is also possible to assign some of the cyclic shifts for legacy PUCCH format 2 users as well, allowing for minimized UCI overhead and UL resource fragmentation.

[0071] The advantages of the exemplary embodiments include frequency diversity being maximized allowing for maximizing the performance in various scenarios. The solution of the exemplary embodiments can be done with small amount of additional signaling. Backwards compatibility can be maximized, with the exemplary embodiments operating on top of existing PUCCH format 2/2a/2b resources and coexisting with legacy PUCCH Format 2/2a/2b transmission on the same PRB. The solution is also scalable in terms of supported TTI length, supporting TTI lengths between 0.5ms and one DFT-S-OFDM symbol

[0072] Transmitting multiple DMRS sequences in parallel will cause some increase of the peak-to-average power ratio (PAPR). However, this is not expected to be a significant issue in the scenario where the UEs are not often power limited. Furthermore, multi-sequence modulation as described in e.g. 3GPP contribution R1-074326 can further reduce the PAPR.

[0073] If desired, the different functions discussed herein may be performed in a different order and/or concurrently with each other. Furthermore, if desired, one or more of the above-described functions may be optional or may be combined.

[0074] Although various aspects are set out above, other aspects comprise other combinations of features from the described embodiments, and not solely the combinations described above.

[0075] It is also noted herein that while the above describes example embodiments of the invention, these descriptions should not be viewed in a limiting sense. Rather, there are several variations and modifications which may be made without departing from the scope of the present invention.

[0076] The following abbreviations that may be found in the specification and/or the drawing figures are defined as follows:

3GPP	Third Generation Partnership Project
ACK/NACK	Acknowledgment of successful/unsuccessful transmission
BLER	Block error rate
CAZAC	Constant amplitude zero autocorrelation
CDM	Code division multiplex
CQI	Channel Quality Indicator
CS	Cyclic Shift
CSI	Channel State Information
DL	DownLink
DFT	Discrete Fourier Transform
DFT-S-OFDMA	DFT spread OFDMA, known as single-carrier (SC)-OFDMA
DM-RS	Demodulation Reference Sequence
HARQ	Hybrid Automatic Repeat ReQuest

L1	Layer 1, Physical Layer
LTE	Long Term Evolution
M-CS	Modulated Cyclic Shift (of a base sequence)
OFDMA	Orthogonal frequency division multiple access
PAPR	Peak-to-Average Power Ratio
PDCCH	Physical Downlink Control Channel
PMI	Precoding Matrix Indicator
PUCCH	Physical Uplink Control Channel
PUSCH	Physical Uplink Shared Channel
QPSK	Quadrature Phase Shift Key
RAN	Radio Access Network
RB	Resource Block
Rel	Release
RI	Rank Indicator
SCell	Secondary Cell
SC-FDMA	Single Carrier Frequency Division Multiple Access
SNR	Signal to noise ratio
SI	Study Item
sPUCCH	short Physical Uplink Control CHannel
SR	Scheduling Request
SRI	SR Indicator
TSG	Technical specification group
sTTI	short TTI
TTI	Transmit Time Interval
UCI	Uplink Control Information
UL	Uplink

CLAIMS

What is claimed is:

1. A method, comprising the steps of:

receiving a configuration to operate in a reduced latency mode;

determining uplink control information to be reported using a short physical uplink control channel;

determining a short physical uplink control channel resource for transmitting the uplink control information, wherein the determined short physical uplink control channel resource is a reduced latency mode physical uplink control channel resource, and wherein the short physical uplink control channel resource comprises a first and a second instance of LTE Rel-8 length 12 uplink DMRS sequence transmitted in one or more DFT-S-OFDM symbols on a first physical resource block, followed by a third and a fourth instance of LTE Rel-8 length 12 uplink DMRS sequence transmitted in one or more DFT-S-OFDM symbols on a second physical resource block; and

transmitting the uplink control information on the determined reduced latency mode physical uplink control channel resource.

2. The method according to claim 1, wherein the uplink control information includes at least one of HARQ-ACK for one or more downlink transport block for one or more downlink carriers, a channel state information and a scheduling request indicator .

3. The method according to claim 1, wherein the reduced latency mode includes operation with transmit time intervals shorter than one millisecond.

4. The method according to claim 1, wherein the first and the second physical resource blocks are located on the opposite edges of the system bandwidth.

5. The method according to claim 1, wherein the cyclic shifts applied for the said first and the second instances of the LTE Rel-8 length 12 uplink DMRS sequence are different.

6. The method according to claim 5, wherein the cyclic shift for the second instance is implicitly derived based on the cyclic shift for the first instance.

7. The method according to claim 1, wherein the cyclic shifts applied for the said third and the fourth instances of the LTE Rel-8 length 12 uplink DMRS sequence are different.

8. The method according to claim 7, wherein the cyclic shift for the fourth instance is implicitly derived based on the cyclic shift for the first or the third instance.

9. The method according to claim 1, wherein at least one of the said first or the second instances of LTE Rel-8 length 12 uplink DMRS sequence is not modulated and is used as a demodulation reference signal.

10. The method according to claim 1, wherein at least one of the said third or the fourth instances of LTE Rel-8 length 12 uplink DMRS sequence is not modulated and is used as a demodulation reference signal.

11. The method according to claim 1, wherein at least one of the said first, the second, the third, and the fourth LTE Rel-8 length 12 uplink DMRS sequence is modulated and carries uplink control information including at least one of a HARQ-ACK, channel state information and scheduling request indicator.

12. The method according to claim 11, wherein the modulation is at least one of quadrature phase shift key modulation and multi-sequence modulation.

13. The method according to claim 1, wherein at least some of the demodulation reference signals for two subsequent short physical uplink control channel resources are located on the same DFT-S-OFDM symbol on the same physical resource block and have different cyclic shifts.

14. The method according to claim 1, wherein the short physical uplink control channel resource includes at least a portion of four LTE PUCCH format 2 resources.

15. The method according to claim 1, wherein each said first and a second instance of LTE Rel-8 length 12 uplink DMRS sequence and said third and a fourth instance of LTE Rel-8 length 12 uplink DMRS sequence has a distinct cyclic shift assigned for each sequence.

16. The method according to claim 1, wherein the cyclic shift for each modulated or un-modulated DMRS sequence is determined in the same way as for PUCCH format 2/2a/2b resources on the same physical resource block.

17. An apparatus, comprising:
at least one processor; and
at least one memory including computer program code,
the at least one memory and the computer program code configured to, with the at least one processor, cause the apparatus to perform at least the following:
receive a configuration to operate in a reduced latency mode;

determine uplink control information to be reported using a short physical uplink control channel;

determine a short physical uplink control channel resource for transmitting the uplink control information, wherein the determined short physical uplink control channel resource is a reduced latency mode physical uplink control channel resource, and wherein the short physical uplink control channel resource comprises a first and a second instance of LTE Rel-8 length 12 uplink DMRS sequence transmitted in one or more DFT-S-OFDM symbols on a first physical resource block, followed by a third and a fourth instance of LTE Rel-8 length 12 uplink DMRS sequence transmitted in one or more DFT-S-OFDM symbols on a second physical resource block ; and

transmit the uplink control information on the determined reduced latency mode physical uplink control channel resource.

18. A computer program product comprising a computer-readable medium bearing computer program code embodied therein for use with a computer, the computer program code comprising:
code for ;

receiving a configuration to operate in a reduced latency mode;

determining uplink control information to be reported using a short physical uplink control channel;

determining a short physical uplink control channel resource for transmitting the uplink control information, wherein the determined short physical uplink control channel resource is a reduced latency mode physical uplink control channel resource, and wherein the short physical uplink control channel resource comprises a first and a second instance of LTE Rel-8 length 12 uplink DMRS sequence transmitted in one or more DFT-S-OFDM symbols on a first physical resource block, followed by a third and a fourth instance of LTE Rel-8 length 12 uplink DMRS sequence transmitted in one or more DFT-S-OFDM symbols on a second physical resource block ; and

transmitting the uplink control information on the determined reduced latency mode physical uplink control channel resource.

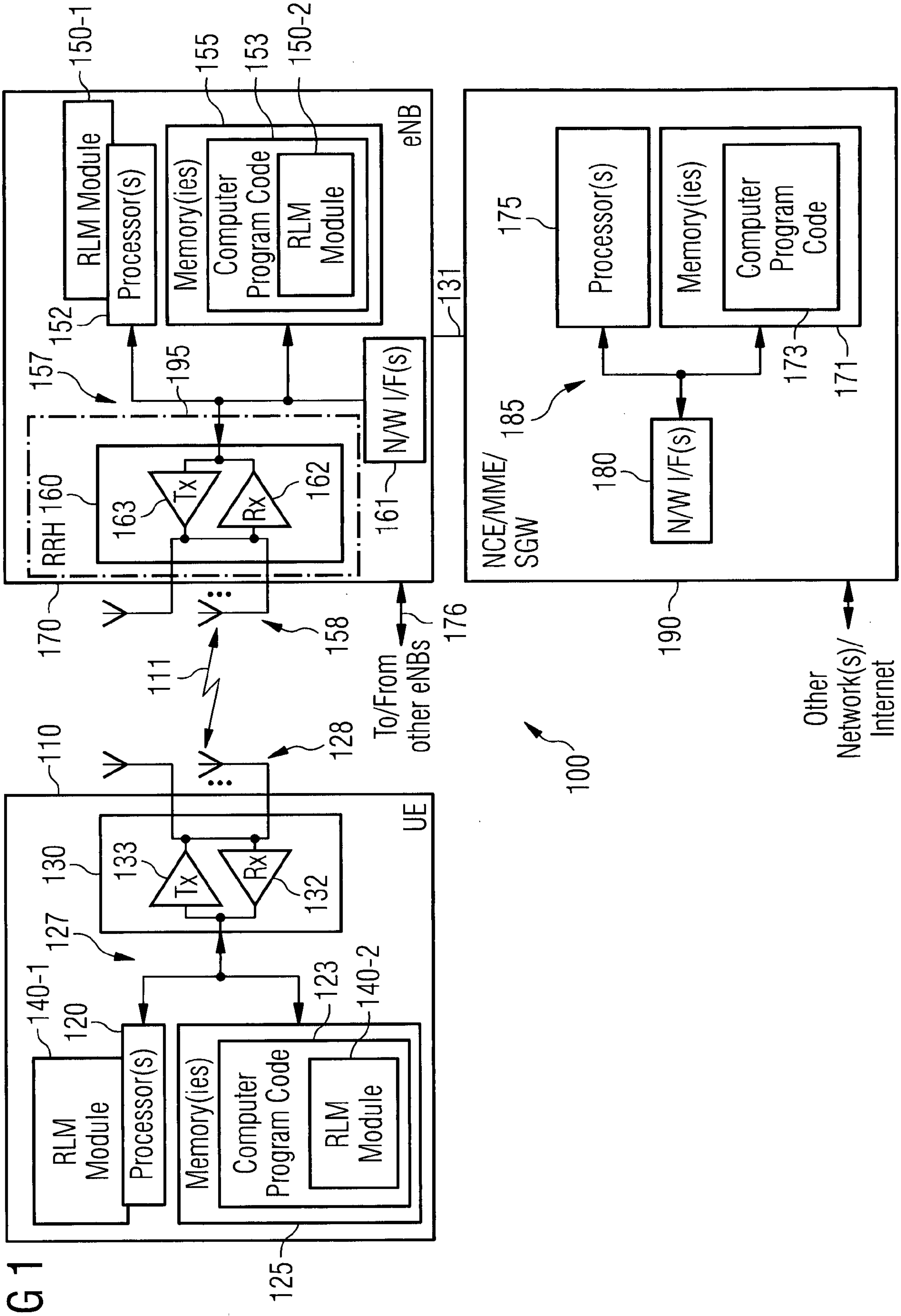
19. A method, comprising the steps of:

determining a user equipment will transmit uplink control information in a reduced latency mode);

determining a short physical uplink control channel resource for receiving the uplink control information, wherein the determined short physical uplink control channel resource is a reduced latency mode physical uplink control channel resource, and wherein the short physical uplink control channel resource comprises a first and a second instance of LTE Rel-8 length 12 uplink DMRS sequence transmitted in one or more DFT-S-OFDM symbols on a first physical resource block, followed by a third and a fourth instance of LTE Rel-8 length 12 uplink DMRS sequence transmitted in one or more DFT-S-OFDM symbols on a second physical resource block ; and

receiving the uplink control information on the determined reduced latency mode physical uplink control channel resource.

20. The method according to claim 19, wherein the reduced latency mode includes operation with transmit time intervals shorter than one millisecond.



UE
RLM Module
Processor(s)
Memory(ies)
Computer Program Code
RLM Module
Tx
Rx
110
120
123
125
127
128
130
132
133
140-1
140-2
111
eNB
RLM Module
Processor(s)
Memory(ies)
Computer Program Code
RLM Module
N/W I/F(s)
RRH 160
Tx
Rx
150-1
150-2
152
153
155
157
158
161
162
163
170
176
195
131
To/From other eNBs
NCE/MME/SGW
Processor(s)
Memory(ies)
Computer Program Code
N/W I/F(s)
171
173
175
180
185
190
Other Network(s)/ Internet
100

FIG 1

FIG 2A

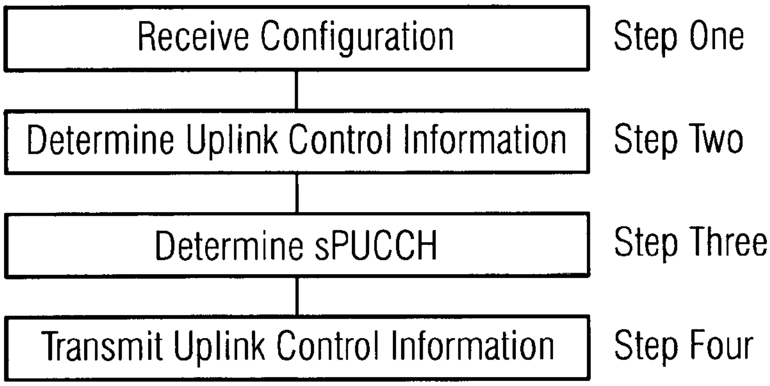
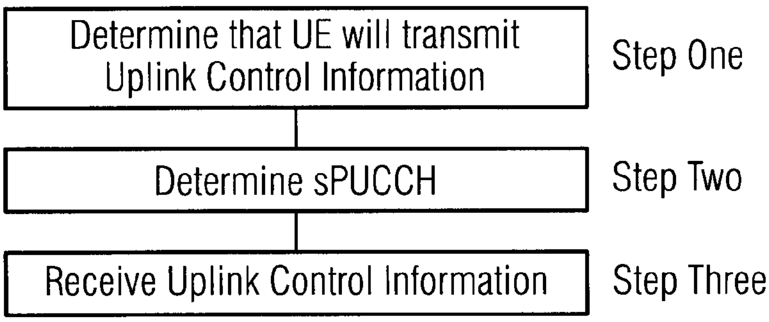

Receive Configuration
Step One
Determine Uplink Control Information
Step Two
Determine sPUCCH
Step Three
Transmit Uplink Control Information
Step Four

FIG 2B


Determine that UE will transmit Uplink Control Information
Step One
Determine sPUCCH
Step Two
Receive Uplink Control Information
Step Three

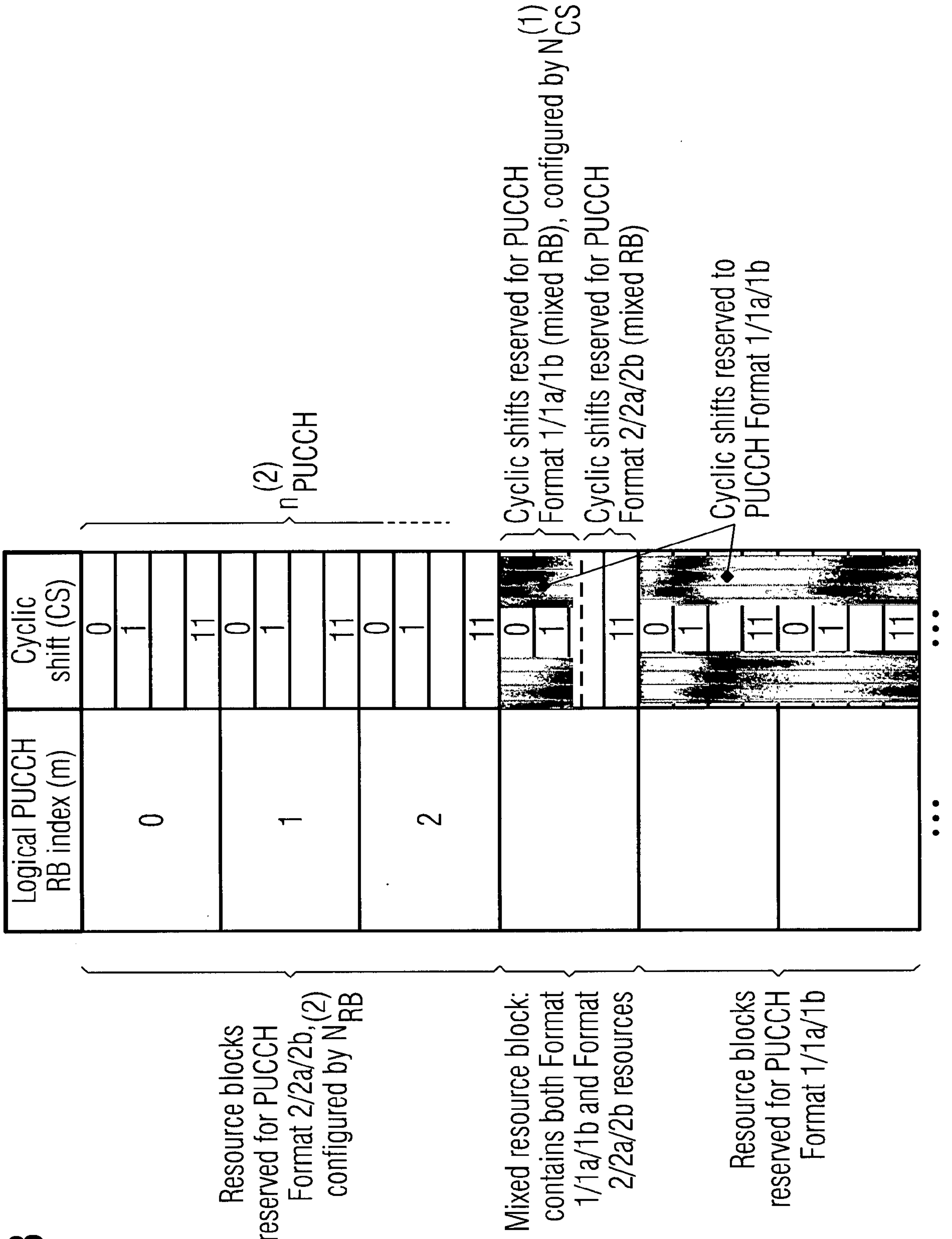
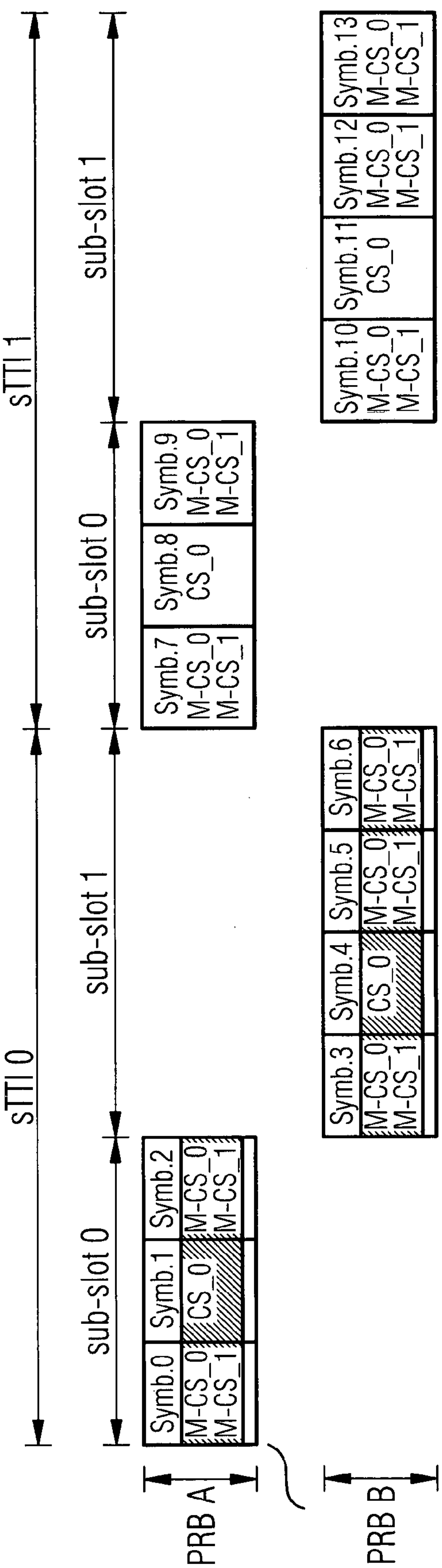

Logical PUCCH RB index (m)
Cyclic shift (CS)
0
1
2
0
1
11
$n^{(2)}_{PUCCH}$
Cyclic shifts reserved for PUCCH Format 1/1a/1b (mixed RB), configured by $N^{(1)}_{CS}$
Cyclic shifts reserved for PUCCH Format 2/2a/2b (mixed RB)
Cyclic shifts reserved to PUCCH Format 1/1a/1b
Resource blocks reserved for PUCCH Format 2/2a/2b, configured by $N^{(2)}_{RB}$
Mixed resource block: contains both Format 1/1a/1b and Format 2/2a/2b resources
Resource blocks reserved for PUCCH Format 1/1a/1b

FIG 3

FIG 4


PRB A
PRB B
sTTI 0
sTTI 1
sub-slot 0
sub-slot 1
sub-slot 0
sub-slot 1
Symb.0 M-CS_0 M-CS_1
Symb.1 CS_0
Symb.2 M-CS_0 M-CS_1
Symb.3 M-CS_0 M-CS_1
Symb.4 CS_0
Symb.5 M-CS_0 M-CS_1
Symb.6 M-CS_0 M-CS_1
Symb.7 M-CS_0 M-CS_1
Symb.8 CS_0
Symb.9 M-CS_0 M-CS_1
Symb.10 M-CS_0 M-CS_1
Symb.11 CS_0
Symb.12 M-CS_0 M-CS_1
Symb.13 M-CS_0 M-CS_1

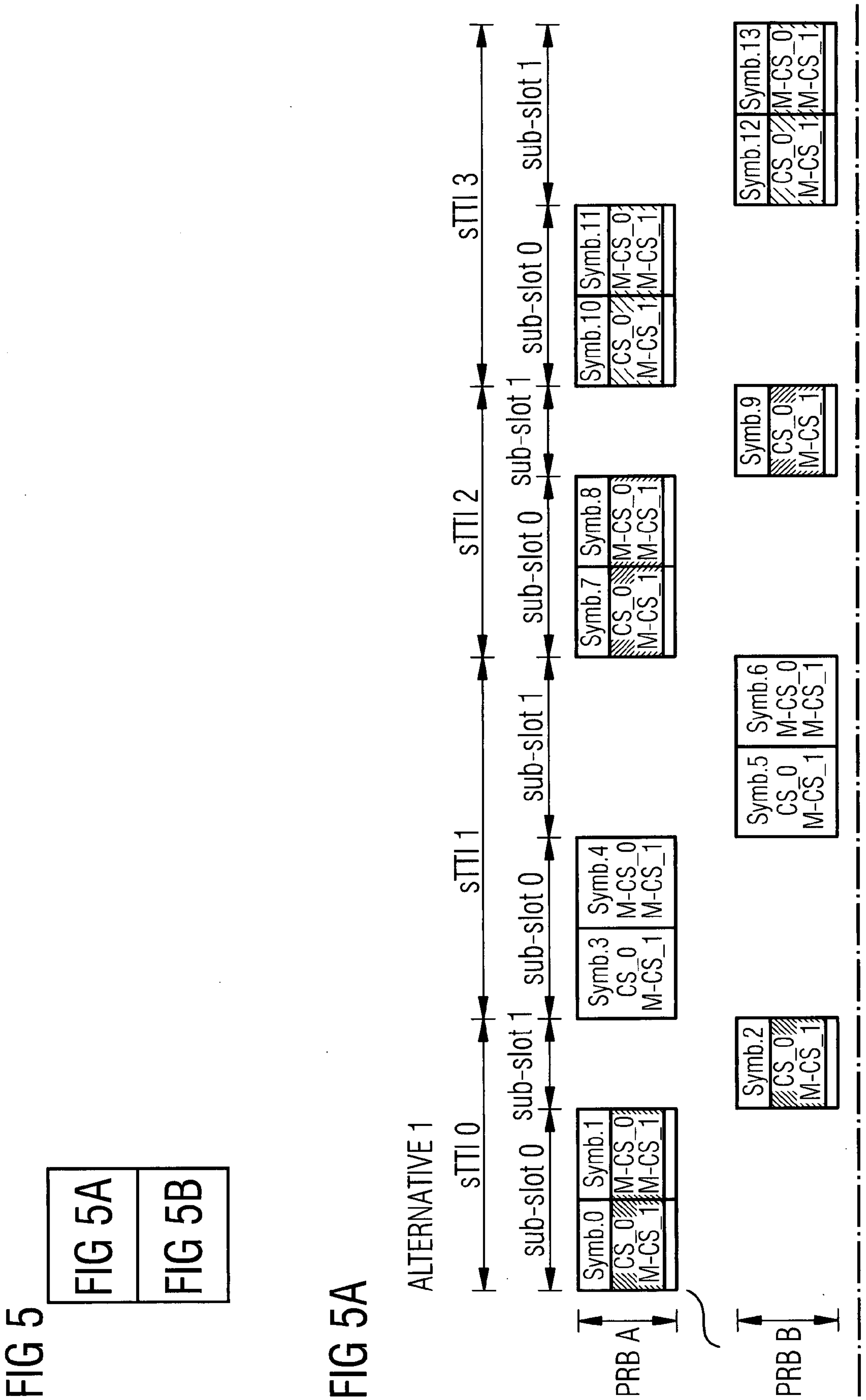


FIG 5A
FIG 5B
ALTERNATIVE 1
sTTI 0
sTTI 1
sTTI 2
sTTI 3
sub-slot 0
sub-slot 1
PRB A
PRB B
Symb.0 CS_0 M-CS_1
Symb.1 M-CS_0 M-CS_1
Symb.2 CS_0 M-CS_1
Symb.3 CS_0 M-CS_1
Symb.4 M-CS_0 M-CS_1
Symb.5 CS_0 M-CS_1
Symb.6 M-CS_0 M-CS_1
Symb.7 CS_0 M-CS_1
Symb.8 M-CS_0 M-CS_1
Symb.9 CS_0 M-CS_1
Symb.10 CS_0 M-CS_1
Symb.11 M-CS_0 M-CS_1
Symb.12 CS_0 M-CS_1
Symb.13 M-CS_0 M-CS_1

FIG 5

FIG 5A

FIG 5B

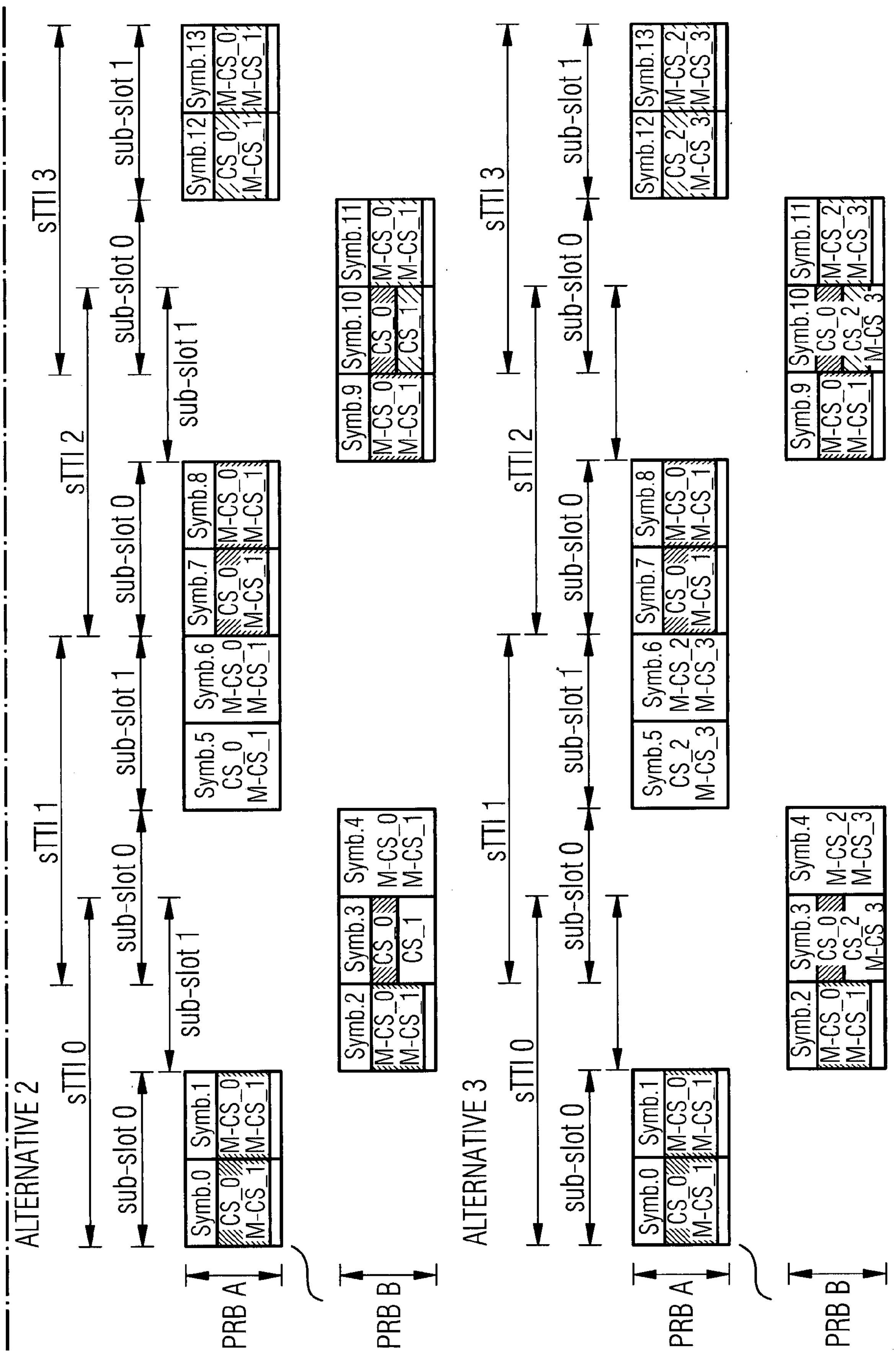

ALTERNATIVE 2
sTTI 0
sTTI 1
sTTI 2
sTTI 3
sub-slot 0
sub-slot 1
PRB A
PRB B
Symb.0
Symb.1
Symb.2
Symb.3
Symb.4
Symb.5
Symb.6
Symb.7
Symb.8
Symb.9
Symb.10
Symb.11
Symb.12
Symb.13
CS_0
CS_1
M-CS_0
M-CS_1
ALTERNATIVE 3
CS_2
M-CS_2
M-CS_3

FIG 6

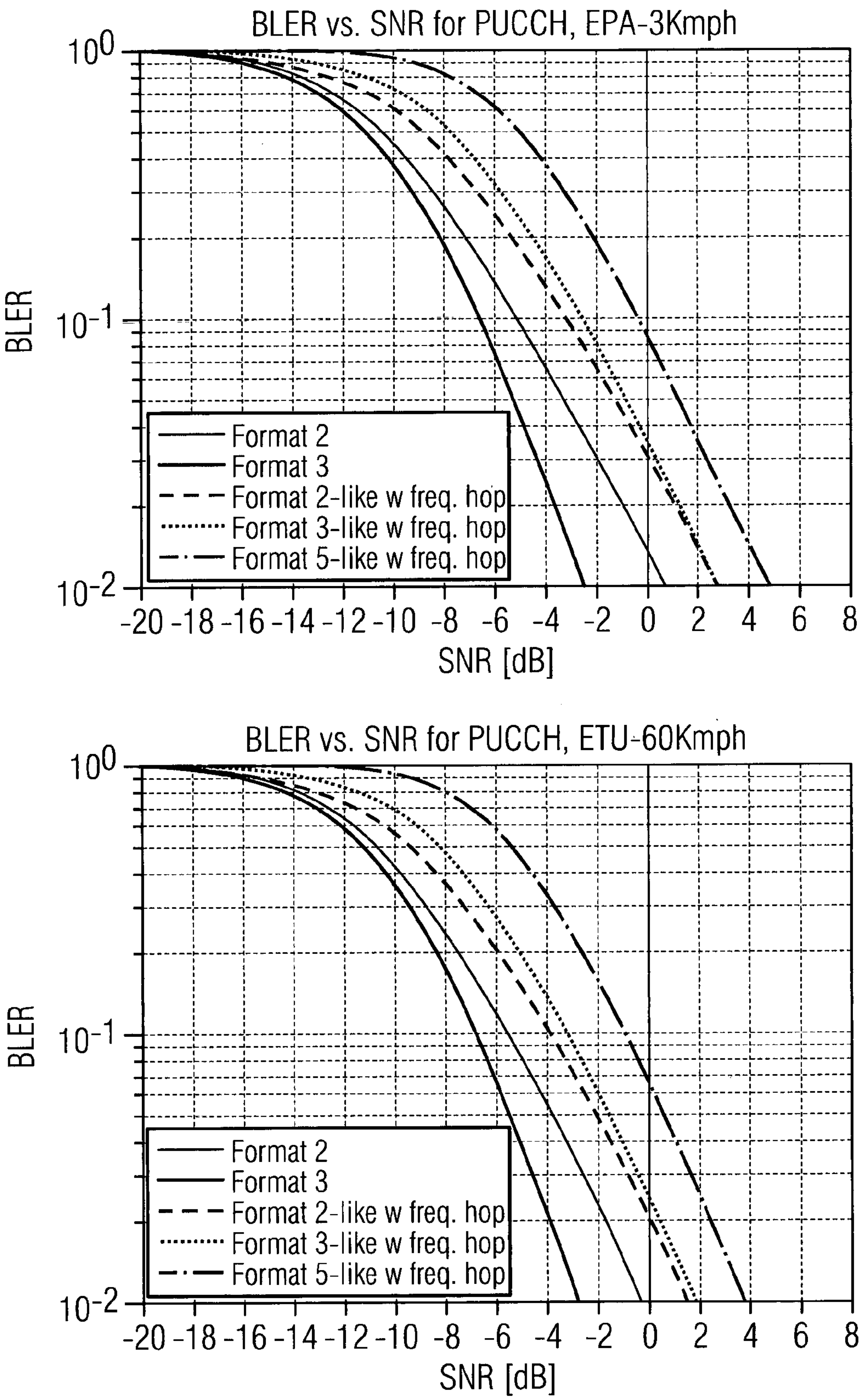

BLER vs. SNR for PUCCH, EPA-3Kmph
BLER
10^0
10^{-1}
10^{-2}
-20 -18 -16 -14 -12 -10 -8 -6 -4 -2 0 2 4 6 8
SNR [dB]
Format 2
Format 3
Format 2-like w freq. hop
Format 3-like w freq. hop
Format 5-like w freq. hop
BLER vs. SNR for PUCCH, ETU-60Kmph
BLER
10^0
10^{-1}
10^{-2}
-20 -18 -16 -14 -12 -10 -8 -6 -4 -2 0 2 4 6 8
SNR [dB]
Format 2
Format 3
Format 2-like w freq. hop
Format 3-like w freq. hop
Format 5-like w freq. hop

FIG 7

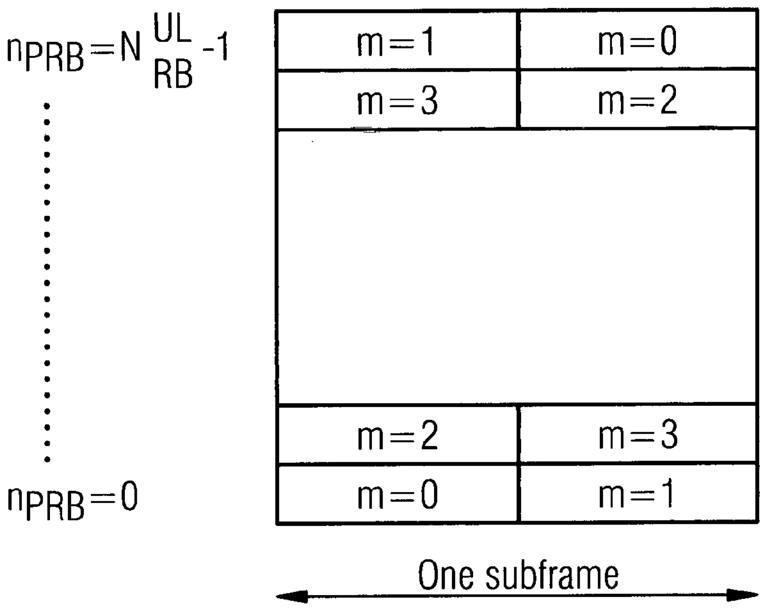
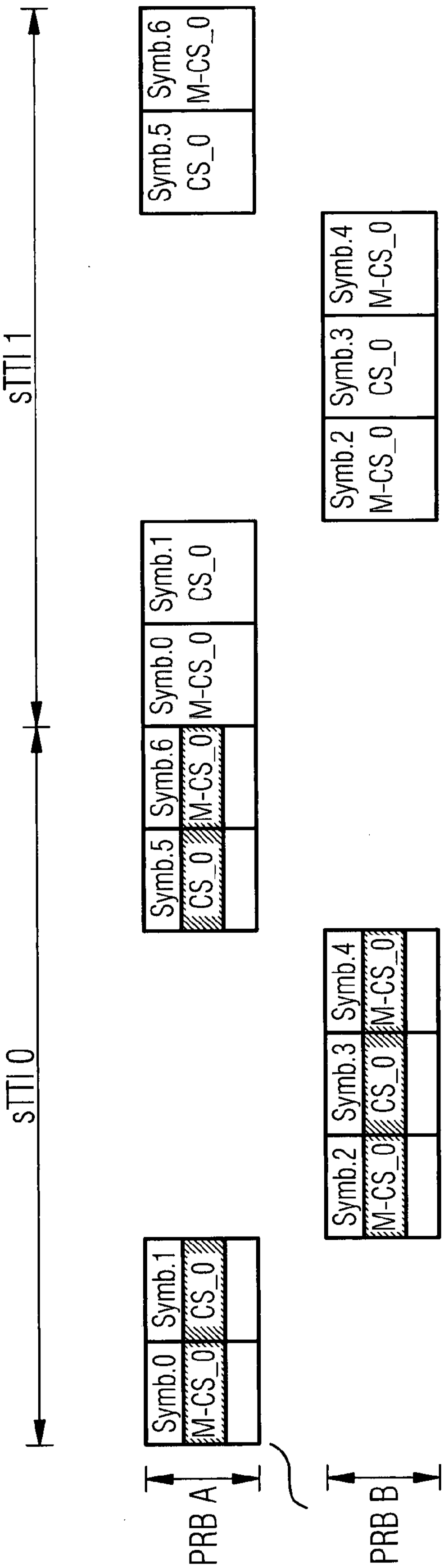


FIG 8


sTTI 0
sTTI 1
PRB A
PRB B
Symb.0 M-CS_0
Symb.1 CS_0
Symb.2 M-CS_0
Symb.3 CS_0
Symb.4 M-CS_0
Symb.5 CS_0
Symb.6 M-CS_0
Symb.0 M-CS_0
Symb.1 CS_0
Symb.2 M-CS_0
Symb.3 CS_0
Symb.4 M-CS_0
Symb.5 CS_0
Symb.6 M-CS_0

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2017/061109

A. CLASSIFICATION OF SUBJECT MATTER
INV. H04L12/701
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

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, 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	US 2016/037491 A1 (HWANG DAESUNG [KR] ET AL) 4 February 2016 (2016-02-04) abstract paragraphs [0007] - [0017], [0033] - [0036], [0038], [0057], [0058], [0060] paragraphs [0062], [0063], [0069], [0070], [0072], [0174] paragraphs [0175] - [0178], [0187] - [0189], [0208] - [0209] paragraphs [0230] - [0231] claim 5 -----	1-20

-/--

[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
27 July 2017	02/08/2017

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	Lai, Cristiana

4

International application No
PCT/EP2017/061109

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2013/141515 A1 (SAMSUNG ELECTRONICS CO LTD [KR]) 26 September 2013 (2013-09-26) abstract paragraphs [0030], [0034], [0042], [0065] - [0068], [0089], [0091] paragraphs [0098] - [0108] claims 1-22 figures 7-10 -----	1-20

4

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/EP2017/061109

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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