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(54) Title: DESIGN AND RESOURCE ALLOCATION OF AN ADVANCED PHYSICAL UPLINK CONTROL CHANNEL

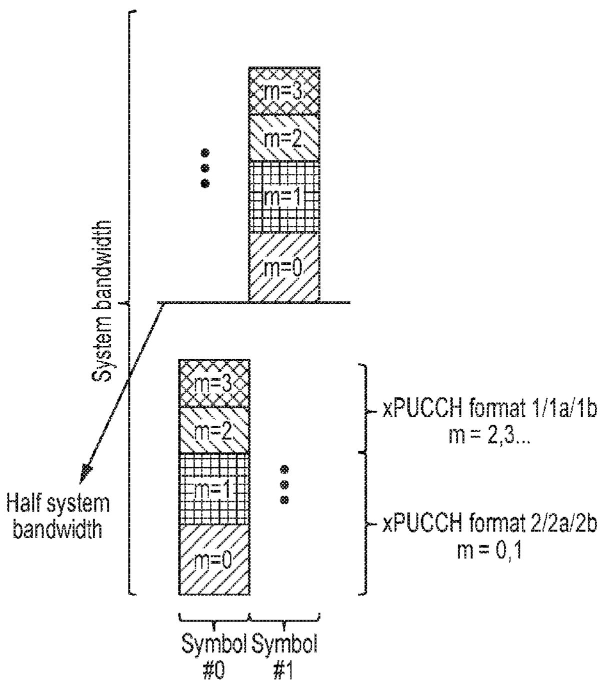

FIG.17

(57) Abstract: Briefly, in accordance with one or more embodiments, an apparatus of a user equipment (UE) comprises baseband processing circuitry to generate hybrid automatic repeat request (HARQ) acknowledgement or negative acknowledgment (ACK/NACK) information, or a channel state information (CSI) report, or a combination thereof, to be transmitted in an advanced physical uplink control channel (xPUCCH), and generate the xPUCCH to carry the HARQ ACK/NACK information or the CSI report, or a combination thereof, on an allocated resource. In accordance with one or more other embodiments, an apparatus of an evolved Node B (eNB) comprises baseband processing circuitry to generate a resource allocation configuration for an advanced physical uplink control channel (xPUCCH) to be transmitted by a UE to the eNB, and process a xPUCCH format transmitted from the UE on the configured resource.

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DESIGN AND RESOURCE ALLOCATION OF AN ADVANCED PHYSICAL UPLINK CONTROL CHANNEL

CROSS-REFERENCE TO RELATED APPLICATIONS

The present application claims the benefit of U.S. Application No. 62/256,335 filed Nov. 17, 2015. The present application also claims the benefit of U.S. Application No. 62/264,234 filed Dec. 7, 2015. Said Application No. 62/256,335 and said Application No. 62/264,234 are hereby incorporated herein by reference in their entireties.

BACKGROUND

Mobile communication has evolved significantly from early voice systems to today's highly sophisticated integrated communication platforms. The next generation wireless communication system, known as the Fifth Generation (5G), will provide access to information and sharing of data anywhere, anytime by various users and applications. It is expected that 5G will be a unified network and system targeted to meet vastly different and sometime conflicting performance dimensions and services. Such diverse multi-dimensional requirements are driven by different services and applications. In general, 5G will evolve based on the Third Generation Partnership Project (3GPP) Long Term Evolution Advanced (LTE) Advance with additional potential new Radio Access Technologies (RATs) to enrich users with better, simpler and more seamless wireless connectivity solutions. In addition, 5G will enable myriad devices connected by wireless links to deliver fast and rich contents and services.

DESCRIPTION OF THE DRAWING FIGURES

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

FIG. 1 is a diagram of self-contained time division duplex (TDD) subframe structures in the downlink in accordance with one or more embodiments;

FIG. 2 is a diagram of resource allocation for a physical uplink control channel (PUCCH) in accordance with one or more embodiments;

FIG. 3 is a diagram of a procedure for the generation of an advanced physical uplink control channel (xPUCCH) in accordance with one or more embodiments;

FIG. 4 is a diagram of a demodulation reference signal (DM-RS) pattern for xPUCCH transmission with two antenna ports in accordance with one or more embodiments;

FIG. 5 is a diagram of an example of multiplexing an advanced physical uplink control channel (xPUCCH) transmission in frequency-division multiplexing (FDM) with two antenna ports in accordance with one or more embodiments;

FIG. 6 is a diagram of one example of multiplexing an advanced physical uplink control channel (xPUCCH) transmission in code-division multiplexing (CDM) with two antenna ports in accordance with one or more embodiments;

FIG. 7 is a diagram of frequency hopping based on a mirroring pattern in accordance with one or more embodiments;

FIG. 8 is a diagram of frequency hopping based on sub-band hopping in accordance with one or more embodiments;

FIG. 9 is a diagram of an example of an advanced physical uplink control channel (xPUCCH) resource mapping for a single carrier waveform in accordance with one or more embodiments;

FIG. 10 is a diagram of one option for xPUCCH resource mapping with one OFDM symbol duration in accordance with one or more embodiments;

FIG. 11 is a diagram of another option for xPUCCH resource mapping with one OFDM symbol duration in accordance with one or more embodiments;

FIG. 12 is a diagram of yet another option for xPUCCH resource mapping with one OFDM symbol duration in accordance with one or more embodiments;

FIG. 13 is a diagram of one option for xPUCCH resource mapping with two OFDM symbol duration in accordance with one or more embodiments;

FIG. 14 is a diagram of another option for xPUCCH resource mapping with two OFDM symbol duration in accordance with one or more embodiments;

FIG. 15 is a diagram of yet another option for xPUCCH resource mapping with two OFDM symbol duration in accordance with one or more embodiments;

FIG. 16 is a diagram of a further option for xPUCCH resource mapping with two OFDM symbol duration in accordance with one or more embodiments;

FIG. 17 is a diagram of yet a further option for xPUCCH resource mapping with two OFDM symbol duration in accordance with one or more embodiments;

FIG. 18 is a diagram of example components of a wireless device in accordance with one or more embodiments.

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

DETAILED DESCRIPTION

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

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

Referring now to FIG. 1, a diagram of self-contained time division duplex (TDD) subframe structures in the downlink in accordance with one or more embodiments will be discussed. FIG. 1 illustrates two types of self-contained TDD subframe structures in the (DL), low latency structure 110 and high throughput structure 112, to enable low latency transmission for enhanced mobile broadband communication. In particular, for these two types of structures, an advanced physical downlink shared channel (xPDSCH) may be scheduled by a Fifth Generation (5G) advanced physical downlink control channel (xPDCCH) and may be transmitted right after the xPDCCH. A guard time (GT) may or may not be inserted between the xPDSCH and the advanced physical uplink control channel (xPUCCH) in order to accommodate the downlink (DL) to uplink (UL) switching time, UL to DL switching time, and round-trip propagation delay.

In order to increase the data rate, two or more subframes may be aggregated for one xPDSCH transmission for UE as shown in high throughput structure 112. In a high throughput structure 112, the xPDSCH spans two subframes, and GT is inserted in the second subframe. In such an arrangement, GT overhead may be reduced by half compared to low latency structure 110. In some embodiments, an additional xPDCCH may be inserted into every subframe to allow same subframe scheduling for the DL data channel transmission.

In accordance with a Long Term Evolution (LTE) specification, PUCCH may be transmitted in a frequency region on the edges of the system bandwidth. Furthermore, the PUCCH and the physical uplink shared channel (PUSCH) may be multiplexed in a frequency-division multiplexing (FDM) manner. As depicted in the FIG. 1, however, the xPUCCH and data channel may be multiplexed in a time division multiplexing (TDM) manner. In the case when uplink control information (UCI) includes hybrid automatic repeat request (HARQ) acknowledgement/negative acknowledgment (ACK/NACK) feedback and/or channel state information (CSI) report, for example channel quality indicator (CQI), pre-coding matrix indicator (PMI) and rank indicator (RI) and/or beam related information, the xPUCCH may be designed to carry such information as discussed, below.

Referring now to FIG. 2, a diagram of resource allocation for a physical uplink control channel (PUCCH) in accordance with one or more embodiments will be discussed. In an existing LTE specification, the PUCCH may be transmitted in a frequency region on the edges of the system bandwidth. FIG. 2 illustrates the resource allocation for the PUCCH using the existing LTE specification. To exploit frequency diversity, each PUCCH transmission in one subframe may comprise a single resource block (RB) in the first slot at or near one edge of the system bandwidth, followed by a second RB in the second slot at or near the opposite edge of the system bandwidth. As shown in the FIG. 2, the PUCCH formats 2/2a/2b are mapped and transmitted on the band-edge RBs, for example in PUCCH region m = 0, 1, followed by the PUCCH scheduling request (SR) and HARQ ACK/NACK format 1/1a/1b, for example regions m=2, 3, 4, 5).

As shown in FIG. 1 above in high throughput structure 112, multiple subframes may be aggregated to increase the data rate. In such an arrangement, the xPUCCH in the last subframe of the aggregated subframes of high throughput structure may carry the HARQ ACK/NACK feedback for the xPDSCH within the aggregated subframes. Depending on the aggregation level, the number of ACK/NACK bits may be relatively large. Furthermore, similar to the existing LTE specification, the xPUCCH also may carry the periodic CSI report to facilitate frequency dependent scheduling. Based on such an arrangement, the number of uplink control information (UCI) bits carried by the xPUCCH can be assumed as X number of bits. In this arrangement, the generation procedure of the xPUCCH is shown in and described with respect to FIG. 3, below.

Referring now to FIG. 3, a diagram of a procedure for the generation of an advanced physical uplink control channel (xPUCCH) in accordance with one or more embodiments will be discussed. FIG. 3 illustrates the procedure for the generation of the xPUCCH. The detailed design for the xPUCCH may be as follows. In a first operation 310, coding may be applied for the xPUCCH information bit, for example X bits. In one example, the block coding scheme may be based on the Reed-Müller code used for the PUCCH format 2 as defined in the section 5.2.3.3 of the Third Generation Partnership Project (3GPP) Technical Standard (TS) 36.212. In another example, if the number of information bits is relatively large, a tail-biting convolutional coder (TBCC) as defined in the section 5.1.3.1 of 3GPP TS 36.212 may be applied for the xPUCCH. In such an arrangement, a cyclic redundancy check (CRC) may be appended on the xPUCCH formation bit first prior to the encoding. Two CRC sequences may be predefined by the system, and whether the Scheduling Request (SR) is enabled or disabled may be utilized to determine which CRC sequence is applied.

After the coding at operation 310, a user equipment (UE) specific scrambling at operation 312 may be utilized to further randomize the interference. More specifically, the scrambling seed may be defined as a function of a physical cell identifier (ID) and/or a virtual cell ID and/or UE ID, for example in a form of Cell-Radio Network Temporary Identifier (C-RNTI), and/or subframe/slot/symbol index for the transmission of the xPUCCH. In one example, the scrambling seed may be given by:

$$c_{init} = \left(\left\lfloor \frac{n_s}{2} \right\rfloor + 1\right) \cdot \left(2N_{cell}^{ID} + 1\right) \cdot 2^{16} + n_{RNTI}$$

where n_s is the slot index, N_{cell}^{ID} is the physical cell ID, and n_{RNTI} is the C-RNTI. I n another example, in the case when multiple receive points (RP) receive the xPUCCH simultaneously on the same time and frequency resource, the scrambling sequence may be initialized as a function of virtual cell ID or a cluster/sub-cluster ID, namely:

$$c_{init} = \left(\left\lfloor \frac{n_s}{2} \right\rfloor + 1\right) \cdot \left(2N_{xPUCCH} + 1\right) \cdot 2^{16} + n_{ID}$$

where N_{xPUCCH} is the virtual cell ID which may be configured by higher layer signaling via a 5G master information block (xMIB), 5G advanced system information block (xSIB), and UE specific dedicated radio resource control (RRC) signaling, and n_{ID} is a UE specific parameter which may be indicated in the downlink control information (DCI) format.

Subsequently, at modulation operation 314, binary phase-shift keying (BPSK) or quadrature phase-shift keying (QPSK) may be utilized for the modulation to ensure robust performance. In resource mapping operation 316, modulated symbols may be mapped to the allocated resources. It should be noted that the xPUCCH can be transmitted in one or more orthogonal frequency-division multiplexing (OFDM) symbols in the last part of the self-contained subframe structures of FIG. 1. The resource mapping mechanism of operation 316 is shown in and described with respect to FIG. 4, below.

Referring now to FIG. 4, a diagram of a demodulation reference signal (DM-RS) pattern for an advanced physical uplink control channel (xPUCCH) transmission with two antenna ports (APs) in accordance with one or more embodiments will be discussed. FIG. 4 illustrates resource mapping for the xPUCCH when one symbol is allocated for the xPUCCH transmission. As shown in FIG. 4, the demodulation Reference Signal (DM-RS) pattern for the transmission of xPDCCH can may be reused for the transmission of the xPUCCH. The DM-RS for two antenna ports (AP) may be multiplexed using frequency-division multiplexing (FDM) as shown in pattern 410 or using code division multiplexing (CDM) as shown in pattern 412. According to such DM-RS patterns, various options may be considered for the resource mapping of the xPUCCH transmission on two antenna ports as discussed with respect to FIG. 5 and FIG. 6, below.

Referring now to FIG. 5, a diagram of an example of multiplexing an advanced physical uplink control channel (xPUCCH) transmission in frequency-division multiplexing (FDM) with two antenna ports in accordance with one or more embodiments will be discussed. In one embodiment, a modulated symbol for the xPUCCH transmission on different antenna ports (APs) is multiplexed in a FDM manner. FIG. 5 illustrates one example of multiplexing the xPUCCH transmission in the FDM manner with two antenna ports, AP0 510 and AP1 512. In such an embodiment, half of the resource elements (RE) in each antenna port is not used. Furthermore, two options may be considered to map the modulated symbols for xPUCCH transmission on the REs. In a first option, different modulated symbols are mapped to the REs in different antenna ports in an alternative fashion. For example, d(0) is mapped to the first RE in AP0 510, d(1) is mapped to the 2nd RE in the AP1 512, and so on, where d(n) is the modulated symbols for the xPUCCH transmission. In another option, the same modulated symbols are mapped to two consecutive REs in different antenna ports. For example, d(0) is mapped to the first RE in the AP0 510 and the 2nd RE in the AP1 512. It should be noted that such a repeated transmission may achieve superior performance compared to the first option with the tradeoff of a larger overhead.

Furthermore, the starting position, or comb index, of resource mapping for the modulated symbol on each antenna port may be configured by higher layer signaling via user equipment (UE) specific dedicated RRC signaling. For example, for a first UE, the modulated symbol may be mapped to a first RE in AP0 510, and then to the second RE in AP1 510. For a second UE, the modulated symbol may be mapped to a second RE in AP0 510 and then to the first RE in AP1 510. For beam aggregation and dynamic point selection, a group of the xPUCCH resource including the starting position and/or the xPUCCH resource block allocation may be configured via higher layer signaling. In the downlink control information (DCI), a PUCCH resource indicator may be added to indicate the xPUCCH resource for current transmission.

In another embodiment, the modulated symbol for the xPUCCH transmission on different antenna ports may be multiplexed in a CDM manner. For each modulated symbol, an orthogonal cover code (OCC) may be applied, which may be utilized to multiplex multiple users within the same resource. Furthermore, a different OCC may be applied on different antenna ports to achieve transmission diversity. Examples of the OCC are listed as follows depending on the length of OCC. In one option, an OCC of length two may be considered as shown in Table 1:

Antenna port p	$[w_p(0)\ w_p(1)]$
0	[1 1]
1	[1 -1]

Table 1. OCC with length 2

Referring now to FIG. 6, a diagram of one example of multiplexing an advanced physical uplink control channel (xPUCCH) transmission in code-division multiplexing (CDM) with two antenna ports in accordance with one or more embodiments will be discussed. FIG. 6 illustrates one example of multiplexing the xPUCCH transmission using code division multiplexing (CDM) with two antenna ports. In this example, the OCC with [1 1] is applied on antenna port AP0 610, and the OCC with [1 -1] is applied on antenna port AP1 612 for the xPUCCH transmission. Further different or the same modulated symbols may be transmitted in the same resource elements (REs) for different antenna ports. In one example, d(0) and d(1) may be transmitted in resource element RE0 and resource element RE1 on antenna port AP0 610 and antenna port AP1

612, respectively. In another example, d(0) may be transmitted in RE0 and RE1 on both AP0 610 and AP1 612.

In another option, an OCC of length four may be considered as shown in Table 2, below. It should be noted that this OCC may be applied in the case of four antenna ports or two antenna ports. In the latter case of two antenna ports, different UEs may use different sets of antenna ports for the xPUCCH transmission while the same DM-RS pattern may be applied. For example, a first user equipment (UE1) may utilize antenna port AP0 610 and antenna port AP2 (not shown), and a second user equipment (UE2) may utilize antenna port AP1 612 and antenna port AP3 (not shown) for the xPUCCH transmission. Furthermore, antenna port AP0 610 and antenna port AP2 (not shown) may utilize the same DM-RS pattern, while antenna port AP1 612 and antenna port AP3 (not shown) may utilize the same DM-RS pattern.

Antenna port p	$[w_p(0)\ w_p(1)\ w_p(2)\ w_p(3)]$
0	[1 1 1 1]
1	[1 -1 1 -1]
2	[1 1 -1 -1]
3	[1 -1 -1 1]

Table 2. OCC with length 4

It should be noted that in the two options discussed above, the same OCC may be applied on each antenna port. Alternatively, OCC hopping may be applied on each symbol and antenna port, which may help to randomize the inter-cell interference. In one example, for modulated symbol d(0), the OCC with [1 1] may be applied, and for modulated symbol d(1), the OCC with [1 -1] may be applied. The OCC hopping pattern may be defined as function of physical cell ID and/or virtual cell ID, and/or symbol/slot/frame index. The OCC hopping pattern also may be defined as a function of one parameter which is UE specific, which may be configured by higher layer signaling via UE specific RRC signaling, or indicated in the DCI format for downlink assignment. It should be noted that the above example may be extended to an OCC of length eight or 16, which may help to multiplex a larger number of users for the xPUCCH transmission.

In another embodiment, the Zadoff-Chu (ZC) sequence with length of K, for example K = 12, may be applied on each symbol. In particular, the ZC sequence may be generated as follows:

$$r(n) = \exp(j\alpha n) \cdot \bar{r}_{u,v}(n)$$

where $\bar{r}_{u,v}(n)$ is the base sequence for the ZC sequence, u is the sequence-group number, v is the sequence number, and α is the cyclic shift. It should be noted that u and v may be determined as a function of physical cell identity, or a virtual cell identity or slot/subframe/frame index. Furthermore, the virtual cell ID may be configured by higher layers.

In one example, u and v may be generated according to an existing LTE specification, wherein u is defined in section 3GPP TS 36.212 5.5.1.3 and v is defined in 3GPP TS 36.212 section 5.5.1.4. Similarly, base sequence $\bar{r}_{u,v}(n)$ may be generated as defined in 3GPP TS 36.212 section 5.5.1. Furthermore, cyclic shift value α applied on each modulated symbol may be defined as a function of physical cell ID and/or virtual cell ID, and/or symbol/slot/frame index. The cyclic shift value also be defined as a function of a cell specific, UE specific, and antenna port (AP) specific parameter, where the UE specific parameter may be configured by higher layers via UE specific RRC signaling, or indicated in the DCI format for downlink assignment.

Referring now to FIG. 7, a diagram of frequency hopping based on a mirroring pattern in accordance with one or more embodiments will be discussed. FIG. 7 illustrates resource mapping for the xPUCCH when two symbols are allocated for xPUCCH transmission. In the case where two symbols are allocated for the xPUCCH transmission, frequency hopping may be applied to exploit frequency diversity. In particular, the first half of modulated symbols may be transmitted in the first symbol allocated for the xPUCCH, and the second half of the modulated symbols may be transmitted in the second symbol. It should be noted that the number of OFDM symbols allocated for the xPUCCH transmission may semi-statically configured by higher layers.

In one embodiment, a mirroring pattern is applied on the xPUCCH transmission on two symbols. FIG. 7 illustrates one example of frequency hopping based on a mirror pattern. In particular, the first half of the modulated symbols 710 may be transmitted in the lower edge of the system bandwidth in symbol #0, and the second half of the modulated symbols 712 may be transmitted in the upper edge of the system bandwidth in symbol #1.

Referring now to FIG. 8, a diagram of frequency hopping based on sub-band hopping in accordance with one or more embodiments will be discussed. In another embodiment, sub-band hopping is applied for the xPUCCH transmission in two OFDM symbols. FIG. 8 illustrates one example of frequency hopping based on sub-band hopping. In this example, the frequency hopping distance between xPUCCH transmission 710 and xPUCCH transmission 712 in two symbols is half system bandwidth ceil(BW/2) where ceil() is a ceiling operation. Furthermore, in the case where an OCC is applied, the same or different OCC hopping patterns may be applied for the transmission of the xPUCCH on two OFDM symbols. Similarly, in the case when the ZC sequence is utilized, the same or different cyclic shift patterns applied on each xPUCCH modulated symbols may be utilized for the transmission of the xPUCCH on two OFDM symbols.

Referring now to FIG. 9, a diagram of an example of an advanced physical uplink control channel (xPUCCH) resource mapping for a single carrier waveform in accordance with one or more embodiments will be discussed. In another embodiment, the xPUCCH may be extended to a single carrier waveform scenario within two symbols. For example, as shown in FIG. 9, the xPUCCH spans for two symbols, wherein one symbol (symbol 0) 910 is used for a reference signal, and the other symbol (symbol 1) 912 is used for the xPUCCH transmission. In one option, every four adjacent DM-RS signals are grouped together, with cover code of [1 1 1 1; 1 -1 1 -1; 1 1 -1 -1; 1 -1 -1 1], to enable opportunistic multi-user (MU) transmission with up to four streams.

Turning now to resource allocation schemes for the xPUCCH transmission, as shown in FIG. 1, above, for low latency, self-contained TDD subframe structure 110, the xPUCCH and data channels comprising the xPDSCH and the xPUSCH are multiplexed in a TDM manner. The resource allocation for different xPUCCH formats needs may be defined as described herein. Similar to an LTE specification, various formats may be defined for xPUCCH transmission. For example, xPUCCH format 1 may be defined to support scheduling request (SR) and/or acknowledgment/negative acknowledgment (ACK/NACK) while xPUCCH format 2 may be defined to support ACK/NACK and/or channel quality indicator (CQI) feedback. In another example, xPUCCH format 1 may be defined to support SR, xPUCCH format 2 may be defined to support ACK/NACK, and xPUCCH format 3 may be defined to support ACK/NACK and/or CQI feedback

In the following sections, xPUCCH format 1/1a/1b and format 2/2a/2b may be assumed to be utilized. The designs discussed herein, however, may be extended to support other xPUCCH formats, for example xPUCCH format 3. It should be noted that in the frequency domain, one xPUCCH resource in xPUCCH format 1/1a/1b and format 2/2a/2b may occupy $N_{SC}^{(1)}$ and $N_{SC}^{(2)}$ resource elements (RE) or $N_{PRB}^{(1)}$ and $N_{PRB}^{(2)}$ physical resource blocks (PRB), respectively. Furthermore, the xPUCCH region size for xPUCCH format 1/1a/1b and format 2/2a/2b may occupy $K^{(1)}$ and $K^{(2)}$ xPUCCH resources. In this case, the overall region size for xPUCCH format 1/1a/1b and format 2/2a/2b may occupy $K^{(1)} \cdot N_{SC}^{(1)}$ and $K^{(2)} \cdot N_{SC}^{(2)}$ REs or $K^{(1)} \cdot N_{PRB}^{(1)}$ and $K^{(2)} \cdot N_{PRB}^{(2)}$ PRBs, respectively. The resource allocation configuration for the xPUCCH transmission may include, but not be limited to the following parameters: the number of OFDM symbols allocated for xPUCCH transmission within one subframe; the number of REs or PRBs allocated for one xPUCCH transmission for each xPUCCH format; the number of xPUCCH resources allocated for each xPUCCH format; or the starting frequency position of each xPUCCH format.

In one embodiment, the resource allocation configuration for the xPUCCH transmission may be predefined in the specification. In one example, the number of REs or PRBs allocated for one xPUCCH transmission for each xPUCCH format may be fixed in the specification. Furthermore, some of the parameters may be defined as a function of system bandwidth. In one example, the number of OFDM symbols allocated for the xPUCCH transmission may be defined as a function of system bandwidth. If system bandwidth is less than X MHz, two OFDM symbols may be allocated for xPUCCH transmission. If system bandwidth is greater than or equal to X MHz, one OFDM symbol may be allocated for xPUCCH transmission.

In another embodiment, the resource allocation configuration for the xPUCCH transmission may be configured by higher layers via RRC signaling from primary cell (PCell) or serving cell, 5G advanced master information block (xMIB), or 5G advanced system information block (xSIB) from the serving cell. In one example, the xPUCCH region size for each xPUCCH format may be semi-statically configured by higher layers via xSIB or UE specific dedicated RRC signaling.

In another embodiment, the resource allocation configuration for the xPUCCH transmission may be defined as a function of physical cell ID or virtual cell ID and/or subframe or symbol or slot index or system frame index. In one example, the starting position for xPUCCH format 1/1a/1b in term of PRB may be defined as:

$$n_{PRB} = f(N_{cell}^{ID}, n_{SF})$$

where N_{cell}^{ID} is the physical cell ID or virtual cell ID and n_{SF} the subframe index. In this case, the frequency location of the xPUCCH transmission may be different among cells to randomize the inter-cell interference.

In another embodiment, the resource allocation configuration for the xPUCCH transmission may be dynamically indicated in the downlink control information (DCI) format carried by the xPDCCH within the same subframe or dedicated control channel or signal. Such an arrangement may be particularly suitable for a self-contained TDD subframe.

In another embodiment, the evolved Node B (eNodeB or eNB) may configure a group of resource allocation configurations for the xPUCCH transmission via higher layer signaling. In each subframe, the eNodeB may indicate the index within the resource allocation configuration group via DCI. In one example, the eNodeB may configure four types of resource allocation configuration for the xPUCCH, and in DCI a two bit resource allocation index indicator may be used to indicate which resource allocation configuration is applied in current subframe.

In another embodiment, the aforementioned embodiments may be combined to indicate the resource allocation configuration for the xPUCCH transmission. It should be noted that that different xPUCCH formats may be multiplexed in via time-division multiplexing (TDM), frequency-division multiplexing (FDM), or a combination of TDM and FDM. Depending on the number of OFDM symbols allocated for the transmission of xPUCCH within one subframe, several options may be considered for the resource allocation of different xPUCCH formats as discussed, below.

Referring now to FIG. 10, a diagram of one option for an advanced physical uplink control channel (xPUCCH) resource mapping with one OFDM symbol duration in accordance with one or more embodiments will be discussed. In the case when xPUCCH transmission spans one OFDM symbol, several options can be considered for multiplexing different xPUCCH formats. In a first option, different xPUCCH formats may be allocated continuously within one OFDM symbol. As shown in FIG. 10, two xPUCCH resources may be allocated for xPUCCH format 2/2a/2b, namely $K^{(2)} = 2$, and the remaining frequency resource may be allocated for xPUCCH format 1/1a/1b. It should be noted that in FIG. 10, xPUCCH format 2/2a/2b is allocated starting from the first RE in the frequency domain. Other allocation, however, may be similarly extended. In the example, xPUCCH format 1/1a/1b may be allocated starting from the first RE.

Referring now to FIG. 11, a diagram of another option for an advanced physical uplink control channel (xPUCCH) resource mapping with one OFDM symbol duration in accordance with one or more embodiments will be discussed. In a second option, a mirroring pattern may be applied for the resource allocation of the xPUCCH format. As shown in FIG. 11, xPUCCH format 2/2a/2b with m = 0 and m = 1 may be allocated in the edge of the system bandwidth, respectively. Furthermore, xPUCCH format 1/1a/1b with m = 2 and m = 4 follows xPUCCH format 2/2a/2b with m = 0 in the lower edge of the spectrum, while xPUCCH format 1/1a/1b with m = 3 and m = 5 follows xPUCCH format 2/2a/2b with m = 1 in the upper edge of the spectrum.

Referring now to FIG. 12, a diagram of yet another option for an advanced physical uplink control channel (xPUCCH) resource mapping with one OFDM symbol duration in accordance with one or more embodiments will be discussed. In a third option, since the whole symbol may be used for xPUCCH transmission, there may be resource element redundancy which may be used to enable distributed xPUCCH transmission for potential frequency diversity gain. Such an arrangement may be utilized to enhance the xPUCCH performance of some poor users, such as suboptimal beam formed users. Here, distributed transmission of the xPUCCH transmissions may be made from less than all users in order to make a tradeoff between performance and resources. In this option, the sub-band hopping may be applied for some xPUCCH blocks in the frequency pattern. As shown in FIG. 12, the xPUCCH with m = 0 will be transmitted at both the start and the bottom resource blocks in a distributed way, while the other xPUCCH transmissions are made within the concessive resource blocks.

Referring now to FIG. 13, a diagram of one option for an advanced physical uplink control channel (xPUCCH) resource mapping with two OFDM symbol duration in accordance with one or more embodiments will be discussed. In the case when xPUCCH transmission spans two OFDM symbols, several options may be considered for multiplexing different xPUCCH formats. In a first option, different xPUCCH formats may be allocated continuously. Furthermore, the same frequency locations may be allocated for the xPUCCH format in two OFDM symbols. FIG. 13 illustrates one example of xPUCCH resource mapping schemes with a duration of two OFDM symbols for the first option. Such a resource allocation scheme may be helpful to increase the channel estimation performance.

Referring now to FIG. 14, a diagram of another option for an advanced physical uplink control channel (xPUCCH) resource mapping with two OFDM symbol duration in accordance with one or more embodiments will be discussed. In a second option, a mirroring pattern may be applied on the xPUCCH resource allocation in two OFDM symbols. FIG. 14 illustrates one example of xPUCCH resource mapping schemes with a duration of two OFDM symbols for the second option. In FIG. 14, xPUCCH format 2/2a/2b with m = 0 may be transmitted in the lower edge of system bandwidth in symbol #0 and in the upper edge of the system bandwidth in symbol #1. Similarly, xPUCCH format 2/2a/2b with m = 0 may be transmitted in the lower edge of system bandwidth in symbol #0 and in the upper edge of the system bandwidth in symbol #1.

Referring now to FIG. 15, a diagram of yet another option for an advanced physical uplink control channel (xPUCCH) resource mapping with two OFDM symbol duration in accordance with one or more embodiments will be discussed. In a third option, one symbol may be allocated for one xPUCCH format. FIG. 15 illustrates one example of xPUCCH resource mapping schemes with a duration of two OFDM symbols for the third option. In FIG. 15, xPUCCH format 2/2a/2b may be allocated in the symbol #0, and xPUCCH format 1/1a/1b may be allocated in the symbol #1.

Referring now to FIG. 16, a diagram of a further option for an advanced physical uplink control channel (xPUCCH) resource mapping with two OFDM symbol duration in accordance with one or more embodiments will be discussed. In a fourth option, sub-band hopping may be applied for the xPUCCH resource allocation in two OFDM symbols. Furthermore, the xPUCCH in each xPUCCH format may be transmitted in a time first order. FIG. 16 illustrates one example of xPUCCH resource mapping schemes with a duration of two OFDM symbols for the fourth option. As shown in FIG. 16, the frequency hopping distance for different xPUCCH formats may be half the system bandwidth. For example, xPUCCH format 2/2a/2b with $m = 0$ may be transmitted in the first frequency resource in symbol #0, and the starting frequency position in symbol #1 is half the system bandwidth, ceil(BW/2), where BW is the system bandwidth. Furthermore, the starting frequency position for xPUCCH format 2/2a/2b with $m = 1$ in symbol #0 is ceil(BW/2) while in symbol #1 the starting frequency position is the first frequency position.

Referring now to FIG. 17, a diagram of yet a further option for an advanced physical uplink control channel (xPUCCH) resource mapping with two OFDM symbol duration in accordance with one or more embodiments will be discussed. In a fifth option, sub-band hopping may be applied for the xPUCCH resource allocation in two OFDM symbols. Furthermore, the xPUCCH in each xPUCCH format may be transmitted in a frequency first order. FIG. 17 illustrates one example of xPUCCH resource mapping schemes with a duration of two OFDM symbols for the fifth option. As shown in FIG. 17, xPUCCH format 2/2a/2b with $m = 1$ follows $m = 0$ in the same OFDM symbol in the frequency domain.

Referring now to FIG. 18, example components of a wireless device such as an evolved NodeB (eNB) device or a User Equipment (UE) device in accordance with one or more embodiments will be discussed. In some embodiments, device 1800 may include application circuitry 1802, baseband circuitry 1804, Radio Frequency (RF) circuitry 1806, front-end module (FEM) circuitry 1808 and one or more antennas 1810, coupled together at least as shown. In other embodiments, the above described circuitries may be included in various devices, in whole or in part, for example an eNB according to a cloud-RAN (C-RAN) implementation, and the scope of the claimed subject matter is not limited in these respects.

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.

Application circuitry 1800 may include one or more application processors. For example, application circuitry 1800 may include circuitry such as, but not limited to, one or more single-core or multi-core processors. The one or more processors may include any combination of general-purpose processors and dedicated processors, for example graphics processors, application processors, and so on. The processors may be coupled with and/or may include memory and/or storage and may be configured to execute instructions stored in the memory and/or storage to enable various applications and/or operating systems to run on the system.

Baseband circuitry 1804 may include circuitry such as, but not limited to, one or more single-core or multi-core processors. Baseband circuitry 1804 may include one or more baseband processors and/or control logic to process baseband signals received from a receive signal path of RF circuitry 1806 and to generate baseband signals for a transmit signal path of the RF circuitry 1806. Baseband processing circuity 1804 may interface with the application circuitry 1802 for generation and processing of the baseband signals and for controlling operations of the RF circuitry 1806. For example, in some embodiments, the baseband circuitry 1804 may include a second generation (2G) baseband processor 1804a, third generation (3G) baseband processor 1804b, fourth generation (4G) baseband processor 1804c, and/or one or more other baseband processors 1804d for other existing generations, generations in development or to be developed in the future, for example fifth generation (5G), sixth generation (6G), and so on. Baseband circuitry 1804, for example one or more of baseband processors 1804a through 1804d, may handle various radio control functions that enable communication with one or more radio networks via RF circuitry 1806. The radio control functions may include, but are not limited to, signal modulation and/or demodulation, encoding and/or decoding, radio frequency shifting, and so on. In some embodiments, modulation and/or demodulation circuitry of baseband circuitry 1804 may include Fast-Fourier Transform (FFT), precoding, and/or constellation mapping and/or demapping functionality. In some embodiments, encoding and/or decoding circuitry of baseband circuitry 1804 may include convolution, tail-biting convolution, turbo, Viterbi, and/or Low Density Parity Check (LDPC) encoder and/or decoder functionality. Embodiments of modulation and/or demodulation and encoder and/or decoder functionality are not limited to these examples and may include other suitable functionality in other embodiments.

In some embodiments, baseband circuitry 1804 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. Processor 1804e of the baseband circuitry 1004 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 processors (DSP) 1004f. The one or more audio DSPs 1804f may include elements for compression and/or decompression and/or 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 baseband circuitry 1804 and application circuitry 1802 may be implemented together such as, for example, on a system on a chip (SOC).

In some embodiments, baseband circuitry 1804 may provide for communication compatible with one or more radio technologies. For example, in some embodiments, baseband circuitry 1804 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 baseband circuitry 1804 is configured to support radio communications of more than one wireless protocol may be referred to as multi-mode baseband circuitry.

RF circuitry 1806 may enable communication with wireless networks using modulated electromagnetic radiation through a non-solid medium. In various embodiments, RF circuitry 1806 may include switches, filters, amplifiers, and so on, to facilitate the communication with the wireless network. RF circuitry 1806 may include a receive signal path which may include circuitry to down-convert RF signals received from FEM circuitry 1808 and provide baseband signals to baseband circuitry 1804. RF circuitry 1806 may also include a transmit signal path which may include circuitry to up-convert baseband signals provided by the baseband circuitry 1804 and provide RF output signals to FEM circuitry 1808 for transmission.

In some embodiments, RF circuitry 1806 may include a receive signal path and a transmit signal path. The receive signal path of RF circuitry 1806 may include mixer circuitry 1806a, amplifier circuitry 1806b and filter circuitry 1806c. The transmit signal path of RF circuitry 1806 may include filter circuitry 1806c and mixer circuitry 1806a. RF circuitry 1806 may also include synthesizer circuitry 1806d for synthesizing a frequency for use by the mixer circuitry 1806a of the receive signal path and the transmit signal path. In some embodiments, the mixer circuitry 1806a of the receive signal path may be configured to down-convert RF signals received from FEM circuitry 1808 based on the synthesized frequency provided by synthesizer circuitry 1806d. Amplifier circuitry 1806b may be configured to amplify the down-converted signals and the filter circuitry 1806c 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 baseband circuitry 1804 for further processing. In some embodiments, the output baseband signals may be zero-frequency baseband signals, although this may be optional. In some embodiments, mixer circuitry 1806a of the receive signal path may comprise passive mixers, although the scope of the embodiments is not limited in this respect.

In some embodiments, mixer circuitry 1806a of the transmit signal path may be configured to up-convert input baseband signals based on the synthesized frequency provided by synthesizer circuitry 1806d to generate RF output signals for FEM circuitry 1808. The baseband signals may be provided by the baseband circuitry 1804 and may be filtered by filter circuitry 1806c. Filter circuitry 1806c may include a low-pass filter (LPF), although the scope of the embodiments is not limited in this respect.

In some embodiments, mixer circuitry 1806a of the receive signal path and the mixer circuitry 1806a of the transmit signal path may include two or more mixers and may be arranged for quadrature down conversion and/or up conversion respectively. In some embodiments, mixer circuitry 1806a of the receive signal path and the mixer circuitry 1806a of the transmit signal path may include two or more mixers and may be arranged for image rejection, for example Hartley image rejection. In some embodiments, mixer circuitry 1806a of the receive signal path and the mixer circuitry 1806a may be arranged for direct down conversion and/or direct up conversion, respectively. In some embodiments, mixer circuitry 1806a of the receive signal path and mixer circuitry 1806a 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, RF circuitry 1006 may include analog-to-digital converter (ADC) and digital-to-analog converter (DAC) circuitry, and baseband circuitry 1804 may include a digital baseband interface to communicate with RF circuitry 1806. In some dual-mode embodiments, separate radio integrated circuit (IC) circuitry may be provided for processing signals for one or more spectra, although the scope of the embodiments is not limited in this respect.

In some embodiments, synthesizer circuitry 1806d 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 1806d may be a delta-sigma synthesizer, a frequency multiplier, or a synthesizer comprising a phase-locked loop with a frequency divider.

Synthesizer circuitry 1806d may be configured to synthesize an output frequency for use by mixer circuitry 1806a of RF circuitry 1806 based on a frequency input and a divider control input. In some embodiments, synthesizer circuitry 1806d may be a fractional N/N+1 synthesizer.

In some embodiments, frequency input may be provided by a voltage controlled oscillator (VCO), although this may be optional. Divider control input may be provided by either baseband circuitry 1804 or applications processor 1802 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 applications processor 1802.

Synthesizer circuitry 1806d of RF circuitry 1806 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, for example 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 1806d 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, for example twice the carrier frequency, four times the carrier frequency, and so on, 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 local oscillator (LO) frequency (fLO). In some embodiments, RF circuitry 1806 may include an in-phase and quadrature (IQ) and/or polar converter.

FEM circuitry 1808 may include a receive signal path which may include circuitry configured to operate on RF signals received from one or more antennas 710, amplify the received signals and provide the amplified versions of the received signals to the RF circuitry 1806 for further processing. FEM circuitry 1808 may also include a transmit signal path which may include circuitry configured to amplify signals for transmission provided by RF circuitry 1806 for transmission by one or more of the one or more antennas 1810.

In some embodiments, FEM circuitry 1808 may include a transmit/receive (TX/RX) switch to switch between transmit mode and receive mode operation. FEM circuitry 1808 may include a receive signal path and a transmit signal path. The receive signal path of FEM circuitry 1808 may include a low-noise amplifier (LNA) to amplify received RF signals and to provide the amplified received RF signals as an output, for example to RF circuitry 1806. The transmit signal path of FEM circuitry 1808 may include a power amplifier (PA) to amplify input RF signals, for example provided by RF circuitry 1806, and one or more filters to generate RF signals for subsequent transmission, for example by one or more of antennas 1810. In some embodiments, device 1800 may include additional elements such as, for example, memory and/or storage, display, camera, sensor, and/or input/output (I/O) interface, although the scope of the claimed subject matter is not limited in this respect.

The following are example implementations of the subject matter described herein. It should be noted that any of the examples and the variations thereof described herein may be used in any permutation or combination of any other one or more examples or variations, although the scope of the claimed subject matter is not limited in these respects. In example one, an apparatus of a user equipment (UE) comprises baseband processing circuitry to generate scheduling request information, hybrid automatic repeat request (HARQ) acknowledgement or negative acknowledgment (ACK/NACK) information, a channel state information (CSI) report, or beam related information, or a combination thereof, to be transmitted in an advanced physical uplink control channel (xPUCCH), and generate the xPUCCH to carry the scheduling request information, the HARQ ACK/NACK information, the CSI report, or the beam related information, or a combination thereof, on an allocated resource. In example two, the apparatus may include the subject matter of example one or any of the examples described herein, wherein one orthogonal frequency-division multiplexing (OFDM) symbol is allocated for the xPUCCH transmission, wherein a modulated symbol for xPUCCH transmission on different antenna ports (AP) is multiplexed in a frequency-division multiplexing (FDM) manner. In example three, the apparatus may include the subject matter of example one or any of the examples described herein, wherein half of resource elements (RE) in each AP is not used, wherein different modulated symbols are mapped to resource elements (REs) in different APs in an alternative fashion, or wherein same modulated symbols are mapped to two consecutive REs in different APs, wherein a starting position or comb index of resource mapping for the modulated symbol on each AP is configured by higher layer signaling via UE specific dedicated radio resource control (RRC) signaling, or a combination thereof. In example four, the apparatus may include the subject matter of example one or any of the examples described herein,, wherein a group of xPUCCH resources including a starting position for a xPUCCH resource block is configured via higher layer signaling, wherein a PUCCH resource indicator in Downlink Control Information (DCI) format is used to indicate a xPUCCH resource for a current transmission. In example five, the apparatus may include the subject matter of example one or any of the examples described herein, wherein a modulated symbol for xPUCCH transmission on different antenna ports (AP) is multiplexed in a Code-division multiplexing (CDM) manner, wherein an orthogonal cover code (OCC) is applied on each OFDM symbol, or wherein a different OCC is applied on different antenna ports, or a combination thereof. In example six, the apparatus may include the subject matter of example one or any of the examples described herein, wherein OCC hopping is applied on each modulated symbol and antenna port, wherein an OCC hopping pattern is defined as function of physical cell ID, virtual cell ID, symbol index, slot index, or frame index, or a combination thereof, or is defined as a function of a cell specific parameter, a UE specific parameter, or an antenna port parameter, wherein the UE specific parameter is configured by higher layers via UE specific radio resource control (RRC) signaling, or indicated in the DCI format for downlink assignment. In example seven, the apparatus may include the subject matter of example one or any of the examples described herein, wherein a Zadoff-Chu (ZC) sequence or a constant amplitude zero autocorrelation sequence with length of K is applied on each modulated symbol, wherein root index for the ZC sequence is determined as a function of physical cell identity, a virtual cell identity, a slot index, a subframe index, or a frame index, or a combination thereof, wherein a cyclic shift value applied on each modulated symbol is defined as a function of physical cell ID, virtual cell ID, a slot index, a subframe index, or a frame index, or a combination thereof, or a function of a cell specific parameter, a UE specific parameter, or an antenna port specific parameter, wherein the UE specific parameter is configured by higher layers via UE specific RRC signaling, or indicated in a Downlink Control Information (DCI) format for downlink assignment. In example eight, the apparatus may include the subject matter of example one or any of the examples described herein, wherein two orthogonal frequency-division multiplexing (OFDM) symbols are allocated for the xPUCCH transmission, wherein the number of OFDM symbols allocated for the xPUCCH transmission is semi-statically configured by higher layers, wherein frequency hopping is applied, or wherein a first half of modulated symbols is transmitted in a first OFDM symbol allocated for the xPUCCH transmission, and a second half of the modulated symbols is transmitted in a second OFDM symbol. In example nine, the apparatus may include the subject matter of example one or any of the examples described herein, wherein a mirroring pattern is applied on the xPUCCH transmission on two symbols, wherein sub-band hopping is applied for the xPUCCH transmission in two OFDM symbols, or wherein for a single carrier waveform scenario, one symbol is used for a reference signal while another symbol is used for xPUCCH transmission, or a combination thereof. In example ten, the apparatus may include the subject matter of example one or any of the examples described herein, wherein one, two or four antenna ports are used for the transmission of xPUCCH, wherein a number of antenna ports used for the transmission of xPUCCH is configured by UE specific dedicated radio resource control (RRC) signaling.

In example eleven, an apparatus of an evolved Node B (eNB) comprises baseband processing circuitry to generate a resource allocation configuration for an advanced physical uplink control channel (xPUCCH) to be transmitted by a user equipment to the eNB, and process a xPUCCH format transmitted from the UE on the configured resource. In example twelve, the apparatus may include the subject matter of example eleven or any of the examples described herein, wherein the resource allocation configuration for the xPUCCH transmission comprises a number of orthogonal frequency-division multiplexing (OFDM) symbols allocated for xPUCCH transmission within one subframe, a number of resource elements (REs) or physical resource blocks (PRBs) allocated for one xPUCCH transmission for each xPUCCH format, a number of xPUCCH resources allocated for each xPUCCH format, or a starting frequency position of each xPUCCH format, or a combination thereof. In example thirteen, the apparatus may include the subject matter of example eleven or any of the examples described herein, wherein the resource allocation configuration for the xPUCCH transmission may be predefined, or wherein the number of resource elements (RE) or physical resource blocks (PRB) allocated for one xPUCCH transmission for each xPUCCH format may be fixed, or a combination thereof. In example fourteen, the apparatus may include the subject matter of example eleven or any of the examples described herein, wherein a number of orthogonal frequency-division multiplexing (OFDM) symbols allocated for the xPUCCH transmission is a function of system bandwidth. In example fifteen, the apparatus may include the subject matter of example eleven or any of the examples described herein, wherein the resource allocation configuration for the xPUCCH transmission is configured by higher layer signaling via radio resource control (RRC) signaling from a primary cell (PCell), a serving cell, an advanced master information block (xMIB), or an advanced system information block (xSIB) from the serving cell. In example sixteen, the apparatus may include the subject matter of example eleven or any of the examples described herein, wherein the resource allocation configuration for the xPUCCH transmission is defined as a function of a physical cell ID, virtual cell ID, a subframe index, a symbol index, a slot index, or a system frame index, or a combination thereof. In example seventeen, the apparatus may include the subject matter of example eleven or any of the examples described herein, wherein the resource allocation configuration for the xPUCCH transmission is indicated in a Downlink Control Information (DCI) format carried by an advanced physical downlink control channel (xPDCCH) within a same subframe or a dedicated control channel. In example eighteen, the apparatus may include the subject matter of example eleven or any of the examples described herein, wherein the baseband processing circuitry is configured to generate a group of resource allocation configurations for the xPUCCH transmission via higher layer signaling, wherein in each subframe an index is indicated within a resource allocation configuration group via Downlink Control Information (DCI). In example nineteen, the apparatus may include the subject matter of example eleven or any of the examples described herein, wherein different xPUCCH formats are multiplexed in a time division multiplexing (TDM) manner, or a frequency division multiplexing (FDM) manner, or a combination thereof. In example twenty, the apparatus may include the subject matter of example eleven or any of the examples described herein, wherein if the xPUCCH transmission spans one orthogonal frequency-division multiplexing (OFDM) symbol, different xPUCCH formats are allocated continuously within one OFDM symbol, or a mirroring pattern is applied for the resource allocation of the xPUCCH format, or a distributed model is used for the resource allocation of the xPUCCH format, or a combination thereof. In example twenty-one, the apparatus may include the subject matter of example eleven or any of the examples described herein, wherein if the xPUCCH transmission spans two orthogonal frequency-division multiplexing (OFDM) symbols, different xPUCCH formats are allocated continuously and same frequency locations are allocated for the xPUCCH format in two OFDM symbols, or a mirroring pattern is applied on the xPUCCH resource allocation in two OFDM symbols, or one symbol is allocated for one xPUCCH format. In example twenty-two, the apparatus may include the subject matter of example eleven or any of the examples described herein, wherein if the xPUCCH transmission spans two orthogonal frequency-division multiplexing (OFDM) symbols, sub-band hopping is applied for the xPUCCH resource allocation in two OFDM symbols and the xPUCCH in each xPUCCH format is transmitted in a time first order or a frequency first order.

In example twenty-three, one or more computer-readable media have instructions stored thereon that, if executed by a user equipment (UE), result in generating scheduling request information, hybrid automatic repeat request (HARQ) acknowledgement or negative acknowledgment (ACK/NACK) information, a channel state information (CSI) report, or beam related information, or a combination thereof, to be transmitted in an advanced physical uplink control channel (xPUCCH), and generating the xPUCCH to carry the scheduling request information, the HARQ ACK/NACK information, the CSI report, or the beam related information, or a combination thereof, on an allocated resource. In example twenty-four, the one or more computer readable media may have instructions stored thereon, that executed, result in the subject matter of example twenty-three or any of the examples described herein, wherein one orthogonal frequency-division multiplexing (OFDM) symbol is allocated for the xPUCCH transmission, wherein a modulated symbol for xPUCCH transmission on different antenna ports (AP) is multiplexed in a frequency-division multiplexing (FDM) manner. In example twenty-five, the one or more computer readable media may have instructions stored thereon, that executed, result in the subject matter of example twenty-three or any of the examples described herein, wherein half of resource elements (RE) in each AP is not used, wherein different modulated symbols are mapped to resource elements (REs) in different APs in an alternative fashion, or wherein same modulated symbols are mapped to two consecutive REs in different APs, wherein a starting position or comb index of resource mapping for the modulated symbol on each AP is configured by higher layer signaling via UE specific dedicated radio resource control (RRC) signaling, or a combination thereof. In example twenty-six, the one or more computer readable media may have instructions stored thereon, that executed, result in the subject matter of example twenty-three or any of the examples described herein, wherein a group of xPUCCH resources including a starting position for a xPUCCH resource block is configured via higher layer signaling, wherein a PUCCH resource indicator in Downlink Control Information (DCI) format is used to indicate a xPUCCH resource for a current transmission.

In example twenty-seven, one or more computer-readable media have instructions stored thereon that, if executed by an evolved Node B (eNB), result in generating a resource allocation configuration for an advanced physical uplink control channel (xPUCCH) to be transmitted by a user equipment to the eNB, and processing a xPUCCH format transmitted from the UE on the configured resource. In example twenty-eight, the one or more computer readable media may have instructions stored thereon, that executed, result in the subject matter of example twenty-seven or any of the examples described herein, wherein the resource allocation configuration for the xPUCCH transmission comprises a number of orthogonal frequency-division multiplexing (OFDM) symbols allocated for xPUCCH transmission within one subframe, a number of resource elements (REs) or physical resource blocks (PRBs) allocated for one xPUCCH transmission for each xPUCCH format, a number of xPUCCH resources allocated for each xPUCCH format, or a starting frequency position of each xPUCCH format, or a combination thereof. In example twenty-nine, the one or more computer readable media may have instructions stored thereon, that executed, result in the subject matter of example twenty-seven or any of the examples described herein, wherein the resource allocation configuration for the xPUCCH transmission may be predefined, or wherein the number of resource elements (RE) or physical resource blocks (PRB) allocated for one xPUCCH transmission for each xPUCCH format may be fixed, or a combination thereof. In example thirty, the one or more computer readable media may have instructions stored thereon, that executed, result in the subject matter of example twenty-seven or any of the examples described herein, wherein a number of orthogonal frequency-division multiplexing (OFDM) symbols allocated for the xPUCCH transmission is a function of system bandwidth.

In example thirty-one, an apparatus comprises means for generating scheduling request information, hybrid automatic repeat request (HARQ) acknowledgement or negative acknowledgment (ACK/NACK) information, a channel state information (CSI) report, or beam related information, or a combination thereof, to be transmitted in an advanced physical uplink control channel (xPUCCH), and means for generating the xPUCCH to carry the scheduling request information, the HARQ ACK/NACK information, the CSI report, or the beam related information, or a combination thereof, on an allocated resource. In example thirty-two, the apparatus may include the subject matter of example thirty-one or any of the examples described herein, wherein one orthogonal frequency-division multiplexing (OFDM) symbol is allocated for the xPUCCH transmission, wherein a modulated symbol for xPUCCH transmission on different antenna ports (AP) is multiplexed in a frequency-division multiplexing (FDM) manner. In example thirty-three, the apparatus may include the subject matter of example thirty-one or any of the examples described herein, wherein half of resource elements (RE) in each AP is not used, wherein different modulated symbols are mapped to resource elements (REs) in different APs in an alternative fashion, or wherein same modulated symbols are mapped to two consecutive REs in different APs, wherein a starting position or comb index of resource mapping for the modulated symbol on each AP is configured by higher layer signaling via UE specific dedicated radio resource control (RRC) signaling, or a combination thereof. In example thirty-four, the apparatus may include the subject matter of example thirty-one or any of the examples described herein, wherein a group of xPUCCH resources including a starting position for a xPUCCH resource block is configured via higher layer signaling, wherein a PUCCH resource indicator in Downlink Control Information (DCI) format is used to indicate a xPUCCH resource for a current transmission.

In example thirty-five, an apparatus comprises means for generating a resource allocation configuration for an advanced physical uplink control channel (xPUCCH) to be transmitted by a user equipment (UE) to an evolved Node B (eNB), and means for processing a xPUCCH format transmitted from the UE on the configured resource. In example thirty-six, the apparatus may include the subject matter of example thirty-five or any of the examples described herein, wherein the resource allocation configuration for the xPUCCH transmission comprises a number of orthogonal frequency-division multiplexing (OFDM) symbols allocated for xPUCCH transmission within one subframe, a number of resource elements (REs) or physical resource blocks (PRBs) allocated for one xPUCCH transmission for each xPUCCH format, a number of xPUCCH resources allocated for each xPUCCH format, or a starting frequency position of each xPUCCH format, or a combination thereof. In example thirty-seven, the apparatus may include the subject matter of example thirty-five or any of the examples described herein, wherein the resource allocation configuration for the xPUCCH transmission may be predefined, or wherein the number of resource elements (RE) or physical resource blocks (PRB) allocated for one xPUCCH transmission for each xPUCCH format may be fixed, or a combination thereof. In example thirty-eight, the apparatus may include the subject matter of example thirty-five or any of the examples described herein, wherein a number of orthogonal frequency-division multiplexing (OFDM) symbols allocated for the xPUCCH transmission is a function of system bandwidth.

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

CLAIMS

What is claimed is:

1. An apparatus of a user equipment (UE) comprising baseband processing circuitry to:

generate scheduling request information, hybrid automatic repeat request (HARQ) acknowledgement or negative acknowledgment (ACK/NACK) information, a channel state information (CSI) report, or beam related information, or a combination thereof, to be transmitted in an advanced physical uplink control channel (xPUCCH); and

generate the xPUCCH to carry the scheduling request information, the HARQ ACK/NACK information, the CSI report, or the beam related information, or a combination thereof, on an allocated resource.

2. The apparatus as claimed in claim 1, wherein one orthogonal frequency-division multiplexing (OFDM) symbol is allocated for the xPUCCH transmission, wherein a modulated symbol for xPUCCH transmission on different antenna ports (AP) is multiplexed in a frequency-division multiplexing (FDM) manner.

3. The apparatus as claimed in claim 2, wherein half of resource elements (RE) in each AP is not used, wherein different modulated symbols are mapped to resource elements (REs) in different APs in an alternative fashion, or wherein same modulated symbols are mapped to two consecutive REs in different APs, wherein a starting position or comb index of resource mapping for the modulated symbol on each AP is configured by higher layer signaling via UE specific dedicated radio resource control (RRC) signaling, or a combination thereof.

4. The apparatus as claimed in any of claims 2-3, wherein a group of xPUCCH resources including a starting position for a xPUCCH resource block is configured via higher layer signaling, wherein a PUCCH resource indicator in Downlink Control Information (DCI) format is used to indicate a xPUCCH resource for a current transmission.

5. The apparatus as claimed in any of claims 2-4, wherein a modulated symbol for xPUCCH transmission on different antenna ports (AP) is multiplexed in a Code-division multiplexing (CDM) manner, wherein an orthogonal cover code (OCC) is applied on each OFDM symbol, or wherein a different OCC is applied on different antenna ports, or a combination thereof.

6. The apparatus as claimed in claim 5, wherein OCC hopping is applied on each modulated symbol and antenna port, wherein an OCC hopping pattern is defined as function of physical cell ID, virtual cell ID, symbol index, slot index, or frame index, or a combination thereof, or is defined as a function of a cell specific parameter, a UE specific parameter, or an antenna port specific parameter, wherein the UE specific parameter is configured by higher layers via UE specific radio resource control (RRC) signaling, or indicated in the DCI format for downlink assignment.

7. The apparatus as claimed in any of claims 5-6, wherein a Zadoff-Chu (ZC) or constant amplitude zero autocorrelation (CAZAC) sequence with length of K is applied on each modulated symbol, wherein root index for the ZC sequence is determined as a function of physical cell identity, a virtual cell identity, a slot index, a subframe index, or a frame index, or a combination thereof, wherein a cyclic shift value applied on each modulated symbol is defined as a function of physical cell ID, virtual cell ID, a slot index, a subframe index, or a frame index, or a combination thereof, or a function of a cell specific parameter, a UE specific parameter, or an antenna port specific parameter, wherein the UE specific parameter is configured by higher layers via UE specific RRC signaling, or indicated in a Downlink Control Information (DCI) format for downlink assignment.

8. The apparatus as claimed in any of claims 1-7, wherein two orthogonal frequency-division multiplexing (OFDM) symbols are allocated for the xPUCCH transmission, wherein the number of OFDM symbols allocated for the xPUCCH transmission is semi-statically configured by higher layers, wherein frequency hopping is applied, or wherein a first half of modulated symbols is transmitted in a first OFDM symbol allocated for the xPUCCH transmission, and a second half of the modulated symbols is transmitted in a second OFDM symbol.

9. The apparatus as claimed in claim 8, wherein a mirroring pattern is applied on the xPUCCH transmission on two symbols, wherein sub-band hopping is applied for the xPUCCH transmission in two OFDM symbols, or wherein for a single carrier waveform scenario, one symbol is used for a reference signal while another symbol is used for xPUCCH transmission, or a combination thereof.

10. The apparatus as claimed in any of claims 1-9, wherein one, two or four antenna ports are used for the transmission of xPUCCH, wherein a number of antenna ports used for the

transmission of xPUCCH is configured by UE specific dedicated radio resource control (RRC) signaling.

11. An apparatus of an evolved Node B (eNB) comprising baseband processing circuitry to:

generate a resource allocation configuration for an advanced physical uplink control channel (xPUCCH) to be transmitted by a user equipment to the eNB; and

process a xPUCCH format transmitted from the UE on the configured resource.

12. The apparatus as claimed in claim 11, wherein the resource allocation configuration for the xPUCCH transmission comprises a number of orthogonal frequency-division multiplexing (OFDM) symbols allocated for xPUCCH transmission within one subframe, a number of resource elements (REs) or physical resource blocks (PRBs) allocated for one xPUCCH transmission for each xPUCCH format, a number of xPUCCH resources allocated for each xPUCCH format, or a starting frequency position of each xPUCCH format, or a combination thereof.

13. The apparatus as claimed in any of claims 11-12, wherein the resource allocation configuration for the xPUCCH transmission may be predefined, or wherein the number of resource elements (RE) or physical resource blocks (PRB) allocated for one xPUCCH transmission for each xPUCCH format may be fixed, or a combination thereof.

14. The apparatus as claimed in claim 13, wherein a number of orthogonal frequency-division multiplexing (OFDM) symbols allocated for the xPUCCH transmission is a function of system bandwidth.

15. The apparatus as claimed in any of claims 11-14, wherein the resource allocation configuration for the xPUCCH transmission is configured by higher layer signaling via radio resource control (RRC) signaling from a primary cell (PCell) or a serving cell, an advanced master information block (xMIB), or an advanced system information block (xSIB) from the serving cell.

16. The apparatus as claimed in any of claims 11-15, wherein the resource allocation configuration for the xPUCCH transmission is defined as a function of a physical cell ID, virtual

cell ID, a subframe index, a symbol index, a slot index, or a system frame index, or a combination thereof.

17. The apparatus as claimed in any of claims 11-16, wherein the resource allocation configuration for the xPUCCH transmission is indicated in a Downlink Control Information (DCI) format carried by an advanced physical downlink control channel (xPDCCH) within a same subframe or a dedicated control channel.

18. The apparatus as claimed in any of claims 11-17, wherein the baseband processing circuitry is configured to generate a group of resource allocation configurations for the xPUCCH transmission via higher layer signaling, wherein in each subframe an index is indicated within a resource allocation configuration group via Downlink Control Information (DCI).

19. The apparatus as claimed in any of claims 11-18, wherein different xPUCCH formats are multiplexed in a time division multiplexing (TDM) manner, or a frequency division multiplexing (FDM) manner, or a combination thereof.

20. The apparatus as claimed in claim 19, wherein if the xPUCCH transmission spans one orthogonal frequency-division multiplexing (OFDM) symbol, different xPUCCH formats are allocated continuously within one OFDM symbol, or a mirroring pattern is applied for the resource allocation of the xPUCCH format, or a distributed model is used for the resource allocation of the xPUCCH format, or a combination thereof.

21. The apparatus as claimed in any of claims 19-20, wherein if the xPUCCH transmission spans two orthogonal frequency-division multiplexing (OFDM) symbols, different xPUCCH formats are allocated continuously and same frequency locations are allocated for the xPUCCH format in two OFDM symbols, or a mirroring pattern is applied on the xPUCCH resource allocation in two OFDM symbols, or one symbol is allocated for one xPUCCH format.

22. The apparatus as claimed in any of claims 19-21, wherein if the xPUCCH transmission spans two orthogonal frequency-division multiplexing (OFDM) symbols, sub-band hopping is applied for the xPUCCH resource allocation in two OFDM symbols and the xPUCCH in each xPUCCH format is transmitted in a time first order or a frequency first order.

23. One or more computer-readable media having instructions stored thereon that, if executed by a user equipment (UE), result in:

generating scheduling request information, hybrid automatic repeat request (HARQ) acknowledgement or negative acknowledgment (ACK/NACK) information, a channel state information (CSI) report, or beam related information, or a combination thereof, to be transmitted in an advanced physical uplink control channel (xPUCCH); and

generating the xPUCCH to carry the scheduling request information, HARQ ACK/NACK information the CSI report, or the beam related information, or a combination thereof, on an allocated resource.

24. The one or more computer-readable media as claimed in claim 23, wherein one orthogonal frequency-division multiplexing (OFDM) symbol is allocated for the xPUCCH transmission, wherein a modulated symbol for xPUCCH transmission on different antenna ports (AP) is multiplexed in a frequency-division multiplexing (FDM) manner.

25. The one or more computer-readable media as claimed in claim 24, wherein half of resource elements (RE) in each AP is not used, wherein different modulated symbols are mapped to resource elements (REs) in different APs in an alternative fashion, or wherein same modulated symbols are mapped to two consecutive REs in different APs, wherein a starting position or comb index of resource mapping for the modulated symbol on each AP is configured by higher layer signaling via UE specific dedicated radio resource control (RRC) signaling, or a combination thereof.

26. The one or more computer-readable media as claimed in any of claims 24-25, wherein a group of xPUCCH resources including a starting position for a xPUCCH resource block is configured via higher layer signaling, wherein a PUCCH resource indicator in Downlink Control Information (DCI) format is used to indicate a xPUCCH resource for a current transmission.

27. One or more computer-readable media having instructions stored thereon that, if executed by an evolved Node B (eNB), result in:

generating a resource allocation configuration for an advanced physical uplink control channel (xPUCCH) to be transmitted by a user equipment to the eNB; and

processing a xPUCCH format transmitted from the UE on the configured resource.

28. The one or more computer-readable media as claimed in claim 27, wherein the resource allocation configuration for the xPUCCH transmission comprises a number of orthogonal frequency-division multiplexing (OFDM) symbols allocated for xPUCCH transmission within one subframe, a number of resource elements (REs) or physical resource blocks (PRBs) allocated for one xPUCCH transmission for each xPUCCH format, a number of xPUCCH resources allocated for each xPUCCH format, or a starting frequency position of each xPUCCH format, or a combination thereof.

29. The one or more computer-readable media as claimed in any of claims 27-28, wherein the resource allocation configuration for the xPUCCH transmission may be predefined, or wherein the number of resource elements (RE) or physical resource blocks (PRB) allocated for one xPUCCH transmission for each xPUCCH format may be fixed, or a combination thereof.

30. The one or more computer-readable media as claimed in claim 29, wherein a number of orthogonal frequency-division multiplexing (OFDM) symbols allocated for the xPUCCH transmission is a function of system bandwidth.

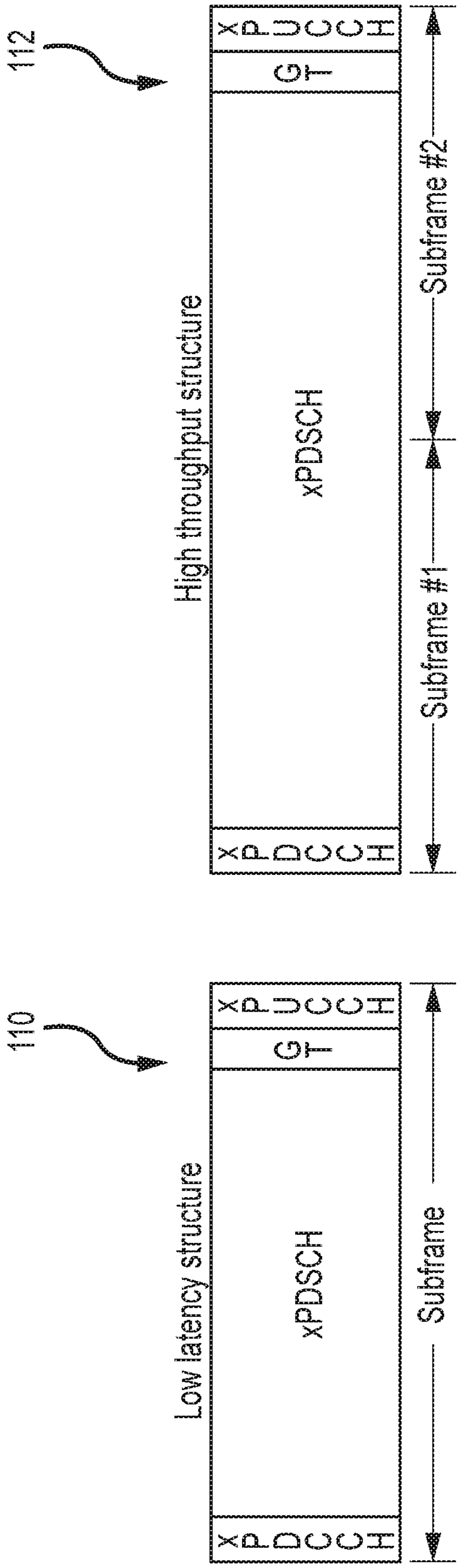
112
High throughput structure
xPUCCH
GT
xPDSCH
xPDCCH
Subframe #2
Subframe #1
110
Low latency structure
xPUCCH
GT
xPDSCH
xPDCCH
Subframe

FIG. 1

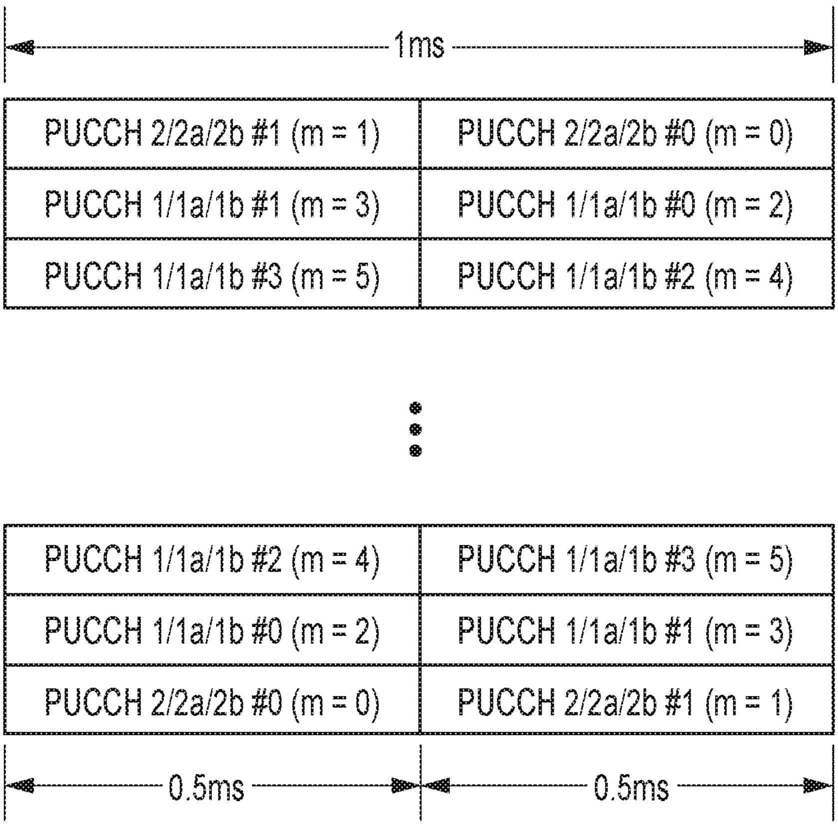
1ms
PUCCH 2/2a/2b #1 (m = 1)
PUCCH 2/2a/2b #0 (m = 0)
PUCCH 1/1a/1b #1 (m = 3)
PUCCH 1/1a/1b #0 (m = 2)
PUCCH 1/1a/1b #3 (m = 5)
PUCCH 1/1a/1b #2 (m = 4)
PUCCH 1/1a/1b #2 (m = 4)
PUCCH 1/1a/1b #3 (m = 5)
PUCCH 1/1a/1b #0 (m = 2)
PUCCH 1/1a/1b #1 (m = 3)
PUCCH 2/2a/2b #0 (m = 0)
PUCCH 2/2a/2b #1 (m = 1)
0.5ms
0.5ms

FIG.2

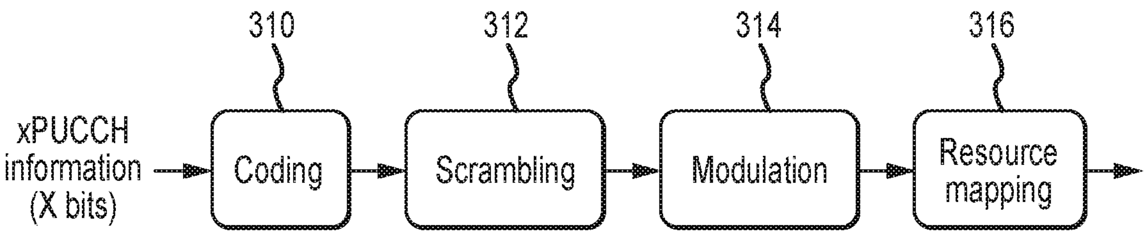
xPUCCH information (X bits)
310
Coding
312
Scrambling
314
Modulation
316
Resource mapping

FIG.3

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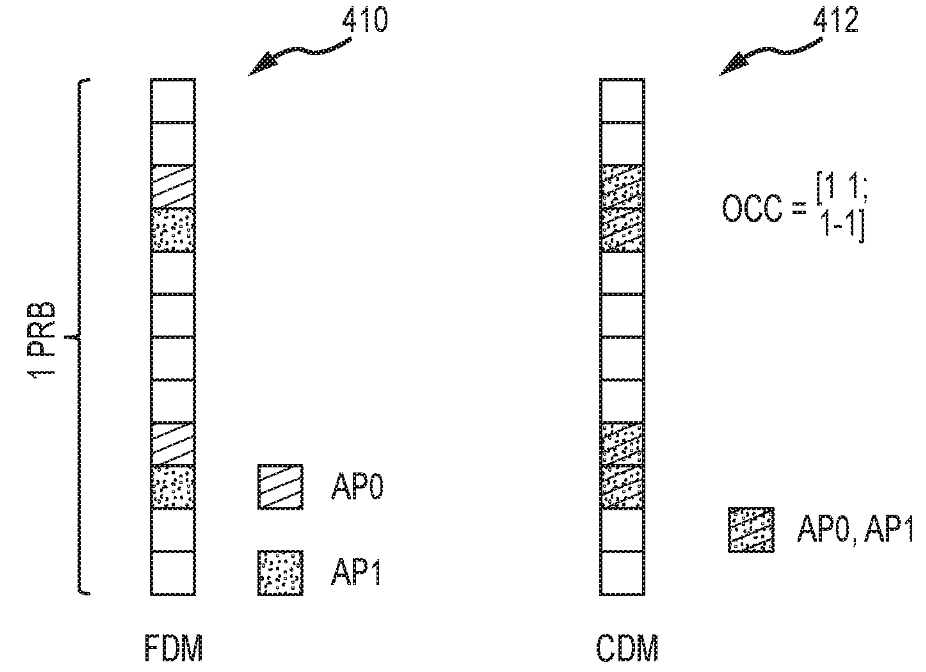


FIG.4

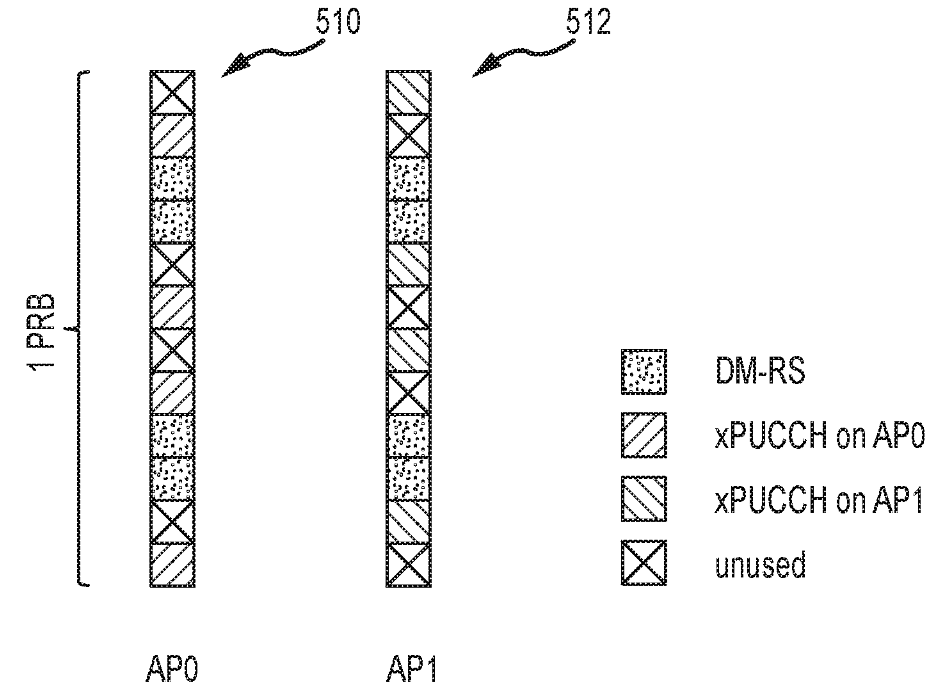


FIG.5

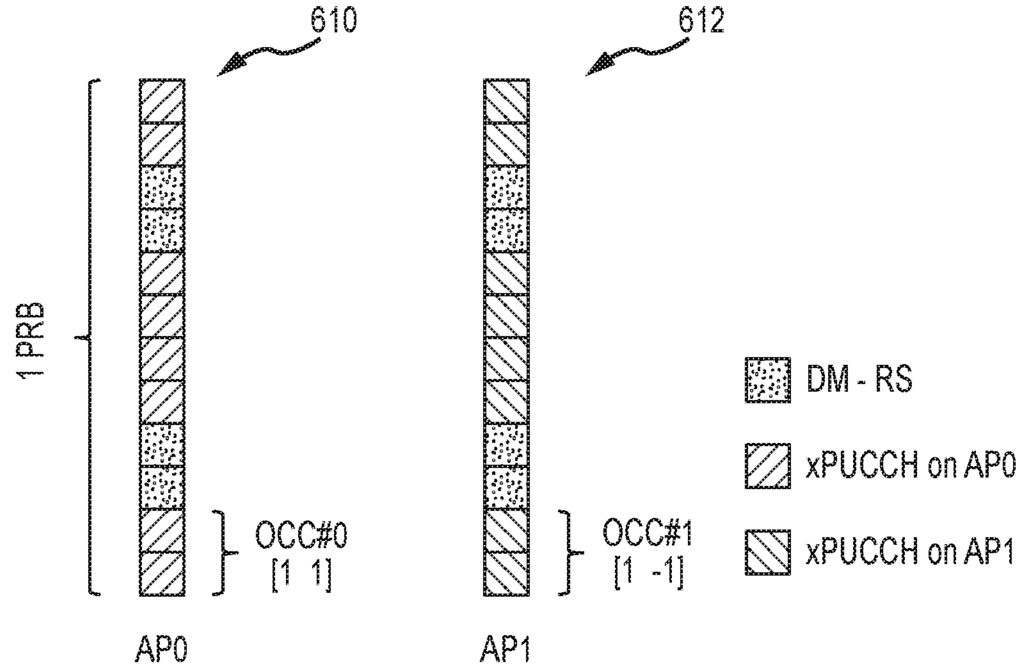

610
612
1 PRB
OCC#0
[1 1]
OCC#1
[1 -1]
AP0
AP1
DM - RS
xPUCCH on AP0
xPUCCH on AP1

FIG.6

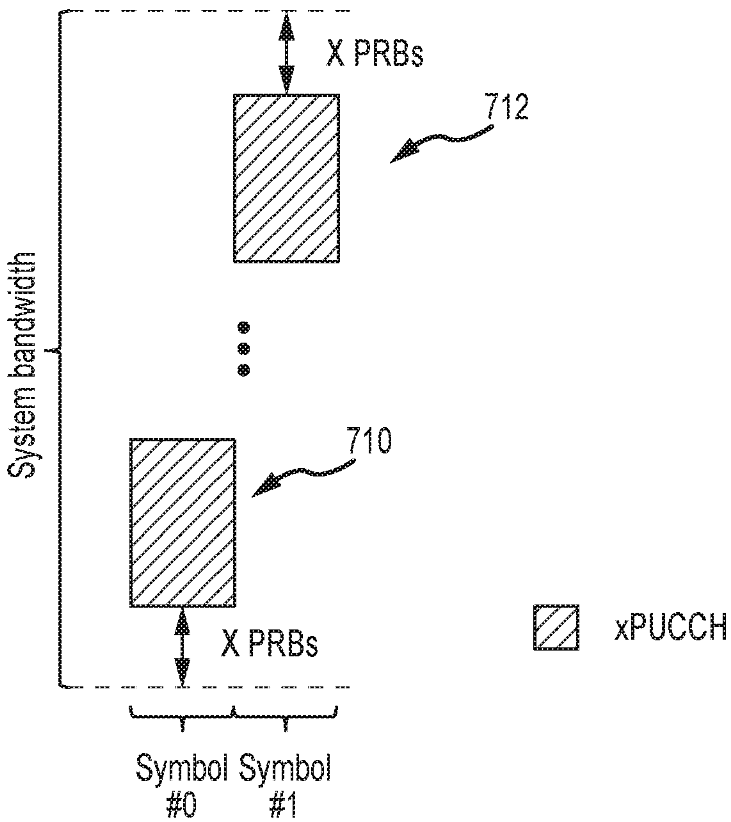
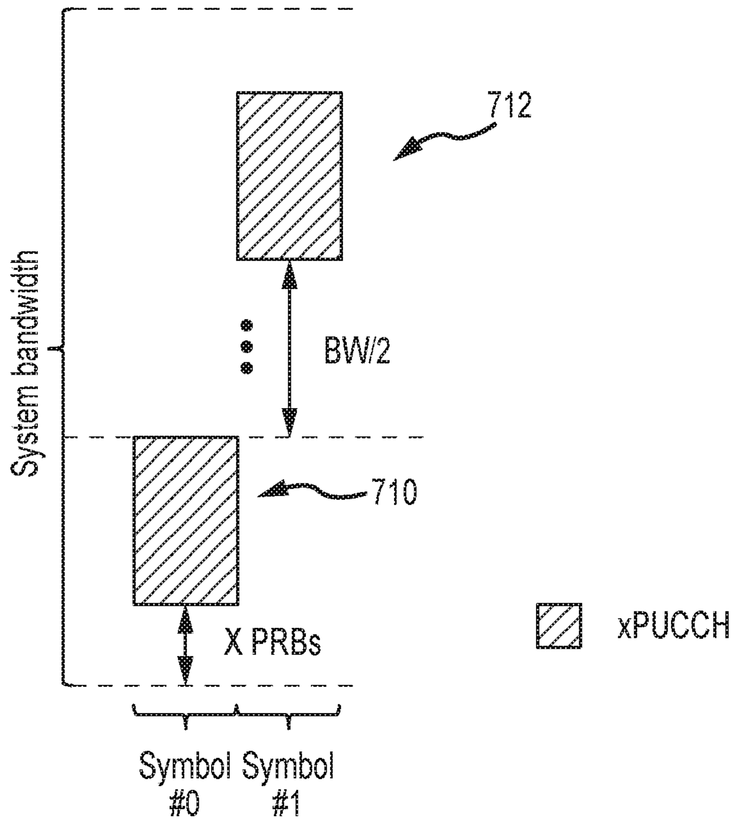
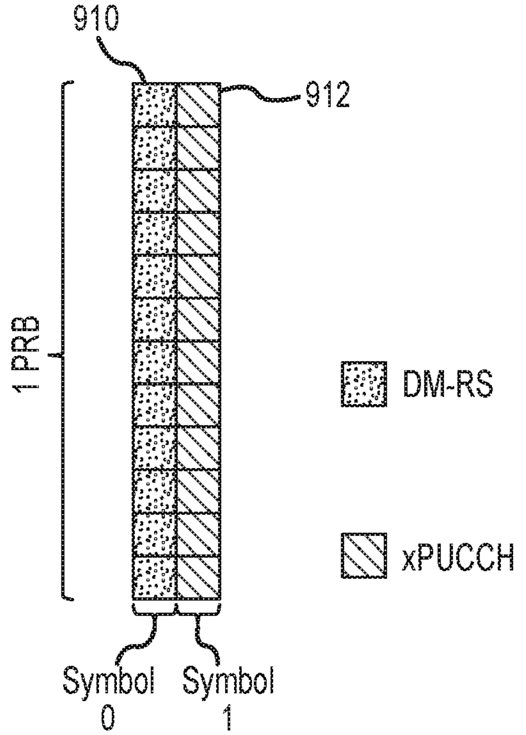

X PRBs
712
System bandwidth
710
X PRBs
xPUCCH
Symbol #0
Symbol #1

FIG.7



712
System bandwidth
BW/2
710
X PRBs
xPUCCH
Symbol #0
Symbol #1

FIG.8



910
912
1 PRB
DM-RS
xPUCCH
Symbol 0
Symbol 1

FIG.9

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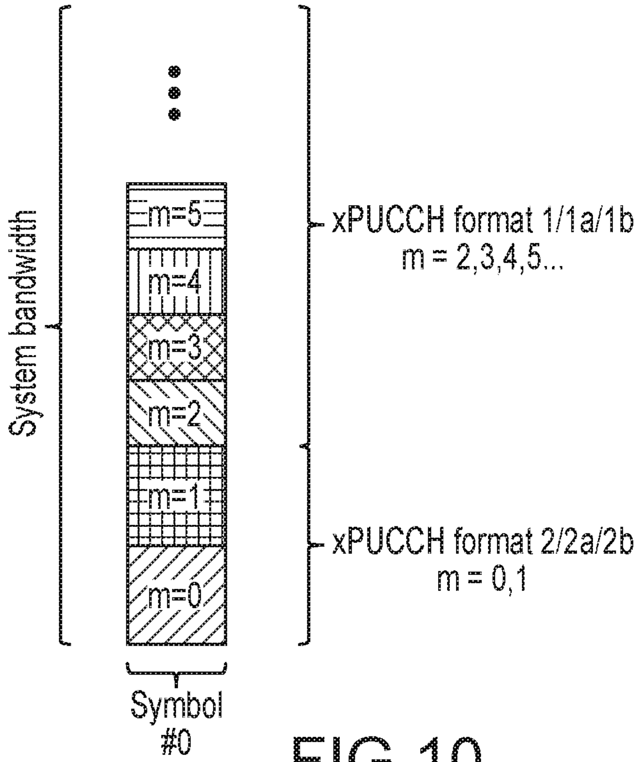

FIG.10

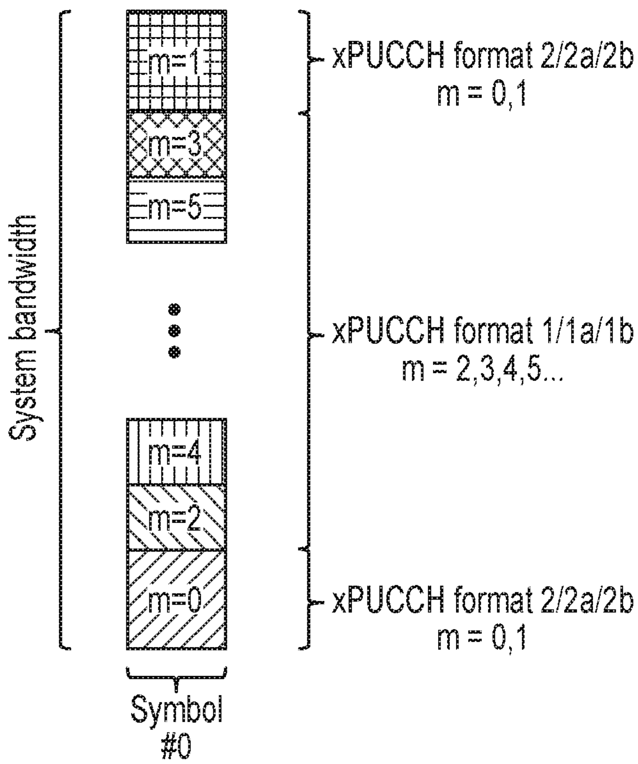

FIG.11

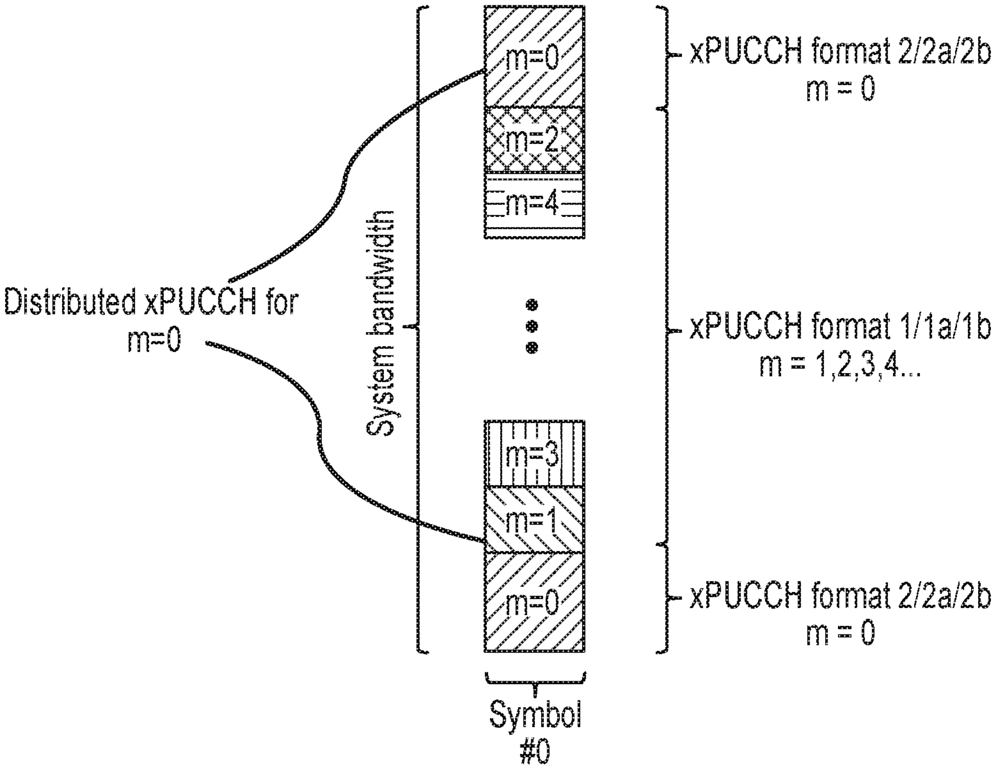
xPUCCH format 2/2a/2b
m = 0
m=0
m=2
m=4
Distributed xPUCCH for
m=0
System bandwidth
xPUCCH format 1/1a/1b
m = 1,2,3,4...
m=3
m=1
m=0
xPUCCH format 2/2a/2b
m = 0
Symbol
#0

FIG.12

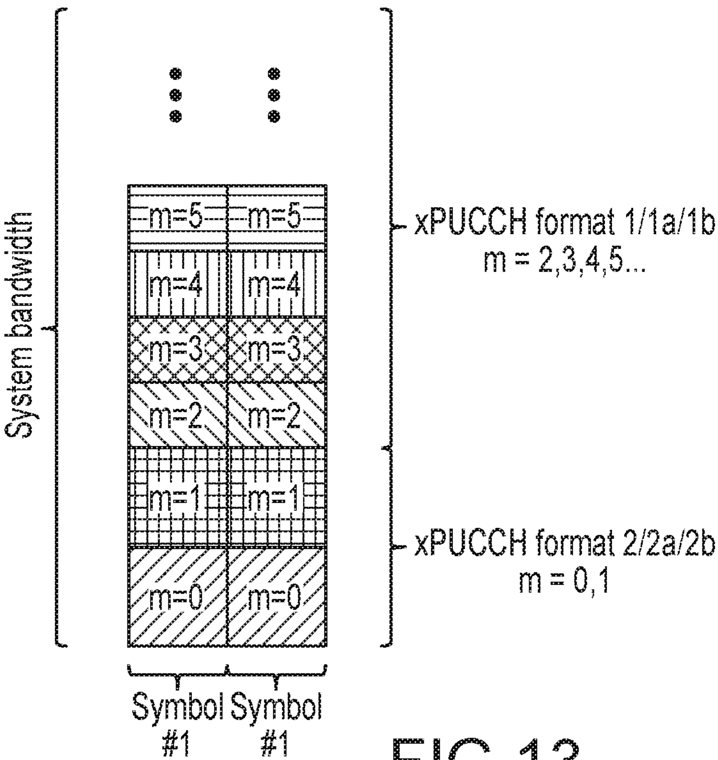
System bandwidth
m=5 m=5
m=4 m=4
m=3 m=3
m=2 m=2
m=1 m=1
m=0 m=0
xPUCCH format 1/1a/1b
m = 2,3,4,5...
xPUCCH format 2/2a/2b
m = 0,1
Symbol
#1
Symbol
#1

FIG.13

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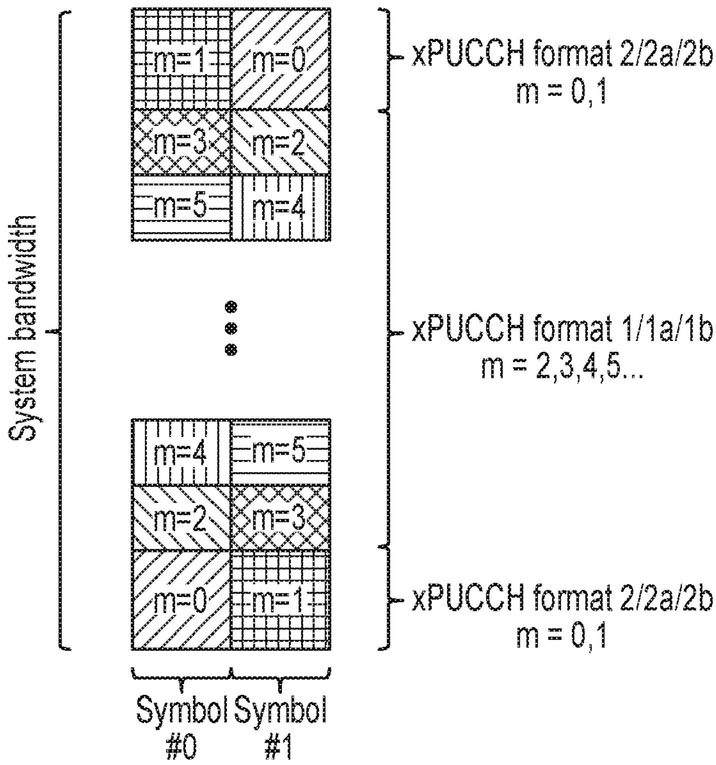


FIG.14

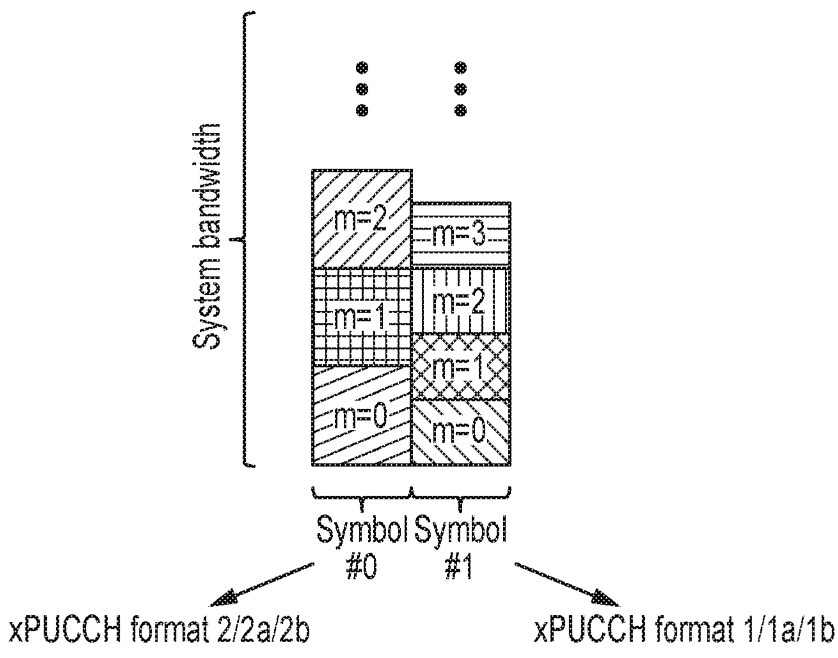
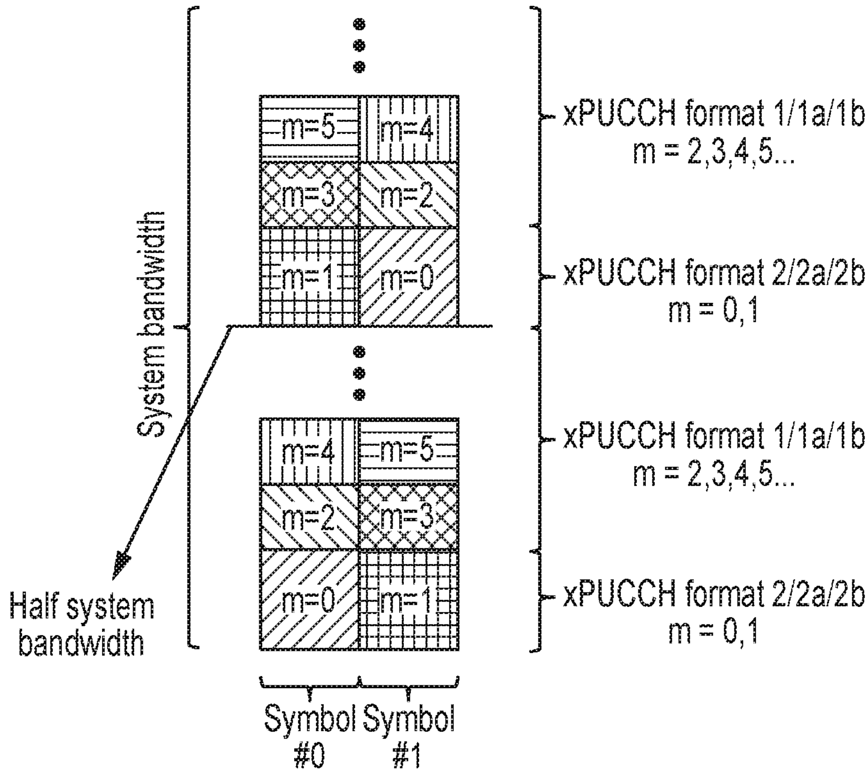


FIG.15



m=5
m=4
m=3
m=2
m=1
m=0
xPUCCH format 1/1a/1b
m = 2,3,4,5...
xPUCCH format 2/2a/2b
m = 0,1
System bandwidth
m=4
m=5
m=2
m=3
m=0
m=1
xPUCCH format 1/1a/1b
m = 2,3,4,5...
xPUCCH format 2/2a/2b
m = 0,1
Half system bandwidth
Symbol #0
Symbol #1

FIG.16

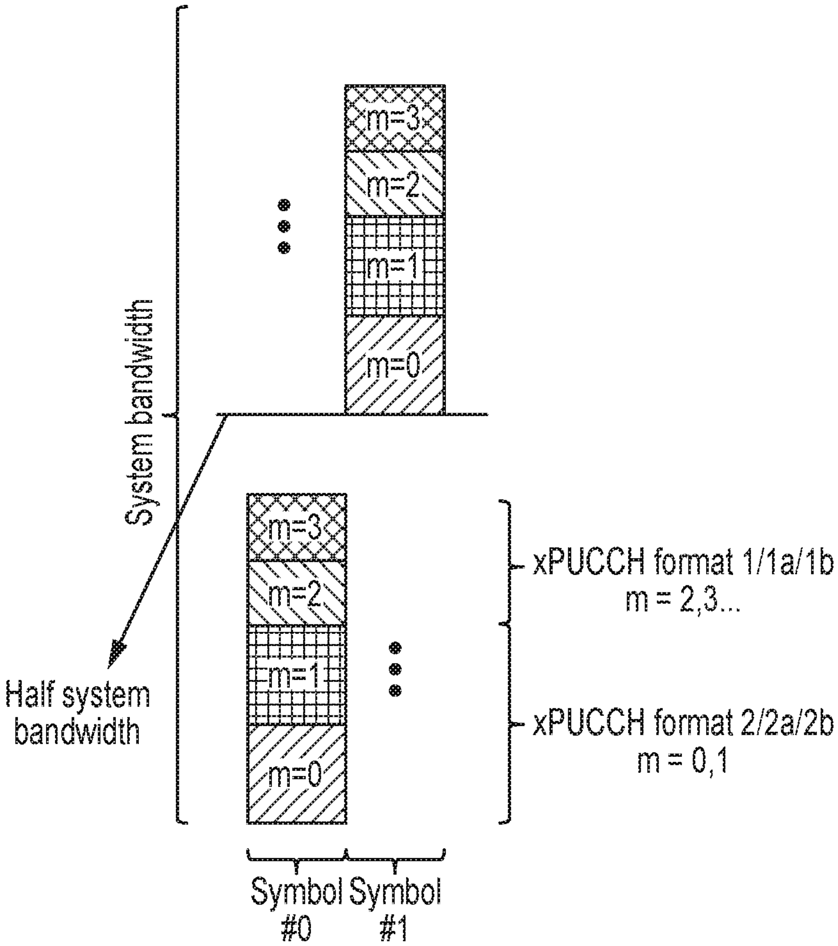

m=3
m=2
m=1
m=0
System bandwidth
m=3
m=2
m=1
m=0
xPUCCH format 1/1a/1b
m = 2,3...
xPUCCH format 2/2a/2b
m = 0,1
Half system
bandwidth
Symbol
#0
Symbol
#1

FIG.17

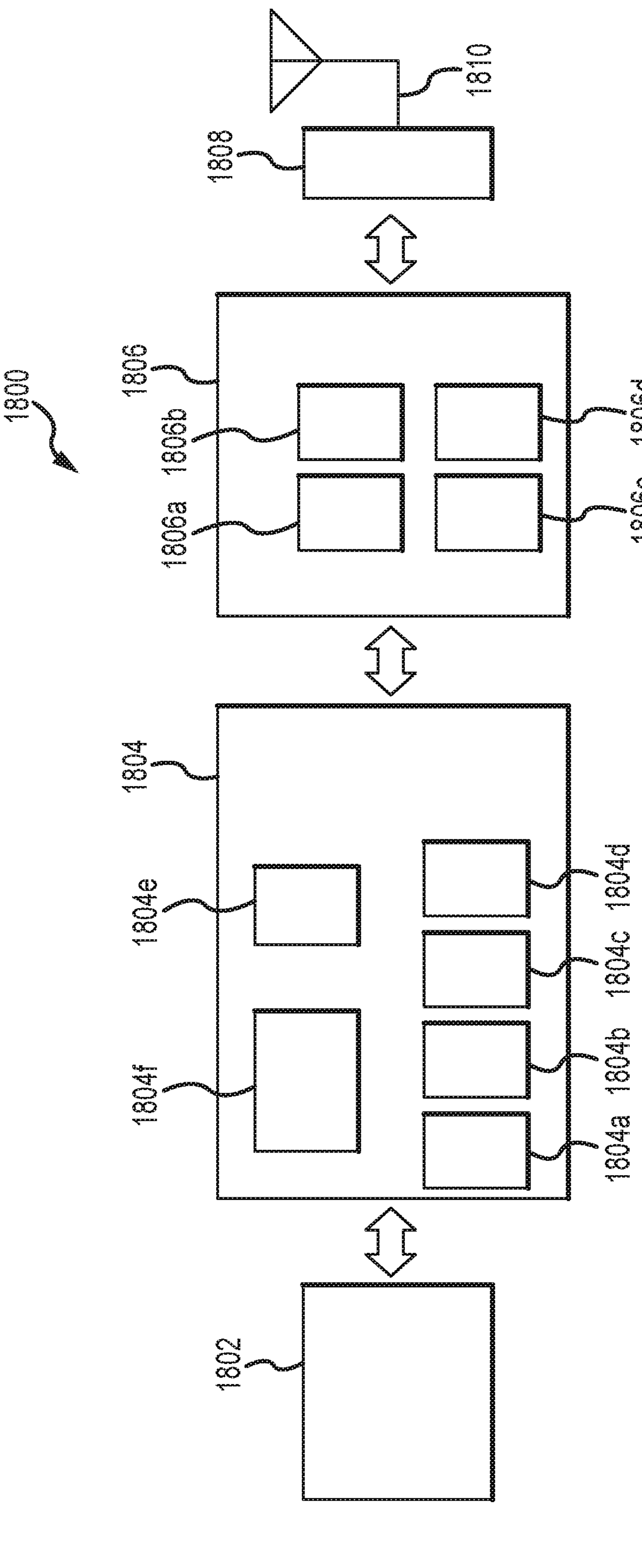

1800
1802
1804
1804a
1804b
1804c
1804d
1804e
1804f
1806
1806a
1806b
1806c
1806d
1808
1810

FIG.18

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2016/026234

A. CLASSIFICATION OF SUBJECT MATTER
INV. H04L1/16 H04L1/18 H04L5/00
ADD.

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
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, COMPENDEX, INSPEC, IBM-TDB, 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	HUAWEI ET AL: "Control signaling enhancements for short TTI", 3GPP DRAFT; R1-156461, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRANCE , vol. RAN WG1, no. Anaheim, USA; 20151115 - 20151122 15 November 2015 (2015-11-15), XP051002921, Retrieved from the Internet: URL:http://www.3gpp.org/ftp/Meetings_3GPP_SYNC/RAN1/Docs/ [retrieved on 2015-11-15] page 5 ----- -/--	1-30

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

[ ] See patent family annex.

* Special categories of cited documents :

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"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
18 July 2016	26/07/2016

Name and mailing address of the ISA/	Authorized officer
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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.
X	HUAWEI ET AL: "Views on TTI length", 3GPP DRAFT; R1-156459, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRANCE , vol. RAN WG1, no. Anaheim, USA; 20151115 - 20151122 15 November 2015 (2015-11-15), XP051002919, Retrieved from the Internet: URL:http://www.3gpp.org/ftp/Meetings_3GPP_SYNC/RAN1/Docs/ [retrieved on 2015-11-15] page 2, paragraph 3.2 -----	1-30
X	CATT: "System Analysis on TTI Shortening", 3GPP DRAFT; R1-156613, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRANCE , vol. RAN WG1, no. Anaheim, CA, USA; 20151115 - 20151122 7 November 2015 (2015-11-07), XP051042078, Retrieved from the Internet: URL:http://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_83/Docs/ [retrieved on 2015-11-07] page 7, paragraph 2.2.2 -----	1-30
X	ERICSSON: "Physical layer aspects of TTI shortening for downlink transmissions", 3GPP DRAFT; R1-157148, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRANCE , vol. RAN WG1, no. Anaheim, USA; 20151115 - 20151122 6 November 2015 (2015-11-06), XP051042007, Retrieved from the Internet: URL:http://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_83/Docs/ [retrieved on 2015-11-06] page 4, paragraph 2.3 ----- -/--	1-30

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INTERNATIONAL SEARCH REPORT

International application No
PCT/US2016/026234

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	"3rd Generation Partnership Project; Technical Specification Group Radio Access Network; Evolved Universal Terrestrial Radio Access (E-UTRA); Physical channels and modulation (Release 12)", 3GPP DRAFT; DRAFT36211-C70, 3RD GENERATION PARTNERSHIP PROJECT (3GPP), MOBILE COMPETENCE CENTRE ; 650, ROUTE DES LUCIOLES ; F-06921 SOPHIA-ANTIPOLIS CEDEX ; FRANCE , 22 September 2015 (2015-09-22), XP051021009, Retrieved from the Internet: URL:http://www.3gpp.org/ftp/tsg_ran/WG1_RL1/DRAFT/ [retrieved on 2015-09-22] page 26 - page 32 -----	1-30

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