US 20250266945A1

(19) United States
(12) Patent Application Publication
(10) Pub. No.: US 2025/0266945 A1
(43) Pub. Date: Aug. 21, 2025
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(54) SIGNALING METHODS FOR OCC-ENABLED PUSCH

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(21) Appl. No.: **19/053,809**

(22) Filed: **Feb. 14, 2025**

(30) **Foreign Application Priority Data**

Feb. 19, 2024 (FI) 20245203

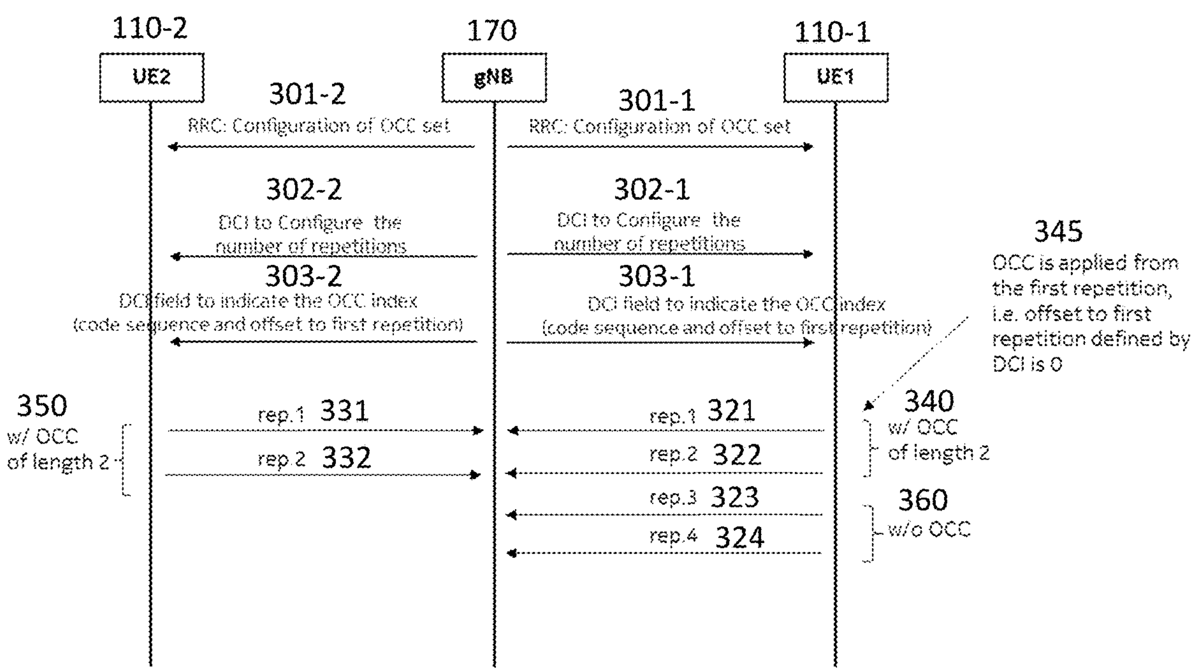
Publication Classification

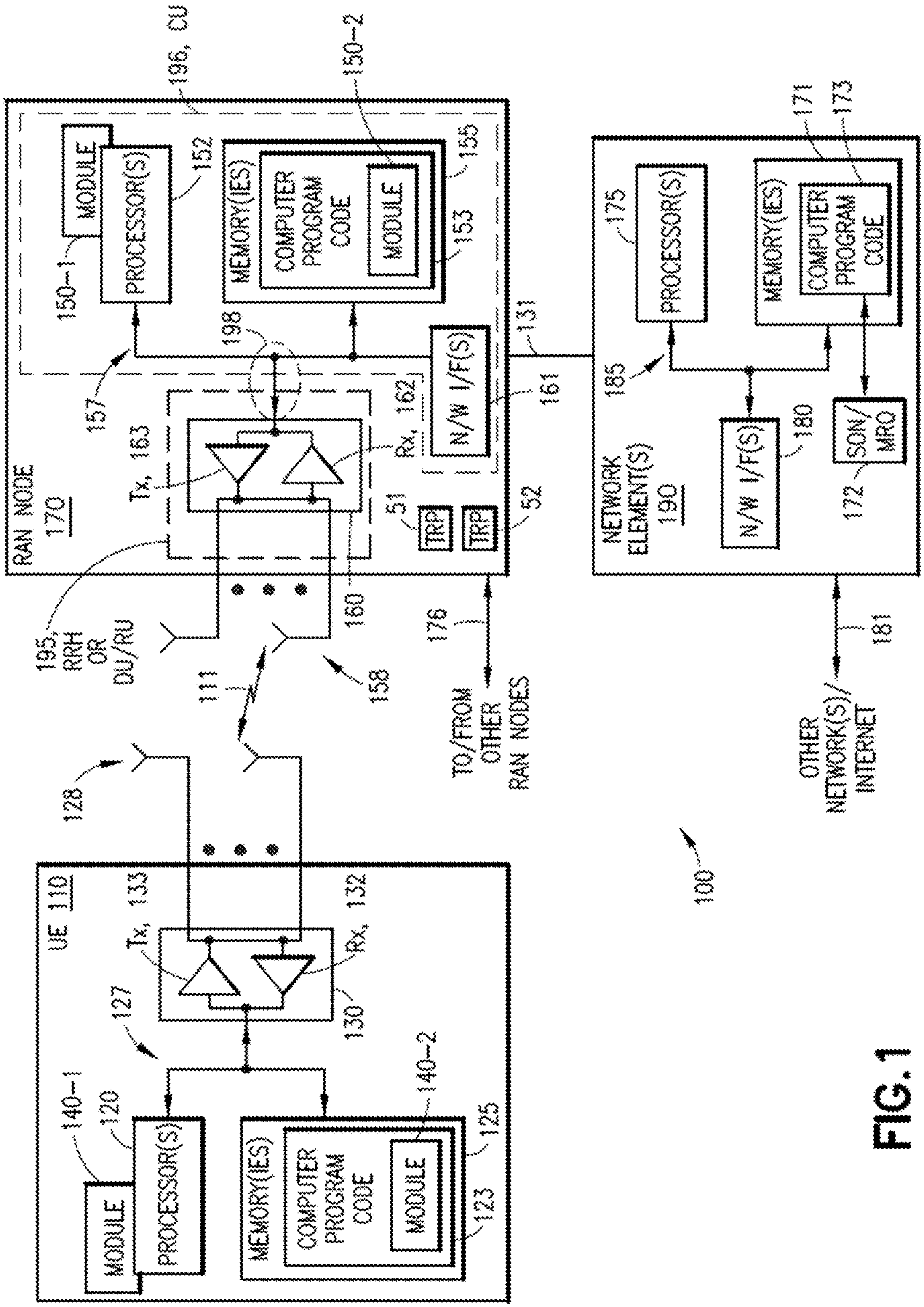
(51) **Int. Cl.**
H04L 5/00 (2006.01)
H04W 72/21 (2023.01)

(52) **U.S. Cl.**
CPC *H04L 5/0016* (2013.01); *H04W 72/21* (2023.01)

(57) **ABSTRACT**

An apparatus including means for receiving a configuration of orthogonal cover code operation; means for determining an orthogonal cover code to use for a physical uplink shared channel transmission, based on the configuration; and means for performing the physical uplink shared channel transmission using the determined orthogonal cover code.





RAN NODE
170
196, CU
MODULE
PROCESSOR(S)
150-1
152
MEMORY(IES)
COMPUTER
PROGRAM
CODE
MODULE
150-2
153
155
157
198
N/W I/F(S)
161
162
131
Tx, 163
Rx,
51
TRP
TRP
52
160
195,
RRH
OR
DU/RU
158
111
176
TO/FROM
OTHER
RAN NODES
NETWORK
ELEMENT(S)
190
PROCESSOR(S)
175
MEMORY(IES)
COMPUTER
PROGRAM
CODE
171
173
185
N/W I/F(S)
180
SON/
MRO
172
181
OTHER
NETWORK(S)/
INTERNET
128
UE 110
Tx, 133
Rx, 132
127
130
MODULE
PROCESSOR(S)
140-1
120
MEMORY(IES)
COMPUTER
PROGRAM
CODE
MODULE
140-2
123
125
100

FIG. 1

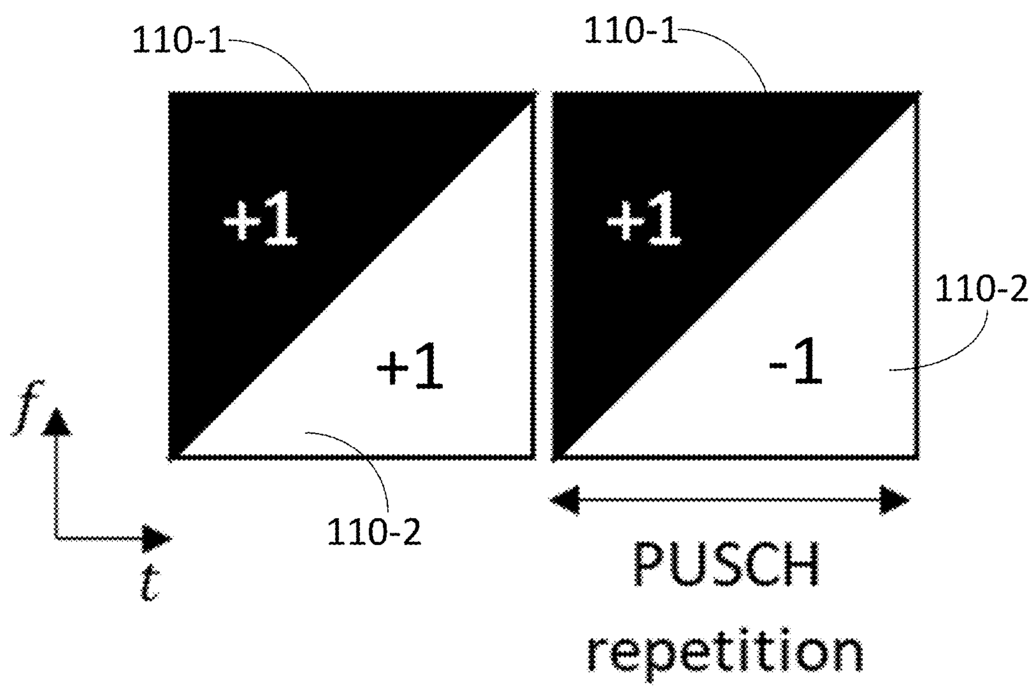


FIG. 2

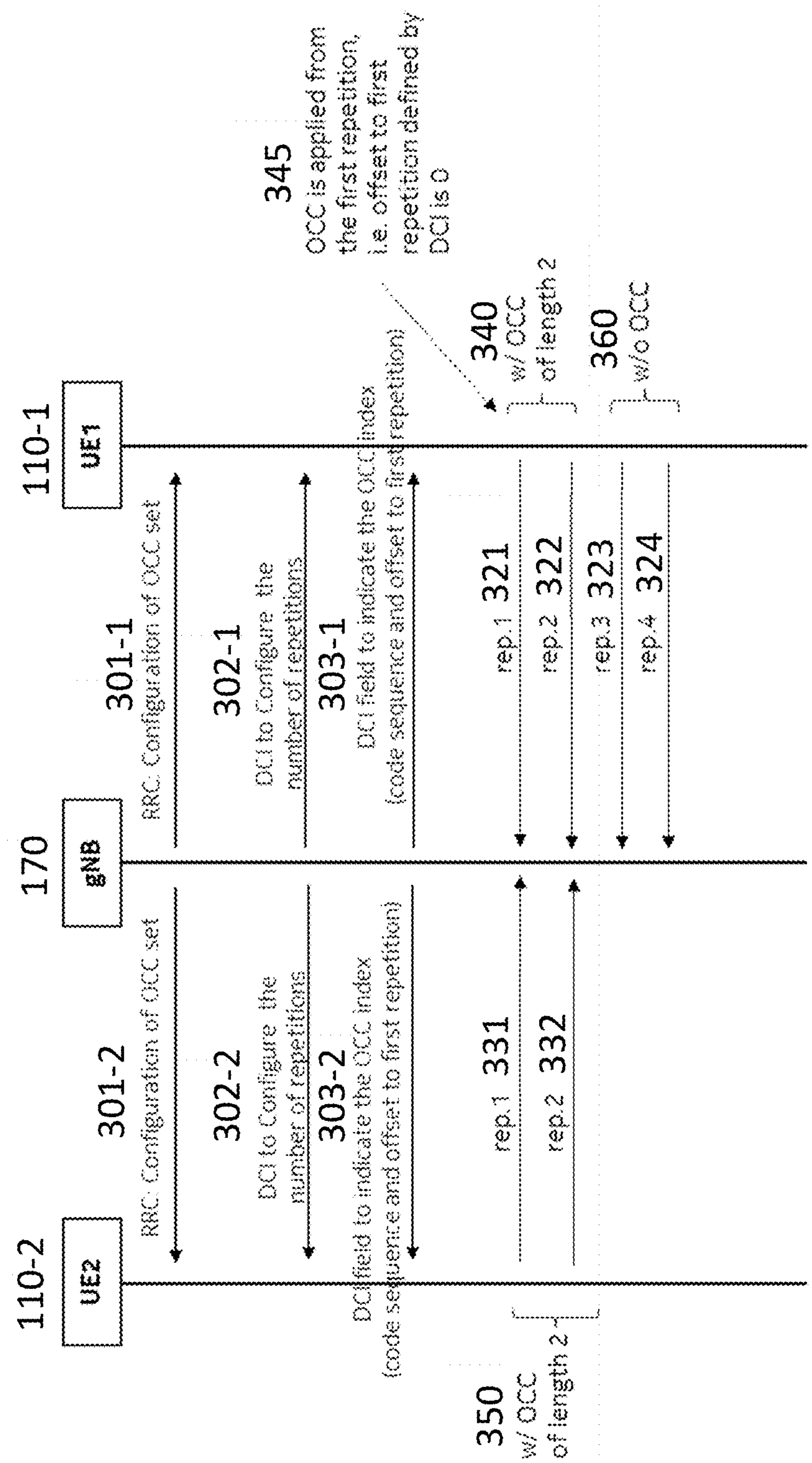

110-1
UE1
170
gNB
110-2
UE2
301-1
RRC: Configuration of OCC set
302-1
DCI to Configure the number of repetitions
303-1
DCI field to indicate the OCC index (code sequence and offset to first repetition)
rep.1 321
rep.2 322
rep.3 323
rep.4 324
340
w/ OCC of length 2
360
w/o OCC
345
OCC is applied from the first repetition, i.e. offset to first repetition defined by DCI is 0
301-2
RRC: Configuration of OCC set
302-2
DCI to Configure the number of repetitions
303-2
DCI field to indicate the OCC index (code sequence and offset to first repetition)
rep.1 331
rep.2 332
350
w/ OCC of length 2

FIG. 3

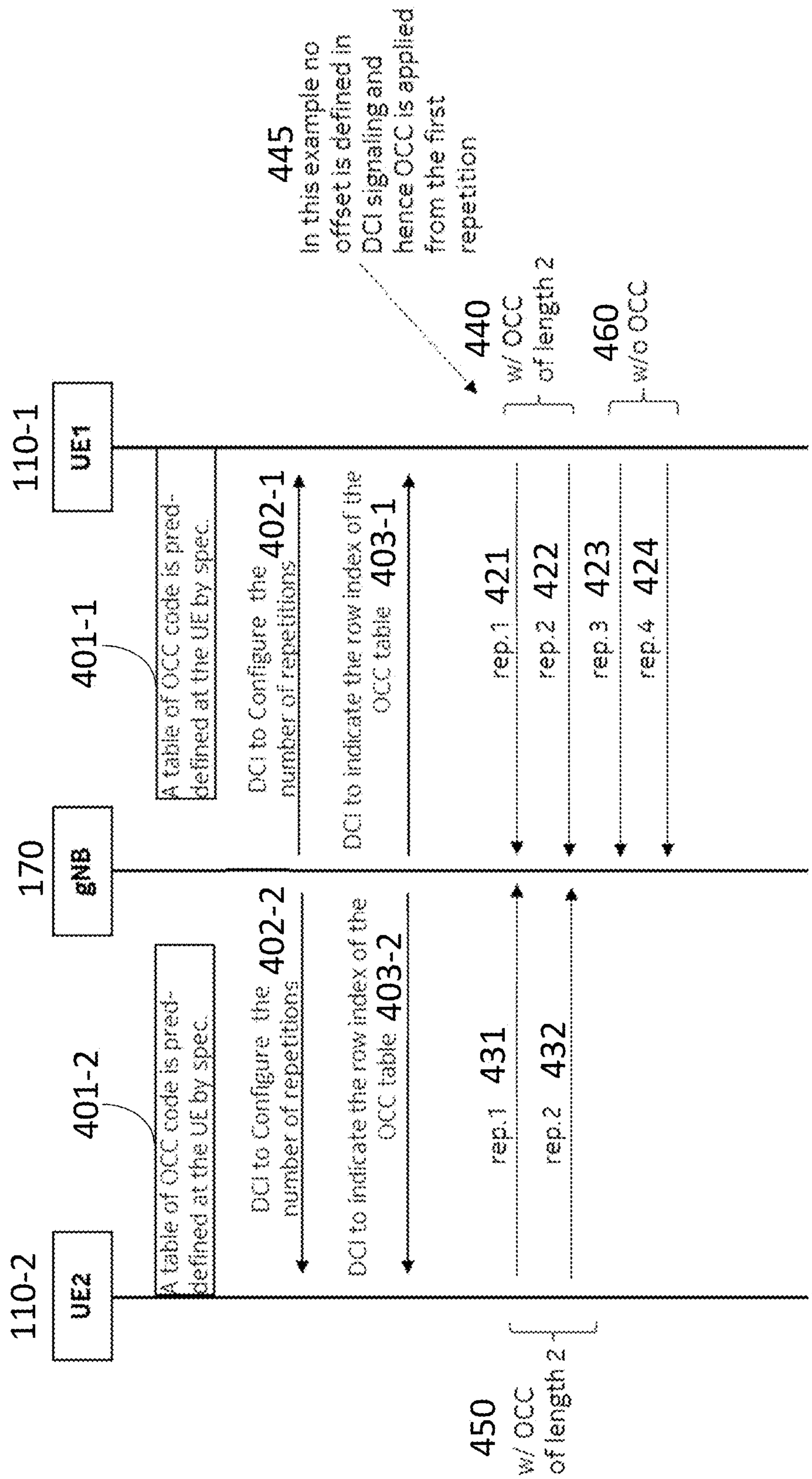

110-1
UE1
170
gNB
110-2
UE2
401-1
A table of OCC code is pred-defined at the UE by spec.
401-2
A table of OCC code is pred-defined at the UE by spec.
DCI to Configure the number of repetitions 402-1
DCI to indicate the row index of the OCC table 403-1
DCI to Configure the number of repetitions 402-2
DCI to indicate the row index of the OCC table 403-2
rep.1 421
rep.2 422
rep.3 423
rep.4 424
rep.1 431
rep.2 432
445
In this example no offset is defined in DCI signaling and hence OCC is applied from the first repetition
440
w/ OCC of length 2
460
w/o OCC
450
w/ OCC of length 2

FIG. 4

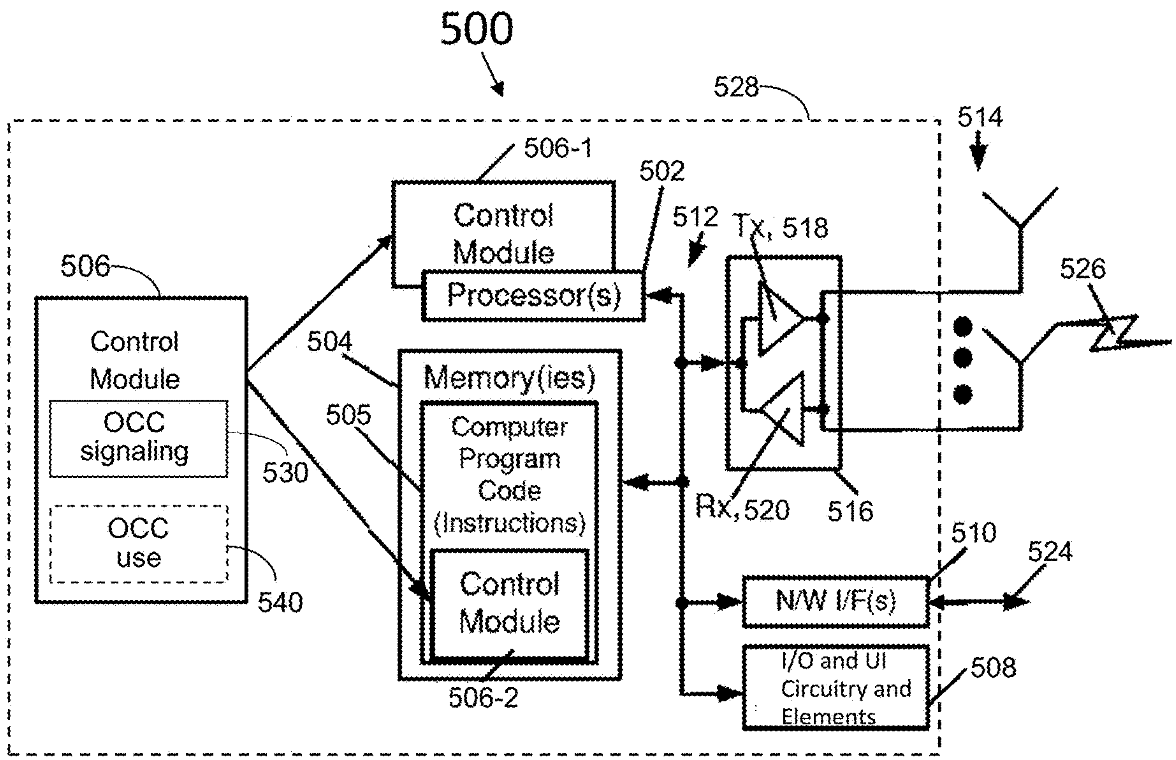

500
528
514
506-1
502
Control Module
512
Tx, 518
526
506
Processor(s)
Control Module
504
Memory(ies)
OCC signaling
505
Computer Program Code (Instructions)
530
Rx, 520
516
OCC use
510
524
Control Module
N/W I/F(s)
540
I/O and UI Circuitry and Elements
508
506-2

FIG. 5

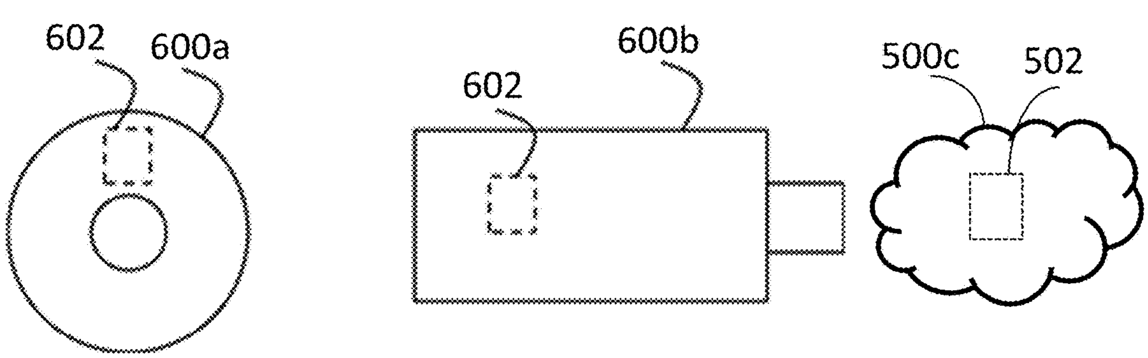

602
600a
600b
602
500c
502

FIG. 6

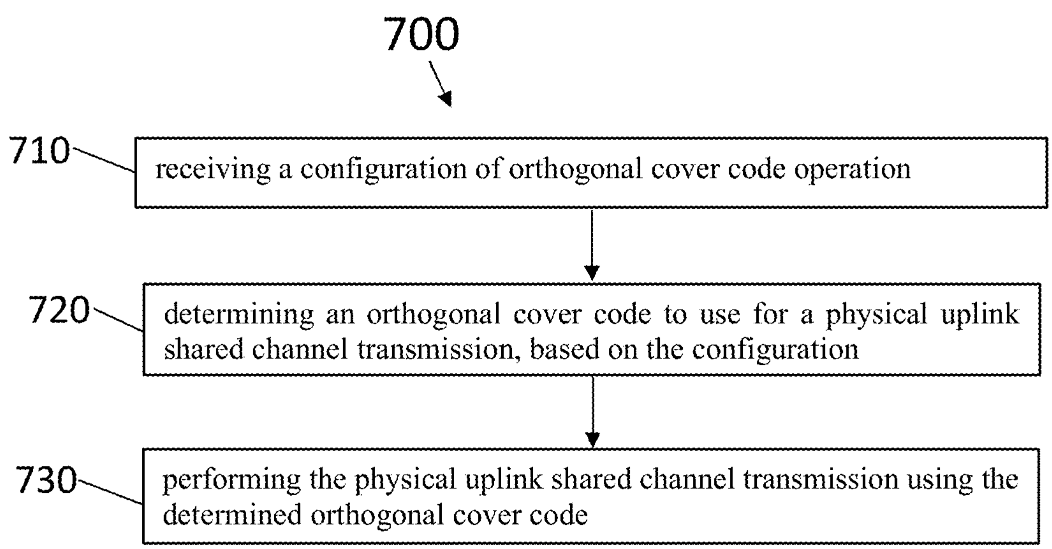

700
710
receiving a configuration of orthogonal cover code operation
720
determining an orthogonal cover code to use for a physical uplink shared channel transmission, based on the configuration
730
performing the physical uplink shared channel transmission using the determined orthogonal cover code

FIG. 7

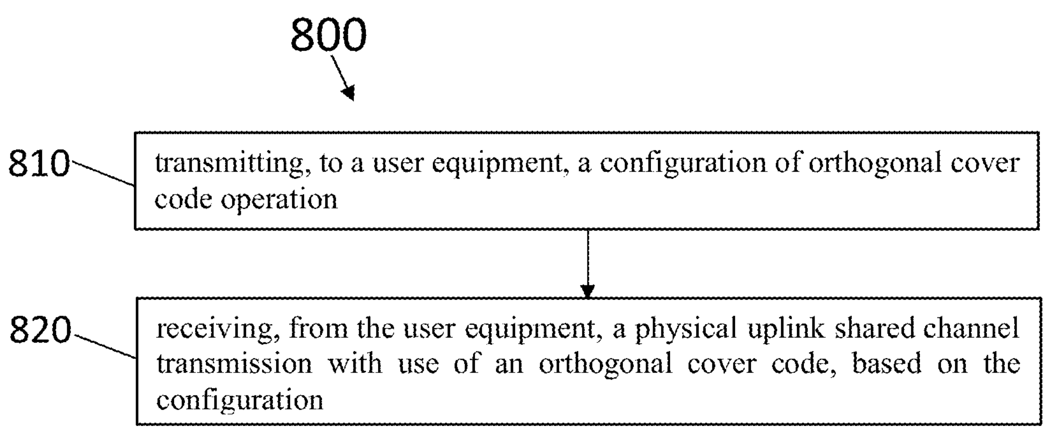

800
810
transmitting, to a user equipment, a configuration of orthogonal cover code operation
820
receiving, from the user equipment, a physical uplink shared channel transmission with use of an orthogonal cover code, based on the configuration

FIG. 8

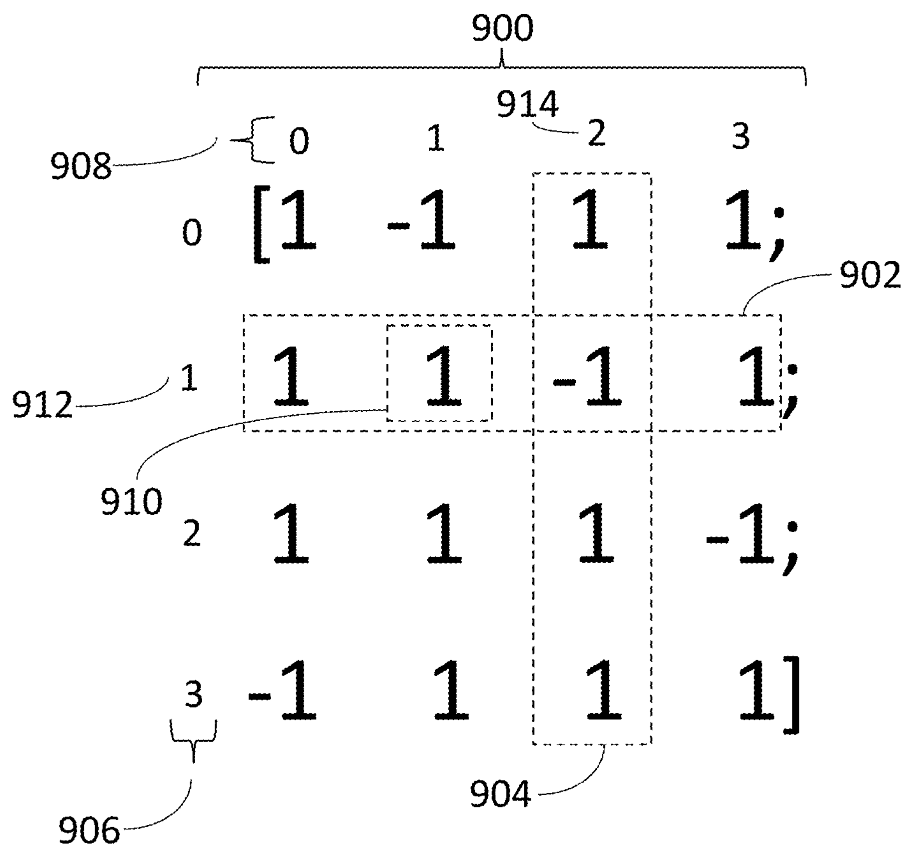


FIG. 9

SIGNALING METHODS FOR OCC-ENABLED PUSCH

TECHNICAL FIELD

[0001] The examples and non-limiting example embodiments relate generally to communications and, more particularly, to signaling methods for OCC-enabled PUSCH.

BACKGROUND

[0002] It is known for a communication device to gain access to a communication network via an access network node.

SUMMARY

[0003] In accordance with an aspect, an apparatus include means for receiving a configuration of orthogonal cover code operation; means for determining an orthogonal cover code to use for a physical uplink shared channel transmission, based on the configuration; and means for performing the physical uplink shared channel transmission using the determined orthogonal cover code.

[0004] In accordance with an aspect, an apparatus includes means for transmitting, to a user equipment, a configuration of orthogonal cover code operation; and means for receiving, from the user equipment, a physical uplink shared channel transmission with use of an orthogonal cover code, based on the configuration.

BRIEF DESCRIPTION OF THE DRAWINGS

[0005] The foregoing aspects and other features are explained in the following description, taken in connection with the accompanying drawings.

[0006] FIG. **1** is a block diagram of one possible and non-limiting system in which the example embodiments may be practiced.

[0007] FIG. **2** shows an example of OCC of length **2** for 2 UEs doing **2** PUSCH repetitions in the same time-frequency resources

[0008] FIG. **3** shows signaling OCC using RRC and DCI fields.

[0009] FIG. **4** shows signaling OCC when code sets at UEs are pre-defined by specification.

[0010] FIG. **5** is an example apparatus configured to implement the examples described herein.

[0011] FIG. **6** shows a representation of an example of non-volatile memory media used to store instructions that implement the examples described herein.

[0012] FIG. **7** is an example method, based on the examples described herein.

[0013] FIG. **8** is an example method, based on the examples described herein.

[0014] FIG. **9** shows an example orthogonal cover code configuration.

DETAILED DESCRIPTION OF EXAMPLE EMBODIMENTS

[0015] Turning to FIG. **1**, this figure shows a block diagram of one possible and non-limiting example in which the examples may be practiced. A user equipment (UE) **110**, radio access network (RAN) node **170**, and network element (s) **190** are illustrated. In the example of FIG. **1**, the user equipment (UE) **110** is in wireless communication with a wireless network **100**. A UE is a wireless device that can access the wireless network **100**. The UE **110** includes one or more processors **120**, one or more memories **125**, and one or more transceivers **130** interconnected through one or more buses **127**. Each of the one or more transceivers **130** includes a receiver, Rx, **132** and a transmitter, Tx, **133**. The one or more buses **127** may be address, data, or control buses, and may include any interconnection mechanism, such as a series of lines on a motherboard or integrated circuit, fiber optics or other optical communication equipment, and the like. The one or more transceivers **130** are connected to one or more antennas **128**. The one or more memories **125** include computer program code **123**. The UE **110** includes a module **140**, comprising one of or both parts **140-1** and/or **140-2**, which may be implemented in a number of ways. The module **140** may be implemented in hardware as module **140-1**, such as being implemented as part of the one or more processors **120**. The module **140-1** may be implemented also as an integrated circuit or through other hardware such as a programmable gate array. In another example, the module **140** may be implemented as module **140-2**, which is implemented as computer program code **123** and is executed by the one or more processors **120**. For instance, the one or more memories **125** and the computer program code **123** may be configured to, with the one or more processors **120**, cause the user equipment **110** to perform one or more of the operations as described herein. The UE **110** communicates with RAN node **170** via a wireless link **111**.

[0016] The RAN node **170** in this example is a base station that provides access for wireless devices such as the UE **110** to the wireless network **100**. The RAN node **170** may be, for example, a base station for 5G, also called New Radio (NR). In 5G, the RAN node **170** may be a NG-RAN node, which is defined as either a gNB or an ng-eNB. A gNB is a node providing NR user plane and control plane protocol terminations towards the UE, and connected via the NG interface (such as connection **131**) to a 5GC (such as, for example, the network element(s) **190**). The ng-eNB is a node providing E-UTRA user plane and control plane protocol terminations towards the UE, and connected via the NG interface (such as connection **131**) to the 5GC. The NG-RAN node may include multiple gNBs, which may also include a central unit (CU) (gNB-CU) **196** and distributed unit(s) (DUs) (gNB-DUs), of which DU **195** is shown. Note that the DU **195** may include or be coupled to and control a radio unit (RU). The gNB-CU **196** is a logical node hosting radio resource control (RRC), SDAP and PDCP protocols of the gNB or RRC and PDCP protocols of the en-gNB that control the operation of one or more gNB-DUs. The gNB-CU **196** terminates the F1 interface connected with the gNB-DU **195**. The F1 interface is illustrated as reference **198**, although reference **198** also illustrates a link between remote elements of the RAN node **170** and centralized elements of the RAN node **170**, such as between the gNB-CU **196** and the gNB-DU **195**. The gNB-DU **195** is a logical node hosting RLC, MAC and PHY layers of the gNB or en-gNB, and its operation is partly controlled by gNB-CU **196**. One gNB-CU **196** supports one or multiple cells. One cell may be supported with one gNB-DU **195**, or one cell may be supported/shared with multiple DUs under RAN sharing. The gNB-DU **195** terminates the F1 interface **198** connected with the gNB-CU **196**. Note that the DU **195** is considered to include the transceiver **160**, e.g., as part of a RU, but some examples of this may have the transceiver **160** as part of a separate RU, e.g., under control of and connected to the DU **195**. The RAN node **170** may also be an eNB (evolved NodeB) base station, for LTE (long term evolution), or any other suitable base station or node.

[0017] The RAN node **170** includes one or more processors **152**, one or more memories **155**, one or more network interfaces (N/W I/F(s)) **161**, and one or more transceivers **160** interconnected through one or more buses **157**. Each of the one or more transceivers **160** includes a receiver, Rx, **162** and a transmitter, Tx, **163**. The one or more transceivers **160** are connected to one or more antennas **158**. The one or more memories **155** include computer program code **153**. The CU **196** may include the processor(s) **152**, one or more memories **155**, and network interfaces **161**. Note that the DU **195** may also contain its own memory/memories and processor (s), and/or other hardware, but these are not shown.

[0018] The RAN node **170** includes a module **150**, comprising one of or both parts **150-1** and/or **150-2**, which may be implemented in a number of ways. The module **150** may be implemented in hardware as module **150-1**, such as being implemented as part of the one or more processors **152**. The module **150-1** may be implemented also as an integrated circuit or through other hardware such as a programmable gate array. In another example, the module **150** may be implemented as module **150-2**, which is implemented as computer program code **153** and is executed by the one or more processors **152**. For instance, the one or more memories **155** and the computer program code **153** are configured to, with the one or more processors **152**, cause the RAN node **170** to perform one or more of the operations as described herein. Note that the functionality of the module **150** may be distributed, such as being distributed between the DU **195** and the CU **196**, or be implemented solely in the DU **195**.

[0019] The one or more network interfaces **161** communicate over a network such as via the links **176** and **131**. Two or more gNBs **170** may communicate using, e.g., link **176**. The link **176** may be wired or wireless or both and may implement, for example, an Xn interface for 5G, an X2 interface for LTE, or other suitable interface for other standards.

[0020] The one or more buses **157** may be address, data, or control buses, and may include any interconnection mechanism, such as a series of lines on a motherboard or integrated circuit, fiber optics or other optical communication equipment, wireless channels, and the like. For example, the one or more transceivers **160** may be implemented as a remote radio head (RRH) **195** for LTE or a distributed unit (DU) **195** for gNB implementation for 5G, with the other elements of the RAN node **170** possibly being physically in a different location from the RRH/DU **195**, and the one or more buses **157** could be implemented in part as, for example, fiber optic cable or other suitable network connection to connect the other elements (e.g., a central unit (CU), gNB-CU **196**) of the RAN node **170** to the RRH/DU **195**. Reference **198** also indicates those suitable network link(s).

[0021] A RAN node/gNB can comprise one or more TRPs to which the methods described herein may be applied. FIG. **1** shows that the RAN node **170** comprises TRP **51** and TRP **52**, in addition to the TRP represented by transceiver **160**. Similar to transceiver **160**, TRP **51** and TRP **52** may each include a transmitter and a receiver. The RAN node **170** may host or comprise other TRPs not shown in FIG. **1**.

[0022] A relay node in NR is called an integrated access and backhaul node. A mobile termination part of the IAB node facilitates the backhaul (parent link) connection. In other words, the mobile termination part comprises the functionality which carries UE functionalities. The distributed unit part of the IAB node facilitates the so called access link (child link) connections (i.e. for access link UEs, and backhaul for other IAB nodes, in the case of multi-hop IAB). In other words, the distributed unit part is responsible for certain base station functionalities. The IAB scenario may follow the so called split architecture, where the central unit hosts the higher layer protocols to the UE and terminates the control plane and user plane interfaces to the 5G core network.

[0023] It is noted that the description herein indicates that "cells" perform functions, but it should be clear that equipment which forms the cell may perform the functions. The cell makes up part of a base station. That is, there can be multiple cells per base station. For example, there could be three cells for a single carrier frequency and associated bandwidth, each cell covering one-third of a 360 degree area so that the single base station's coverage area covers an approximate oval or circle. Furthermore, each cell can correspond to a single carrier and a base station may use multiple carriers. So if there are three 120 degree cells per carrier and two carriers, then the base station has a total of 6 cells.

[0024] The wireless network **100** may include a network element or elements **190** that may include core network functionality, and which provides connectivity via a link or links **181** with a further network, such as a telephone network and/or a data communications network (e.g., the Internet). Such core network functionality for 5G may include location management functions (LMF(s)) and/or access and mobility management function(s) (AMF(S)) and/or user plane functions (UPF(s)) and/or session management function(s) (SMF(s)). Such core network functionality for LTE may include MME (mobility management entity)/SGW (serving gateway) functionality. Such core network functionality may include SON (self-organizing/optimizing network) functionality. These are merely example functions that may be supported by the network element(s) **190**, and note that both 5G and LTE functions might be supported. The RAN node **170** is coupled via a link **131** to the network element **190**. The link **131** may be implemented as, e.g., an NG interface for 5G, or an SI interface for LTE, or other suitable interface for other standards. The network element **190** includes one or more processors **175**, one or more memories **171**, and one or more network interfaces (N/W I/F(s)) **180**, interconnected through one or more buses **185**. The one or more memories **171** include computer program code **173**. Computer program code **173** may include SON and/or MRO functionality **172**.

[0025] The wireless network **100** may implement network virtualization, which is the process of combining hardware and software network resources and network functionality into a single, software-based administrative entity, or a virtual network. Network virtualization involves platform virtualization, often combined with resource virtualization. Network virtualization is categorized as either external, combining many networks, or parts of networks, into a virtual unit, or internal, providing network-like functionality to software containers on a single system. Note that the virtualized entities that result from the network virtualization are still implemented, at some level, using hardware such as processors **152** or **175** and memories **155** and **171**, and also such virtualized entities create technical effects.

[0026] The computer readable memories **125**, **155**, and **171** may be of any type suitable to the local technical environment and may be implemented using any suitable data storage technology, such as semiconductor based memory devices, flash memory, magnetic memory devices and systems, optical memory devices and systems, non-transitory memory, transitory memory, fixed memory and removable memory. The computer readable memories **125**, **155**, and **171** may be means for performing storage functions. The processors **120**, **152**, and **175** may be of any type suitable to the local technical environment, and may include one or more of general purpose computers, special purpose computers, microprocessors, digital signal processors (DSPs) and processors based on a multi-core processor architecture, as non-limiting examples. The processors **120**, **152**, and **175** may be means for performing functions, such as controlling the UE **110**, RAN node **170**, network element (s) **190**, and other functions as described herein.

[0027] In general, the various example embodiments of the user equipment **110** can include, but are not limited to, cellular telephones such as smart phones, tablets, personal digital assistants (PDAs) having wireless communication capabilities, portable computers having wireless communication capabilities, image capture devices such as digital cameras having wireless communication capabilities, gaming devices having wireless communication capabilities, music storage and playback devices having wireless communication capabilities, internet appliances including those permitting wireless internet access and browsing, tablets with wireless communication capabilities, head mounted displays such as those that implement virtual/augmented/mixed reality, as well as portable units or terminals that incorporate combinations of such functions. The UE **110** can also be a vehicle such as a car, or a UE mounted in a vehicle, a UAV such as e.g. a drone, or a UE mounted in a UAV. The user equipment **110** may be terminal device, such as mobile phone, mobile device, sensor device etc., the terminal device being a device used by the user or not used by the user.

[0028] UE **110**, RAN node **170**, and/or network element(s) **190**, (and associated memories, computer program code and modules) may be configured to implement (e.g. in part) the methods described herein. Thus, computer program code **123**, module **140-1**, module **140-2**, and other elements/features shown in FIG. **1** of UE **110** may implement user equipment related aspects of the examples described herein. Similarly, computer program code **153**, module **150-1**, module **150-2**, and other elements/features shown in FIG. **1** of RAN node **170** may implement gNB/TRP related aspects of the examples described herein. Computer program code **173** and other elements/features shown in FIG. **1** of network element(s) **190** may be configured to implement network element related aspects of the examples described herein.

[0029] Having thus introduced a suitable but non-limiting technical context for the practice of the example embodiments, the example embodiments are now described with greater specificity.

[0030] Background on Rel-19 NTN uplink capacity enhancements

[0031] In RAN #**102**, a new Work Item Description (WID) for NTN targeting NR Rel-19 was approved in RP-**234078**. Among the objectives of the WI, an objective on Uplink Capacity/Throughput Enhancement for FR1-NTN was approved:

Uplink Capacity/Throughput Enhancement for FR1-NTN [RAN1, RAN2, RAN4]
Study then specify, if beneficial, DFT-s-OFDM PUSCH enhancements via Orthogonal Cover Codes (OCC) Determine the achievable capacity improvement to be targeted taking into account realistic impairments (e.g. Doppler, time variation, phase distortion, etc) Specify necessary signalling, if needed Update RF requirements accordingly, if needed Note: The study can consider orthogonal cover codes across OFDM symbols, across slots, and/or within an OFDM symbol. Note: the study phase is targeted to be completed by RAN#104 Notes for this objective: The enhancement is not targeting improvements/impacts of MU-MIMO capability The enhancement is not targeted to PUSCH DMRS No enhancement for initial access Enhancements to PRACH are not in scope. This feature may be applicable for UEs operating in terrestrial networks based on a common design

[0032] More specifically, this objective targets enhancements to the DFT-s-OFDM PUSCH channel via Orthogonal Cover Codes (OCC) to enable multiplexing of multiple UEs in the same time-frequency resources. As can be seen from the description of the objective, the study can consider orthogonal cover codes across OFDM symbols, across slots, and/or within an OFDM symbol, but the examples described herein specifically focus on the OCC application across intra-slot or inter-slot PUSCH repetitions, i.e. across OFDM symbols and across slots.

Background on OCC

[0033] OCC is a coding technique that can be used to enhance the capacity/throughput of a cellular network. In particular, one could generate a set of orthogonal codes (e.g. Walsh-Hadamard codes) having ideal zero cross-correlation and assign different codes to different UEs to achieve orthogonal (i.e. no interference) UL transmissions on the same time-frequency resources.

[0034] FIG. **2** illustrates the principle of OCC. FIG. **2** shows an example of OCC of length **2** for 2 UEs doing **2** PUSCH repetitions in the same time-frequency resources. In FIG. **2**, two UEs are transmitting **2** PUSCH repetitions in the same time-frequency resources. For the transmissions, the two UEs apply different OCCs to their transmission signal (which is assumed here to stay constant across the repetitions) allowing a gNB receiver to receive (i.e. demodulate and decode) the signals of each UE without the interference of the other UE. In mathematical form, how this works is represented in the system of equation 1 below (without channel impairments and additive noise for simplicity of description) where x1 and x2 are the signals transmitted by UE**1** and UE**2**, respectively and in both repetitions, whereas y1 and y2 are the total signals received by the gNB in the first and second repetition, respectively. It is to be noted that in this example UE**1** **110-1** is applying the OCC [**1**, **1**] whereas UE**2** is applying the OCC [1,−1]. In the example of the equations, gNB **170** retrieves the signal of UE**2** **110-2**

without interference from UE**1** **110-1** by cross-correlating the two received signal y1 and y2 with the OCC used by UE**2** (i.e. [1,−1]).

$$\begin{cases} y_1 = (+1)*x_1 + (+1)*x_2 \\ y_2 = (+1)*x_1 + (-1)*x_2 \end{cases} \rightarrow (+1)*y_1 + (-1)*y_2 = 2*x_2 \quad \text{Eq. (1)}$$

[0035] The example above is only illustrative and uses Walsh-Hadamard orthogonal codes as OCC set. Different sequences can be used to realize orthogonality among users without impacting the applicability of the method described herein. In addition, it is to be noted that in general in order to multiplex N UEs a number of at least N PUSCH (or signal) repetitions are necessary.

[0036] UE**1** **110-1** and UE**2** **110-2** are configured similar to UE **110** as shown in FIG. **1** with connection to radio access network node **170** (e.g. gNB **170**).

[0037] 5G NR up to Rel-18 supports OCC for the part of a PUSCH that carries DM-RS. However, 5G NR up to Rel-18 does not support OCC for the part of the PUSCH used for data transmissions. Therefore indication of OCC operation to Rel-19 UEs needs to be introduced to enable orthogonal transmission of multiple UEs over the same time frequency resources. It is indeed fundamental that UEs scheduled in the same time frequency resources use different (and orthogonal) codes for their transmissions, and this can be guaranteed via gNB indication and management of UEs OCC code selection.

[0038] Described herein are methods for signaling and indication of both UE capability of support of OCC operation and configuration of a UE with OCC operation, including indication of the length of and the actual OCC code the UE should apply to PUSCH repetitions, and the position of the OCC with respect to repetitions.

[0039] Described herein are signaling methods to apply OCC to UEs data in uplink (i.e. PUSCH). This signaling indicates whether or not a UE is to use OCC for its uplink data transmission as well as which OCC code has to be used of which length and where the OCC code is located.

[0040] For this described herein are the following signaling methods: UE indication of supporting capability of OCC application to PUSCH transmissions, and gNB indication and configuration of a UE with OCC operation for PUSCH transmissions.

[0041] Regarding UE indication of supporting capability of OCC application to PUSCH transmissions, in one embodiment, the capability of applying OCC is limited to PUSCH repetitions. In another embodiment, the capability of applying OCC applies to DFT-s-OFDM PUSCH transmissions.

[0042] Regarding gNB indication and configuration of a UE with OCC operation for PUSCH transmissions, in one embodiment, UE is configured to use OCC and the length of the OCC to use via RRC (semi-static) signalling. In one alternative of this embodiment, UE is further RRC configured which OCC code to use among the code set with the configured length. In another alternative, which OCC code to use (among the code set with the configured length) is indicated to the UE dynamically via DCI-either via a new DCI field or via repurposing an existing DCI field. The DCI field can further indicate an offset that specifies the OCC elements (or code) position with respect to first repetition, or specifies which part of the OCC code to be used within the OCC code sequence. The code set with the configured length might either be pre-configured at the UE (from specifications) or be further RRC configured by gNB. The code set might be a set of Walsh-Hadamard sequences or a set of DFT sequences or another set of codes (binary or non-binary, where binary is considered as having two discrete states) that are providing inter-code orthogonality given that UE transmissions are synchronized.

[0043] In another embodiment, UE is configured to use OCC and a set of lengths of the OCC to use via RRC (semi-static) signaling. In this case, the OCC to use (length and code) is dynamically indicated to the UE via DCI either via a new DCI field or via repurposing an existing DCI field. The DCI field can further indicate an offset that specifies the OCC elements (or code) position with respect to first repetition, or specifies which part of the OCC code to be used within the OCC code sequence. In an alternative to this dynamic indication, a UE may be provided a table with different lengths and code entries, and the UE is dynamically indicated the specific row and/or column indexes to use. Upon knowing the row and/or column indexes the UE knows the specific OCC code and length to use for UL transmissions.

[0044] In another embodiment, UE is configured to use OCC via RRC (semi-static) signaling and the length of the OCC to use for a number of PUSCH repetitions is related to the number of PUSCH repetitions. In one alternative, the length of the OCC to use for a number of PUSCH repetitions is equal to the number of repetitions. In another alternative, the length of the OCC to use for a number of PUSCH repetitions is the closest power of 2 value lower than the number of repetitions. In yet another alternative the OCC code length may be configured such that the repetition number is divisible by the OCC code length (able to perform division without remainder, meaning that an integer amount of OCC codes can be applied over a repetition window). In one implementation based on the examples described herein, the UE may further be indicated an offset to apply on top of the indication of which code to use.

[0045] In one embodiment, a set of OCC codes to use (each per one or multiple numbers of PUSCH repetitions) is RRC configured and UE autonomously chooses the OCC to apply to the PUSCH transmission. Based on the number of scheduled PUSCH repetitions, UE uses the respective code in the set with for example a length of closest power of 2 value lower than the number of repetitions.

[0046] In another embodiment, UE is indicated the OCC to apply to the PUSCH transmission via DCI among the OCC codes with length as determined by first two bullets above. In one alternative, the DCI field is of variable size depending on the number of scheduled repetitions. In another alternative, the DCI field is of fixed size and equal to a max number of multiplexable UEs and the indication is based on a subset of (MSB) bits e.g. equal to log **2** (N_repetitions). In other words, based on the number of scheduled repetitions a subset of bits of the DCI field are "active" and contain the indication. In yet another alternative, an OCC code with a max length (this max length might be preconfigured at the UE) is RRC configured per UE and UE uses only a number of entries equal to the number of scheduled repetitions. If properly configured this solution works because you can always find an orthogonal N×N Walsh matrix within an orthogonal MxM Walsh matrix with M>N. M and N are power of 2.

[0047] In another embodiment, the UE may be configured to use a "windowing function" similar to the concept of time domain windows used for DMRS bundling, where a UE is committing to maintaining transmit phase over a given window. In an example, the boundaries of the time domain windows are aligned to the periodicity and phase of the OCC code, such that the UE commits to maintaining phase coherence at the receiver side (as is defined for NR over NTN systems as part of Rel-18) over a well-defined period of time.

[0048] In yet another embodiment the gNB may configure two or more UEs to use different code lengths, while still maintaining orthogonality between the UEs due to preferred pairing between various sequences.

[0049] FIG. **3** shows signaling OCC using RRC and DCI fields. In particular, FIG. **3** shows a message sequence chart of an example implementation of the herein described solution based on RRC configured OCC set through which the OCC set, i.e. the elements of different orthogonal sequences, to be used by UEs (**110-1**, **110-2**) are communicated and configured in a semi-static manner. This example includes 2 UEs to be multiplexed with OCC of size **2** (**340**, **350**). The UE**1** **110-1** requires four repetitions (repetition **1** **321**, repetition **2** **322**, repetition **3** **323**, repetition **4** **324**) while UE**2** **110-2** is arranged with only two repetitions (repetition **1** **331**, repetition **2** **332**).

[0050] Step-by-step signaling is as follows:

[0051] 1 (**301-1**, **301-2**). RRC configures the UEs with OCC set to be potentially used such as [1 1], [1-1]. They can be put in a matrix of OCC codes in which each row represents one orthogonal sequence. In this example it is [1 1;1-1].

[0052] 2 (**302-1**, **302-2**). The gNB **170** informs the UEs (**110-1**, **110-2**) the number of repetitions they require, i.e. via a TDRA (Time Domain Resource Allocation) table.

[0053] 3 (**303-1**, **303-2**). To multiplex UE**1** **110-1** and UE**2** **110-2** in the network, the gNB **170** further informs the users if they require to apply OCC to the repetitions and how. For this a DCI field can carry the necessary information that points to each UE which OCC sequence to apply and where the OCC should be applied. In FIG. **3**, UE**1** **110-1** is indicated to apply OCC [1 1] to the first two repetitions, i.e. the start index refers to the first repetition and hence no offset exist with respect to first repetition, while the UE**2** **110-2** only requires to know which orthogonal code has to be used which here could be [1-1]. If the index DCI field is empty or takes a special configured value, one can assume no OCC is applied.

[0054] As further shown in FIG. **3**, repetition **3** **323** and repetition **4** **324** are performed without OCC (**360**). As indicated at **345**, the OCC for UE**1** **110-1** is applied from the first repetition, i.e. offset to the first repetition defined by DCI is 0.

[0055] The examples described herein allow more efficient use of repetitions through code multiplexing. In the above examples 2 UEs are able to share the same resources and hence release new resources for capacity increase. The solution is flexible in order to multiplex different UEs with different level of link budgets. In the example above, UE**1** **110-1** with the poorer link budget can apply OCC to only a portion of the repetitions in order to adapt to the other UE's conditions (conditions of UE **110-2**) that only require 2 repetitions and hence OCC of size **2**.

[0056] FIG. **4** shows signaling OCC when code sets at UEs are pre-defined by specification. In particular, FIG. **4** shows an example where the OCC set is pre-defined by specification and is known for all UEs. The steps are as follows:

[0057] 1. Network decides to code-multiplex UE**1** and UE**2** with their number of repetitions. At **401-1**, a table of one or more OCC codes is pre-defined at the UE**1** **110-1** by specification. At **401-2**, a table of one or more OCC codes is pre-defined at the UE**2** **110-2** by specification.

[0058] 2 (**402-1**, **402-2**). Number of repetitions are communicated to UEs using DCI.

[0059] 3 (**403-1**, **403-2**). The new DCI field is used to indicate which row of the OCC table each UE (**110-1**, **110-2**) has to use to make sure the size of OCC is appropriate and the codes of UE**1** **110-1** and UE**2** **110-2** are orthogonal.

[0060] 4 (**440**, **450**). UEs (**110-1**, **110-2**) apply OCC from the first repetitions and hence (as indicated at **445**) there is no need for the gNB **170** to specify from which repetition OCC is to be applied like the previous case.

[0061] FIG. **4** shows repetition **1** **421**, repetition **2** **422**, repetition **3** **423**, and repetition **4** **424** performed with UE**1** **110-1**, where the OCC of length **2** **440** includes repetition **1** **421** and repetition **2** **422**, and where repetition **3** **423** and repetition **4** **424** are performed without OCC as indicated at **460**. Repetition **1** **431** and repetition **2** **432** are performed with UE**2** **110-2** with OCC of length **2** **450**.

[0062] The examples described herein are relevant to 3GPP NTN WI on UL capacity and throughput enhancements via OCC, and may be applicable to TS 38.214 for UE behavior and TS 38.331 for configuration of relevant parameters.

[0063] FIG. **5** is an example apparatus **500**, which may be implemented in hardware, configured to implement the examples described herein. The apparatus **500** comprises at least one processor **502** (e.g. an FPGA and/or CPU), one or more memories **504** including computer program code **505**, the computer program code **505** having instructions to carry out the methods described herein, wherein the at least one memory **504** and the computer program code **405** are configured to, with the at least one processor **402**, cause the apparatus **400** to implement circuitry, a process, component, module, or function (implemented with control module **406**) to implement the examples described herein. The memory **405** may be a non-transitory memory, a transitory memory, a volatile memory (e.g. RAM), or a non-volatile memory (e.g. ROM).

[0064] OCC signaling **530** and optionally included OCC use 540 may implement the examples described herein related to signaling for OCC-enabled PUSCH.

[0065] The apparatus **500** includes a display and/or I/O interface **508**, which includes user interface (UI) circuitry and elements, that may be used to display aspects or a status of the methods described herein (e.g., as one of the methods is being performed or at a subsequent time), or to receive input from a user such as with using a keypad, camera, touchscreen, touch area, microphone, biometric recognition, one or more sensors, etc. The apparatus **500** includes one or more communication e.g. network (N/W) interfaces (I/F(s)) **510**. The communication I/F(s) **510** may be wired and/or wireless and communicate over the Internet/other network (s) via any communication technique including via one or more links **524**. The link(s) **524** may be the link(s) **131** and/or **176** from FIG. **1**. The link(s) **131** and/or **176** from

FIG. **1** may also be implemented using transceiver(s) **516** and corresponding wireless link(s) **526**. The communication I/F(s) **510** may comprise one or more transmitters or one or more receivers.

[0066] The transceiver **516** comprises one or more transmitters **518** and one or more receivers **520**. The transceiver **516** and/or communication I/F(s) **510** may comprise standard well-known components such as an amplifier, filter, frequency-converter, (de) modulator, and encoder/decoder circuitries and one or more antennas, such as antennas **514** used for communication over wireless link **526**.

[0067] The control module **506** of the apparatus **500** comprises one of or both parts **506-1** and/or **506-2**, which may be implemented in a number of ways. The control module **506** may be implemented in hardware as control module **506-1**, such as being implemented as part of the one or more processors **502**. The control module **506-1** may be implemented also as an integrated circuit or through other hardware such as a programmable gate array. In another example, the control module **506** may be implemented as control module **506-2**, which is implemented as computer program code (having corresponding instructions) **505** and is executed by the one or more processors **502**. For instance, the one or more memories **504** store instructions that, when executed by the one or more processors **502**, cause the apparatus **500** to perform one or more of the operations as described herein. Furthermore, the one or more processors **502**, the one or more memories **504**, and example algorithms (e.g., as flowcharts and/or signaling diagrams), encoded as instructions, programs, or code, are means for causing performance of the operations described herein.

[0068] The apparatus **500** to implement the functionality of control **506** may be UE **110**, RAN node **170** (e.g. gNB), or network element(s) **190** (e.g. LMF **190**). Thus, processor **502** may correspond to processor(s) **120**, processor(s) **152** and/or processor(s) **175**, memory **504** may correspond to one or more memories **125**, one or more memories **155** and/or one or more memories **171**, computer program code **505** may correspond to computer program code **123**, computer program code **153**, and/or computer program code **173**, control module **506** may correspond to module **140-1**, module **140-2**, module **150-1**, and/or module **150-2**, and communication I/F(s) **510** and/or transceiver **516** may correspond to transceiver **130**, antenna(s) **128**, transceiver **160**, antenna(s) **158**, N/W I/F(s) **161**, and/or N/W I/F(s) **180**. Alternatively, apparatus **500** and its elements may not correspond to either of UE **110**, RAN node **170**, or network element(s) **190** and their respective elements, as apparatus **500** may be part of a self-organizing/optimizing network (SON) node or other node, such as a node in a cloud.

[0069] Apparatus **500** may correspond to UE**1** **110-1** or UE**2** **110-2**, where UE**1** **110-1** and UE**2** **110-2** are configured similar to UE **110**.

[0070] The apparatus **500** may also be distributed throughout the network (e.g. **100**) including within and between apparatus **500** and any network element (such as a network control element (NCE) **190** and/or the RAN node **170** and/or UE **110**).

[0071] Interface **512** enables data communication and signaling between the various items of apparatus **500**, as shown in FIG. **5**. For example, the interface **512** may be one or more buses such as address, data, or control buses, and may include any interconnection mechanism, such as a series of lines on a motherboard or integrated circuit, fiber optics or other optical communication equipment, and the like. Computer program code (e.g. instructions) **505**, including control **506** may comprise object-oriented software configured to pass data or messages between objects within computer program code **505**, or computer program code (e.g. instructions) **505**, including control **506** may include functional, scripting, or procedural code. The apparatus **500** need not comprise each of the features mentioned, or may comprise other features as well. The various components of apparatus **500** may at least partially reside in a common housing **528**, or a subset of the various components of apparatus **500** may at least partially be located in different housings, which different housings may include housing **528**.

[0072] FIG. **6** shows a schematic representation of non-volatile memory media **600***a* (e.g. computer/compact disc (CD) or digital versatile disc (DVD)) and **600***b* (e.g. universal serial bus (USB) memory stick) and **600***c* (e.g. cloud storage for downloading instructions and/or parameters **602** or receiving emailed instructions and/or parameters **602**) storing instructions and/or parameters **602** which when executed by a processor allows the processor to perform one or more of the steps of the methods described herein. Instructions and/or parameters **602** may represent a non-transitory computer readable medium.

[0073] FIG. **7** is an example method **700** based on the examples described herein. At **710**, the method includes receiving a configuration of orthogonal cover code operation. At **720**, the method includes determining an orthogonal cover code to use for a physical uplink shared channel transmission, based on the configuration. At **730**, the method includes performing the physical uplink shared channel transmission using the determined orthogonal cover code. Method **700** may be performed with UE **110** or apparatus **500**.

[0074] FIG. **8** is an example method **800** based on the examples described herein. At **810**, the method includes transmitting, to a user equipment, a configuration of orthogonal cover code operation. At **820**, the method includes receiving, from the user equipment, a physical uplink shared channel transmission with use of an orthogonal cover code, based on the configuration. Method **800** may be performed with RAN node **170**, one or more network elements **190**, or apparatus **500**.

[0075] FIG. **9** shows an example OCC configuration **900**. The example OCC configuration **900** is shown in FIG. **9** as a **4*4** table/matrix with the matrix elements equal to elements of OCC code sets (or to elements of OCC codes). In FIG. **9**, there are 4 orthogonal cover codes of length **4** placed in 4 rows in the matrix and the index refers to the row of the matrix. The configuration has a row index (one of **906**). As shown, orthogonal cover code **902** is specified by row index **1** (**912**), and includes OCC sequence 1, 1,−1, 1 (from left to right). In some examples the index also can refer to the column (one of **908**). As shown, orthogonal cover code **904** is specified by column index **2** (**914**), and includes OCC sequence 1,−1, 1, 1 (from top to bottom). The offset also can be preconfigured, and the offset may be indicated by DCI. As shown, element or entry **910** (with value **1**) of orthogonal cover code **902** is specified with row index **1** and an offset of 1 corresponding to column index **1** in the matrix. An orthogonal cover code set may include only one OCC, such as orthogonal cover code **902**, or an orthogonal cover code set may include a plurality of orthogonal cover codes

(OCCs), such as OCC **902** and OCC **904**. OCC configuration **900** may be signaled by the network (e.g. RAN node **170** or one or more network elements **190**) to one UE **110** or to a plurality of user equipments (UEs) including UE **110**. For example, the network may signal to UE **110** to use OCC **902** or one or more of the elements of OCC **902**, and may signal to another UE different from UE **110** to use OCC **904** or one or more elements of the OCC **904**, where UE **110** and the another UE receive the same OCC configuration **900**.

[0076] The following examples are provided and described herein.

[0077] Example 1. An apparatus including: means for receiving a configuration of orthogonal cover code operation; means for determining an orthogonal cover code to use for a physical uplink shared channel transmission, based on the configuration; and means for performing the physical uplink shared channel transmission using the determined orthogonal cover code.

[0078] Example 2. The apparatus of example 1, wherein the configuration comprises an orthogonal cover code set comprising a plurality of orthogonal cover codes, wherein each orthogonal cover code within the orthogonal cover code set has a length determined based on a number of entries of the orthogonal cover code.

[0079] Example 3. The apparatus of example 2, wherein an entry of the orthogonal cover code comprises a coefficient to apply to a data part of the physical uplink shared channel transmission when using the orthogonal cover code.

[0080] Example 4. The apparatus of any of examples 2 to 3, wherein the orthogonal cover code comprises a sequence of coefficients to apply to a sequence of physical uplink shared channel transmissions when using the orthogonal cover code.

[0081] Example 5. The apparatus of any of examples 1 to 4, wherein the configuration comprises a plurality of orthogonal cover code sets.

[0082] Example 6. The apparatus of any of examples 1 to 5, further including: means for determining repetitions of physical uplink shared channel transmissions to perform using the orthogonal cover code.

[0083] Example 7. The apparatus of any of examples 1 to 6, further including: means determining repetitions of physical uplink shared channel transmissions to perform without use of the orthogonal cover code.

[0084] Example 8. The apparatus of any of examples 1 to 7, further including: means for determining an index of the configuration that specifies the orthogonal cover code to use for the physical uplink shared channel transmission.

[0085] Example 9. The apparatus of example 8, wherein the index specifies an orthogonal cover code to use for at least a first repetition of the repetitions of the physical uplink shared channel transmissions.

[0086] Example 10. The apparatus of any of examples 1 to 9, further including: means for determining an offset of the configuration, where the offset specifies an entry of the orthogonal cover code to use for the physical uplink shared channel transmission.

[0087] Example 11. The apparatus of any of examples 1 to 10, wherein the configuration of orthogonal cover code operation is provided as a table and given with a specification.

[0088] Example 12. The apparatus of example 11, further including: means for determining a location within the table where the orthogonal cover code that the apparatus is to use is located.

[0089] Example 13. The apparatus of any of examples 11 to 12, further including: means for determining an indication that specifies a row of the table where the orthogonal cover code that the apparatus is to use is located.

[0090] Example 14. The apparatus of any of examples 1 to 13, further including: means for receiving, from a network an indication of repetitions of physical uplink shared channel transmissions to perform using the orthogonal cover code based on a link budget of the apparatus.

[0091] Example 15. The apparatus of example 14, wherein a number of the repetitions of the physical uplink shared channel transmissions the apparatus is indicated to perform when the apparatus has a first link budget is less than a number of the repetitions of the physical uplink shared channel transmissions the apparatus is indicated to perform when the apparatus has a second link budget, wherein the first link budget is smaller than the second link budget.

[0092] Example 16. The apparatus of any of examples 1 to 15, further including: means for transmitting, to a network, an indication of a capability of the apparatus to use an orthogonal cover code.

[0093] Example 17. The apparatus of any of examples 1 to 16, further including: means for receiving, from a network, an indication of the orthogonal cover code to use.

[0094] Example 18. The apparatus of any of examples 1 to 17, further including: means for receiving, from a network, an indication of repetitions of physical uplink shared channel transmissions to perform using the orthogonal cover code.

[0095] Example 19. The apparatus of any of examples 1 to 18, further including: means for receiving, from a network, an indication of the orthogonal cover code to use for a number of repetitions of physical uplink shared channel transmissions; wherein a length of the orthogonal cover code indicated to be used for the number of physical uplink shared channel transmissions is the closest power of 2 value lower than the number of repetitions; and means for using the orthogonal cover code for the number of repetitions of the physical uplink shared channel transmissions.

[0096] Example 20. The apparatus of any of examples 1 to 19, wherein the apparatus comprises a user equipment, or a user equipment comprises the apparatus.

[0097] Example 21. An apparatus including: means for transmitting, to a user equipment, a configuration of orthogonal cover code operation; and means for receiving, from the user equipment, a physical uplink shared channel transmission with use of an orthogonal cover code, based on the configuration.

[0098] Example 22. The apparatus of example 21, wherein the configuration comprises an orthogonal cover code set comprising a plurality of orthogonal cover codes, wherein each orthogonal cover code within the orthogonal cover code set has a length determined based on a number of entries of the orthogonal cover code.

[0099] Example 23. The apparatus of example 22, wherein an entry of the orthogonal cover code comprises a coefficient to apply to a data part of the physical uplink shared channel transmission with use of the orthogonal cover code.

[0100] Example 24. The apparatus of any of examples 22 to 23, wherein the orthogonal cover code comprises a sequence of coefficients to apply to a sequence of physical uplink shared channel transmissions with use of the orthogonal cover code.

[0101] Example 25. The apparatus of any of examples 21 to 24, wherein the configuration comprises a plurality of orthogonal cover code sets.

[0102] Example 26. The apparatus of any of examples 21 to 25, further including: means for transmitting, to the user equipment, an indication of repetitions of physical uplink shared channel transmissions to perform using the orthogonal cover code.

[0103] Example 27. The apparatus of any of examples 21 to 26, further including: means for transmitting, to the user equipment, an indication of repetitions of physical uplink shared channel transmissions to perform without use of the orthogonal cover code.

[0104] Example 28. The apparatus of any of examples 21 to 27, further including: means for transmitting, to the user equipment, an index of the configuration that specifies the orthogonal cover code to use for the physical uplink shared channel transmission.

[0105] Example 29. The apparatus of example 28, wherein the index specifies the orthogonal cover code to use for at least a first repetition of the repetitions of the physical uplink shared channel transmissions.

[0106] Example 30. The apparatus of any of examples 21 to 29, further including: means for transmitting, to the user equipment, an offset of the configuration, where the offset specifies an entry of the orthogonal cover code to use for the physical uplink shared channel transmission.

[0107] Example 31. The apparatus of any of examples 21 to 30, wherein the configuration of orthogonal cover code operations is provided as a table and given with a specification.

[0108] Example 32. The apparatus of example 31, further including: means for transmitting, to the user equipment, a location within the table where the orthogonal cover code that the user equipment is to use is located.

[0109] Example 33. The apparatus of any of examples 31 to 32, further including: means for transmitting, to the user equipment, an indication of a row of the table where the orthogonal cover code that the user equipment is to use is located.

[0110] Example 34. The apparatus of any of examples 21 to 33, further including: means for determining a link budget of a first user equipment; means for determining a link budget of a second user equipment; means for transmitting, to the first user equipment, an indication of repetitions of physical uplink shared channel transmissions to perform using a first orthogonal cover code, based on the link budget of the first user equipment; and means for transmitting, to the second user equipment, an indication of repetitions of physical uplink shared channel transmissions to perform using a second orthogonal cover code, based on the link budget of the second user equipment.

[0111] Example 35. The apparatus of example 34, wherein a number of the repetitions of the physical uplink shared channel transmissions to perform transmitted to the first user equipment is less than a number of repetitions of the physical uplink shared channel transmissions to perform transmitted to the second user equipment, when the link budget of the first user equipment is smaller than the link budget of the second user equipment.

[0112] Example 36. The apparatus of any of examples 21 to 35, further including: means for receiving, from the user equipment, an indication of a capability of the user equipment to use an orthogonal cover code.

[0113] Example 37. The apparatus of any of examples 21 to 36, further including: means for transmitting, to the user equipment, an indication of the orthogonal cover code to use.

[0114] Example 38. The apparatus of any of examples 21 to 37, further including: means for transmitting, to the user equipment, an indication of repetitions of physical uplink shared channel transmissions to perform using the orthogonal cover code.

[0115] Example 39. The apparatus of any of examples 21 to 38, further including: means for transmitting, to the user equipment, an indication of the orthogonal cover code to use for a number of physical uplink shared channel transmissions; wherein a length of the orthogonal cover code indicated to be used for the number of physical uplink shared channel transmissions is the closest power of 2 value lower than the number of repetitions.

[0116] Example 40. The apparatus of any of examples 21 to 39, wherein: the apparatus comprises a radio access network node, or a radio access network node comprises the apparatus, the apparatus comprises a core network element, or a core network element comprises the apparatus.

[0117] Example 41. A method including: receiving a configuration of orthogonal cover code operation; determining an orthogonal cover code to use for a physical uplink shared channel transmission, based on the configuration; and performing the physical uplink shared channel transmission using the determined orthogonal cover code.

[0118] Example 42. A method including: transmitting, to a user equipment, a configuration of orthogonal cover code operation; and receiving, from the user equipment, a physical uplink shared channel transmission with use of an orthogonal cover code, based on the configuration.

[0119] Example 43. A computer readable medium including instructions stored thereon for performing at least the following: receiving a configuration of orthogonal cover code operation; determining an orthogonal cover code to use for a physical uplink shared channel transmission, based on the configuration; and performing the physical uplink shared channel transmission using the determined orthogonal cover code.

[0120] Example 44. A computer readable medium including instructions stored thereon for performing at least the following: transmitting, to a user equipment, a configuration of orthogonal cover code operation; and receiving, from the user equipment, a physical uplink shared channel transmission with use of an orthogonal cover code, based on the configuration.

[0121] Example 45. An apparatus including: at least one processor; and at least one memory storing instructions that, when executed by the at least one processor, cause the apparatus at least to: receive a configuration of orthogonal cover code operation; determine an orthogonal cover code to use for a physical uplink shared channel transmission, based on the configuration; and perform the physical uplink shared channel transmission using the determined orthogonal cover code.

[0122] Example 46. An apparatus including: at least one processor; and at least one memory storing instructions that, when executed by the at least one processor, cause the apparatus at least to: transmit, to a user equipment, a configuration of orthogonal cover code operation; and receive, from the user equipment, a physical uplink shared channel transmission with use of an orthogonal cover code, based on the configuration.

[0123] References to a 'computer', 'processor', etc. should be understood to encompass not only computers having different architectures such as single/multi-processor architectures and sequential or parallel architectures but also specialized circuits such as field-programmable gate arrays (FPGAs), application specific circuits (ASICs), signal processing devices and other processing circuitry. References to computer program, instructions, code etc. should be understood to encompass software for a programmable processor or firmware such as, for example, the programmable content of a hardware device whether instructions for a processor, or configuration settings for a fixed-function device, gate array or programmable logic device etc.

[0124] The memories as described herein may be implemented using any suitable data storage technology, such as semiconductor based memory devices, flash memory, magnetic memory devices and systems, optical memory devices and systems, non-transitory memory, transitory memory, fixed memory and removable memory. The memories may comprise a database for storing data.

[0125] As used herein, the term 'circuitry' may refer to the following: (a) hardware circuit implementations, such as implementations in analog and/or digital circuitry, and (b) combinations of circuits and software (and/or firmware), such as (as applicable): (i) a combination of processor(s) or (ii) portions of processor(s)/software including digital signal processor(s), software, and memories that work together to cause an apparatus to perform various functions, and (c) circuits, such as a microprocessor(s) or a portion of a microprocessor(s), that require software or firmware for operation, even if the software or firmware is not physically present. As a further example, as used herein, the term 'circuitry' would also cover an implementation of merely a processor (or multiple processors) or a portion of a processor and its (or their) accompanying software and/or firmware. The term 'circuitry' would also cover, for example and if applicable to the particular element, a baseband integrated circuit or applications processor integrated circuit for a mobile phone or a similar integrated circuit in a server, a cellular network device, or another network device.

[0126] It should be understood that the foregoing description is only illustrative. Various alternatives and modifications may be devised by those skilled in the art. For example, features recited in the various dependent claims could be combined with each other in any suitable combination(s). In addition, features from different example embodiments described above could be selectively combined into a new example embodiment. Accordingly, this description is intended to embrace all such alternatives, modifications and variances which fall within the scope of the appended claims.

[0127] The following acronyms and abbreviations that may be found in the specification and/or the drawing figures are given as follows (the abbreviations and acronyms may be appended/combined with each other or with other characters using e.g. a dash, hyphen, slash, letter, or number, and may be case insensitive):

[0128] 3GPP third generation partnership project

[0129] 4G fourth generation

[0130] 5G fifth generation

[0131] 5GC 5G core network

[0132] AMF access and mobility management function

[0133] ASIC application-specific integrated circuit

[0134] CD compact/computer disc

[0135] CPU central processing unit

[0136] CU central unit or centralized unit

[0137] DCI downlink control information

[0138] DFT discrete Fourier transform

[0139] DFT-s-OFDM DFT spread orthogonal frequency division multiplexing

[0140] DMRS demodulation reference signal

[0141] DSP digital signal processor

[0142] DU distributed unit

[0143] DVD digital versatile disc

[0144] eNB evolved Node B (e.g., an LTE base station)

[0145] EN-DC E-UTRAN new radio-dual connectivity

[0146] en-gNB node providing NR user plane and control plane protocol terminations towards the UE, and acting as a secondary node in EN-DC

[0147] E-UTRA evolved UMTS terrestrial radio access, i.e., the LTE radio access technology

[0148] E-UTRAN E-UTRA network

[0149] F**1** interface between the CU and the DU

[0150] FPGA field-programmable gate array

[0151] FR1-NTN frequency range **1** non-terrestrial networks

[0152] gNB generalized node B, base station for 5G/NR, i.e., a node providing NR user plane and control plane protocol terminations towards the UE, and connected via the NG interface to the 5GC

[0153] IAB integrated access and backhaul

[0154] I/F interface

[0155] I/O input/output

[0156] LMF location management function

[0157] LTE long term evolution (4G)

[0158] MAC medium access control

[0159] MIMO multiple input multiple output

[0160] MME mobility management entity

[0161] MRO mobility robustness optimization

[0162] MSB most significant bit

[0163] MU-MIMO multiuser MIMO

[0164] NCE network control element

[0165] ng or NG new generation

[0166] ng-eNB new generation eNB

[0167] NG-RAN new generation radio access network

[0168] NR new radio

[0169] NTN non-terrestrial networks

[0170] N/W network

[0171] OCC orthogonal cover code

[0172] OFDM orthogonal frequency division multiplexing

[0173] PDA personal digital assistant

[0174] PDCP packet data convergence protocol

[0175] PHY physical layer

[0176] PRACH physical random access channel

[0177] PUSCH physical uplink shared channel

[0178] RAM random access memory

[0179] RAN radio access network

[0180] RAN #RAN meeting

[0181] RAN**1** RAN working group **1**

[0182] RAN**2** RAN working group **2**

[0183] RAN**4** RAN working group **4**

[0184] rep. repetition

[0185] Rel release
[0186] RF radio frequency
[0187] RLC radio link control
[0188] ROM read-only memory
[0189] RP RAN plenary
[0190] RRC radio resource control
[0191] RU radio unit
[0192] Rx receive, or receiver, or reception
[0193] SDAP service data adaptation protocol
[0194] SGW serving gateway
[0195] SMF session management function
[0196] SON self-organizing/optimizing network
[0197] TDRA time domain resource allocation
[0198] TRP transmission reception point
[0199] TS technical specification
[0200] Tx transmit, or transmitter, or transmission
[0201] UAV unmanned aerial vehicle
[0202] UE user equipment (e.g., a wireless, typically mobile device)
[0203] UI user interface
[0204] UL uplink
[0205] UMTS Universal Mobile Telecommunications System
[0206] UPF user plane function
[0207] USB universal serial bus
[0208] WI work item
[0209] WID work item description
[0210] X2 network interface between RAN nodes and between RAN and the core network
[0211] Xn network interface between NG-RAN nodes

What is claimed is:

1. An apparatus comprising:
at least one processor; and
at least one memory including computer program code, the at least one memory and the computer program code being configured to, with the at least one processor, cause the apparatus at least to:
receive a configuration of orthogonal cover code operation, wherein the configuration comprises plural orthogonal cover codes, each respective orthogonal cover code of the plural orthogonal cover codes having a length defined by a number of entries of the respective orthogonal cover code, and wherein an entry of the respective orthogonal cover code comprises a coefficient to be applied to a data part of a physical uplink shared channel transmission when using the orthogonal cover code;
determine an orthogonal cover code to use for the physical uplink shared channel transmission, based on the configuration; and
perform the physical uplink shared channel transmission using the determined orthogonal cover code.

2. The apparatus of claim **1**, wherein the at least one memory and the computer program code are configured to, with the at least one processor, cause the apparatus to:
determine an index of the configuration that specifies the orthogonal cover code to use for the physical uplink shared channel transmission.

3. The apparatus of claim **1**, wherein the at least one memory and the computer program code are configured to, with the at least one processor, cause the apparatus to:
determine an offset of the configuration, where the offset specifies an entry of the orthogonal cover code to use for the physical uplink shared channel transmission.

4. The apparatus of claim **1**, wherein the at least one memory and the computer program code are configured to, with the at least one processor, cause the apparatus to:
determine a location of the orthogonal cover code that the apparatus is to use within a table;
wherein the configuration of orthogonal cover code operation is provided as the table.

5. The apparatus of claim **1**, wherein the at least one memory and the computer program code are configured to, with the at least one processor, cause the apparatus to:
receive from a network an indication of repetitions of physical uplink shared channel transmissions to perform using the orthogonal cover code based on a link budget of the apparatus;
wherein a number of the repetitions of the physical uplink shared channel transmissions the apparatus is indicated to perform when the apparatus has a first link budget is less than a number of the repetitions of the physical uplink shared channel transmissions the apparatus is indicated to perform when the apparatus has a second link budget, wherein the first link budget is smaller than the second link budget.

6. The apparatus of claim **1**, wherein the at least one memory and the computer program code are configured to, with the at least one processor, cause the apparatus to:
transmit, to a network, an indication of a capability of the apparatus to use an orthogonal cover code.

7. The apparatus of claim **1**, wherein the at least one memory and the computer program code are configured to, with the at least one processor, cause the apparatus to:
receive, from a network, an indication of the orthogonal cover code to use.

8. The apparatus of claim **1**, wherein the at least one memory and the computer program code are configured to, with the at least one processor, cause the apparatus to:
receive, from a network, an indication of the orthogonal cover code to use for a number of repetitions of physical uplink shared channel transmissions; and
use the orthogonal cover code for the number of repetitions of the physical uplink shared channel transmissions;
wherein a length of the orthogonal cover code indicated to be used for the number of physical uplink shared channel transmissions is a power of 2 value closest to and lower than the number of repetitions.

9. An apparatus comprising:
at least one processor; and
at least one memory including computer program code, the at least one memory and the computer program code being configured to, with the at least one processor, cause the apparatus at least to:
transmit, to a user equipment, a configuration of orthogonal cover code operation, wherein the configuration comprises plural orthogonal cover codes, each respective orthogonal cover code of the plural orthogonal cover codes having a length defined by a number of entries of the respective orthogonal cover code, and wherein an entry of the respective orthogonal cover code comprises a coefficient to be applied to a data part of a physical uplink shared channel transmission when using the orthogonal cover code; and

receive, from the user equipment, a physical uplink shared channel transmission using an orthogonal cover code, based on the configuration.

10. The apparatus of claim **9**, wherein the at least one memory and the computer program code are configured to, with the at least one processor, cause the apparatus to:

transmit, to the user equipment, an index of the configuration that specifies the orthogonal cover code to use for the physical uplink shared channel transmission.

11. The apparatus of claim **9**, wherein the at least one memory and the computer program code are configured to, with the at least one processor, cause the apparatus to:

transmit, to the user equipment, an offset of the configuration, where the offset specifies an entry of the orthogonal cover code to use for the physical uplink shared channel transmission.

12. The apparatus of claim **9**, wherein the at least one memory and the computer program code are configured to, with the at least one processor, cause the apparatus to:

transmit, to the user equipment, a location of the orthogonal cover code that the user equipment is to use within a table;

wherein the configuration of orthogonal cover code operations is provided as the table.

13. The apparatus of claim **9**, wherein the at least one memory and the computer program code are configured to, with the at least one processor, cause the apparatus to:

determine a link budget of a first user equipment;

determine a link budget of a second user equipment;

transmit, to the first user equipment, an indication of repetitions of physical uplink shared channel transmissions to perform using a first orthogonal cover code, based on the link budget of the first user equipment; and

transmit, to the second user equipment, an indication of repetitions of physical uplink shared channel transmissions to perform using a second orthogonal cover code, based on the link budget of the second user equipment;

wherein a number of the repetitions of the physical uplink shared channel transmissions to perform transmitted to the first user equipment is less than a number of repetitions of the physical uplink shared channel transmissions to perform transmitted to the second user equipment and the link budget of the first user equipment is smaller than the link budget of the second user equipment.

14. The apparatus of claim **9**, wherein the at least one memory and the computer program code are configured to, with the at least one processor, cause the apparatus to:

receive, from the user equipment, an indication of a capability of the user equipment to use an orthogonal cover code.

15. The apparatus of claim **9**, wherein the at least one memory and the computer program code are configured to, with the at least one processor, cause the apparatus to:

transmit, to the user equipment, an indication of the orthogonal cover code to use.

16. A method comprising:

receiving, by a user equipment from a network node, a configuration of orthogonal cover code operation, wherein the configuration comprises plural orthogonal cover codes, each respective orthogonal cover code of the plural orthogonal cover codes having a length defined by a number of entries of the respective orthogonal cover code, and wherein an entry of the respective orthogonal cover code comprises a coefficient to be applied to a data part of a physical uplink shared channel transmission when using the orthogonal cover code;

determining, by the user equipment, an orthogonal cover code to use for the physical uplink shared channel transmission, based on the configuration; and

performing, by the user equipment, the physical uplink shared channel transmission using the determined orthogonal cover code.

17. The method of claim **16**, further comprising:

determining, by the user equipment, an index of the configuration that specifies the orthogonal cover code to use for the physical uplink shared channel transmission.

18. The method of claim **16**, further comprising:

determining, by the user equipment, an offset of the configuration, where the offset specifies an entry of the orthogonal cover code to use for the physical uplink shared channel transmission.

19. The method of claim **16**, further comprising:

determining, by the user equipment, a location of the orthogonal cover code that the user equipment is to use within a table;

wherein the configuration of orthogonal cover code operation is provided as the table.

20. The method of claim **16**, further comprising:

receiving, by the user equipment from a network node, an indication of repetitions of physical uplink shared channel transmissions to perform using the orthogonal cover code based on a link budget of the user equipment;

wherein a number of the repetitions of the physical uplink shared channel transmissions the user equipment is indicated to perform when the user equipment has a first link budget is less than a number of the repetitions of the physical uplink shared channel transmissions the user equipment is indicated to perform when the user equipment has a second link budget, wherein the first link budget is smaller than the second link budget.

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