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- (54) Title: TRANSMITTING UPLINK CONTROL INFORMATION

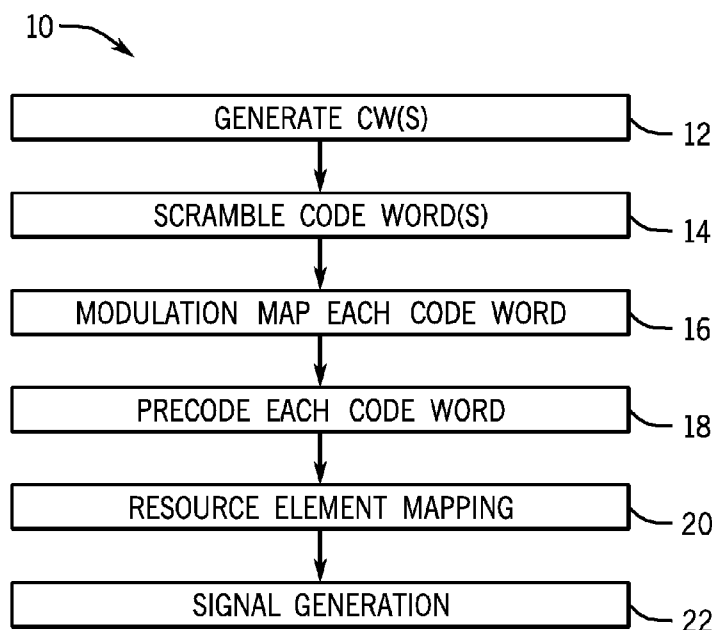


FIG. 1

- (57) Abstract: In accordance with some embodiments, uplink control information, including a channel quality index, may be transmitted using at least two layers. As a result, more information can be provided for use in situations, such as those involving carrier aggregation, where information for a large number of component carriers must all be provided on one primary component carrier.



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TRANSMITTING UPLINK CONTROL INFORMATION

Cross-Reference to Related Applications

[0001] This application claims priority to provisional application Serial No. 61/504,054, filed on July 1, 2011.

Background

[0002] This relates generally to cellular communications and, particularly, to techniques for signaling information about the nature of a channel between two wirelessly connected devices.

[0003] In order to initiate radio communications between two devices, one device needs to tell the other device about the channel conditions between the two devices. Then the transmitting device knows how to send the transmission because the transmitting device has information about the nature of the channel between the two devices.

[0004] One way such information may be exchanged is for a first device, called the base station or eNodeB, to trigger the transmission of channel information from another device, called the user equipment or a mobile station. In such case, the eNodeB sends a pilot (reference) signal to the user equipment and user equipment uses this signal to measure the channel. This channel information is sent to the eNodeB by user equipment through physical uplink shared channel (PUSCH) when the transmission is triggered by the eNodeB. The need for triggering is specific to aperiodic arrangements and is not typically used in periodic arrangements wherein the user equipment periodically advises the eNodeB of the channel conditions.

[0005] As system complexity increases, the amount of information that must be transmitted on the uplink channel in aperiodic triggering situations is increasing.

Brief Description of the Drawings

[0006] Figure 1 is a flow chart for one embodiment of the present invention;

[0007] Figure 2 is a schematic depiction of one embodiment of the present invention;

[0008] Figure 3 is a depiction of layer shifting according to one embodiment;

[0009] Figure 4 is a system depiction for one embodiment; and

[0010] Figures 5A-5E are schematic depictions of different ways for uplink channel information transmission between two radio devices in accordance with some embodiments of the present invention.

Detailed Description

[0011] Uplink control information may include channel quality information (CQI) transmitted from a mobile station to a base station. In the case of some wireless technologies, such as the Long Term Evolution (LTE), the mobile station is generally known as the user equipment (UE) and the base station is generally known as the eNodeB (eNB).

[0012] When the transmission of information from the user equipment to the eNodeB is aperiodic, the transmission of the information may be triggered by a signal sent from the eNodeB to the user equipment. Uplink information is information that is sent from the user equipment to the eNodeB and downlink information is information sent from the eNodeB to the user equipment.

[0013] In some embodiments, once properly triggered, user equipment can send a substantial amount of information over the uplink channel. There are many reasons why the amount of information may become substantial. These will be discussed hereinafter. What will be discussed initially is to enumerate the ways in which more information may be provided on the uplink channel.

[0014] In some embodiments, the uplink channel may be segmented into one or more layers. Each layer may carry the same or different codewords. Thus, in one embodiment, two separate layers may provide one codeword (CW), as shown in Figure 5A. In another embodiment, the two uplink layers can provide two different codewords, codeword (CW) one and codeword (CW) two, as shown in Figure 5B. In

the case of Figure 5B, although two different codewords are used, the same modulation coding scheme (MCS) is used for each layer. The modulation coding scheme indicates the type of modulation, among other things, that may be used in subsequent transmissions. The type of modulation is, to some degree, a function of the channel quality because, for higher order modulation schemes, better channel quality is generally needed. Still another option, shown in Figure 5C, is that two different layers are used for the uplink control information (UCI), with each layer having a different codeword. But, in this case, instead of being stuck with just one MCS, the user equipment can specify one of two MCSs. Still another option, shown in Figure 5D, is to use an uplink layer one (UL1) and an uplink layer two (UL2), each with a different codeword, codeword one (CW1) or codeword two (CW2), each with one MCS, but using layer shifting.

[0015] A problem may arise in that each of the layers may have different transmission conditions and, as a result, data in one layer may be more likely to be compromised than information on the other layers. Thus, a given codeword may be split up and shifted between layers so that a single codeword is broken up and pieces of the codeword may go on one layer and pieces of the same codeword may go on another layer. At the same time, the second codeword may be shifted in the same way. Thus, as shown in Figure 5D, a first codeword, CW1, may be partially sent on one layer and partially sent on another layer, while the second codeword is split between the two layers as well.

[0016] One benefit of layer shifting is that, hopefully, enough information from each codeword gets through, even if it is only the portion that goes on the better quality stream, so that the necessary information is received by the eNodeB.

[0017] Still another option, shown in Figure 5E, is to have two uplink layers, two different codewords, and each layer selecting between one of two available MCSs. One way this may be done is to use the I_MCS signaling for a second transport block to signal two MCSs simultaneously.

[0018] The I_MCS provides indices 0 through 31, which are mapped to different modulation coding and signaling schemes. In some cases, a particular index, such

as $I_MCS=29$ may be used for signaling in connection with uplink control information. Thus, by using two transport blocks, more information may be provided, including the provision of different MCSs for each stream. This allows for a combination of streams experiencing different transmission conditions.

[0019] Thus, referring to Figure 1, in some embodiments, a sequence 10 may be implemented in software, firmware, and/or hardware. In software and firmware embodiments, the sequence may be implemented by computer executed instructions stored in a non-transitory computer readable medium, such as an optical, magnetic, or semiconductor memory. The sequence is generally implemented on the user equipment side of the transaction.

[0020] The sequence begins by generating the codewords at block 12. Then the codewords are scrambled, as indicated in block 14. Next, each codeword is modulation mapped, as indicated in block 16. Each codeword is pre-coded at block 18. Then resource element mapping is done in block 20, followed by signal generation in block 22.

[0021] Generally, multiple-input/multiple-output (MIMO) transmission and receiving schemes are used. MIMO is a wireless technology that uses multiple transmitters and receivers to transfer more data at the same time. It takes advantage of a radio wave phenomenon called multipath, wherein transmitted information bounces off of walls, ceilings, and other objects, reaching the receiving antenna multiple times via different angles and at slightly different times. MIMO technology leverages multipath behavior by using multiple smart transmitters and receivers with an added spatial dimension to increase performance and range. Multiple antennas send and receive multiple spatial streams at the same time, allowing antennas to transmit and receive simultaneously. MIMO enables antennas to combine data streams arriving from different paths and at different times to effectively increase receiver signal-capturing power.

[0022] Aperiodic CQI-only transmission on PUSCH is generally signaled by the eNodeB using downlink control information (DCI) format 0 or 4 via a combination of $I_MCS = 29$, which is a reserved modulation coding scheme, and a small number of

allocated physical resource blocks (PRBs) for transmitting quality information. Generally, the number of physical resource blocks must be less than or equal to 4 for this purpose. The quality information may be the so-called channel quality index (CQI), which is a number indicating the quality of channel to the transmitter provided by a receiver. In general, the channel quality index is supplemented by a so-called pre-coding matrix indicator (PMI) to form what is called the channel state information (CSI). Of course, other ways of providing the channel quality information may also be contemplated.

[0023] More than one component carrier may be assigned in schemes that use carrier aggregation. Since service providers do not always have available a wide band for transmission, they sometimes aggregate narrower bands together to provide a given quality of wireless service. Each port may be one component carrier and, by combining the plurality of component carriers, carrier aggregation of two to five carriers may be accomplished to form a wider transmission band. However, generally, all the quality information is provided on only one of those component carriers, called the primary component carrier. This means that a large amount of quality feedback information must be provided on one component carrier due to the larger number of carriers and the larger maximum number of primary resource blocks supported by carrier aggregation. Specifically, up to 20 primary resource blocks may be used and all the quality information for all those resource blocks is provided on the primary component carrier.

[0024] Due to the limited number of primary resource blocks used for quality transmissions, it is desirable to increase the capacity for the CSI transmission, typically using physical uplink shared channel (PUSCH). (It should be noted that there is no particular reason why, in other embodiments, physical uplink control channel (PUCCH) could not be used, or some other comparable uplink physical channel.)

[0025] Thus, generally, when download control information is in format 0 or format 4, it causes the triggering of the transmission of the uplink control information described herein.

[0026] Currently, for a download control information format 0, the CQI-only transmission on PUSCH is triggered in one of two cases. In the first case, if the channel quality index request field is one bit and the channel quality index request field is one with the $I_MCS = 29$ and the number of primary resource blocks being less than or equal to four, then the triggering will occur.

[0027] In the other situation for downlink control information format 0, if, instead, the channel quality index request field is two bits, then the transmission will be triggered in the following circumstances. If the channel quality index request field is 01, 10, or 11, and if a single downlink component carrier is reported with $I_MCS = 29$ and the number of primary resource blocks is less than or equal to four, then the transmission will be triggered. However, if there are multiple downlink component carriers reported, then it is permissible if $I_MCS = 29$ and the number of primary resource blocks is less than or equal to 20.

[0028] On the other hand, for the download control information format 4, the CQI-only transmission on PUSCH is triggered under the following circumstances. First the downlink control information format must indicate that only one transport block is enabled. Then, if the channel quality index request field is one bit, then the channel quality index request field must be one and for the enabled transport block, I_MCS must equal 29 and the number of programmable resource blocks must be equal to or less than four. However, if the channel quality index request field is two bits, then the channel quality request field must be 01, 10, or 11. Then, if a single downlink component carrier is reported for the enabled transport block I_MCS must be 29 and the number of programmable resource blocks must be less than or equal to four. However, if multiple downlink component carriers are reported, then, for the enabled transport block, I_MCS must be 29 and the number of programmable resource blocks must be less than or equal to 20.

[0029] In the situation shown in Figure 5A where one codeword is mapped to two layers, the initial data transmission contains two codewords. This mapping is already available for data transmission and is used when the initial data transmission

contains two codewords and data retransmission of a codeword mapped to two layers.

[0030] In some embodiments, the modulation scheme for the uplink control information may be limited to QPSK. However, other modulations, such as 16QAM, may also be used in some embodiments.

[0031] In the embodiments shown in Figures 5B and 5C, the channel state information bits are first segmented and then encoded into two codewords. Each codeword is then independently mapped to one layer. In one option for supporting different common modulation schemes for the two codewords, the two codewords use the same MCS, such as QPSK. Thus, in some embodiments, QPSK or some other modulation scheme may be used for both layers. In such case, link adaption is not supported. In link adaptation, the modulation scheme can be changed on the fly based on then current channel conditions. In some embodiments, other modulations may be used in addition to QPSK, such as 16QAM.

[0032] As another example of using two codewords and two layers with one MCS, two codewords supporting link adaption may be used, as indicated in Figure 5C. This involves changing the MCS, for example, changing between QPSK and 16QAM as one example, without explicit signaling. The modulation scheme can be derived based on the two MCSs used in rank 2 uplink data transmission on PUSCH, which is known to both the user equipment and the eNodeB and by applying the same rule predefined for both the user equipment and the eNodeB. This rule can be to choose the lowest order of modulation of the two MCSs, as a conservative example, or, for example, by some kind of averaging where one modulation scheme is chosen when the two MCSs are two particular modulation schemes.

[0033] Transmitting the channel state information on PUSCH with rank higher than one may only be helpful when the uplink channel condition is good enough to support ranks higher than one for both data and the channel state information itself.

[0034] Of course, the examples of Figures 5B and 5C may sometimes be sub-optimal, such as, for example, when the modulation scheme is conservatively

selected to be QPSK. Consequently, although transmission is more robust, good channel conditions cannot be exploited if capacity cannot be increased. In the embodiment of Figure 5C, the modulation scheme can be of higher order than QPSK, but as the two codewords experience different channels, they will have different error probabilities and the performance of the system may depend on the performance of the codeword that experiences the worst channel.

[0035] For example, consider the case where the channel conditions for the first codeword are not good enough and can only support transmission with QPSK, while the second codeword sees good channel conditions which support 64QAM transmission. In the embodiment of Figure 5B, both codewords use QPSK, which is pessimistic for transmitting the second codeword. Similarly, in the option in Figure 5C, 16QAM may be used as the average of QPSK and 64QAM for codewords and, consequently, error probability for this codeword may be high.

[0036] Thus, in the embodiment of Figure 5D, two codewords and two layers are used with layer shifting. Layer shifting is shown in Figure 3 where the first layer (layer 1) and the second layer (layer 2) are provided to the layer shifter 29 that produces two output layers by mixing up the four depicted modulation symbols of each codeword. Specifically, the first and third symbols from layer 2 are interleaved with the second and fourth symbols of layer 1, and so on, in this example. Other shifting techniques may also be used.

[0037] Thus, as shown in Figure 2, the first codeword, CW1, and the second codeword, CW2, are subjected to parallel scrambling at scrambling stages 24. The scrambling randomly changes the bit order. Then the two codewords are subjected to parallel modulation mapping in modulation mappers 26. The modulation mappers 26 map bits to modulation symbols, such as those associated with 16QAM. Next, layer mapping at 28 is done to both codewords simultaneously. Then the output from the layer mapping is provided to the layer shifter 30 that changes the bit sequences already described. Thereafter, the two shifted layers are provided to separate parallel transform pre-coders 32. Next, pre-coding is done at 34 and then each layer is separately resource element mapped at resource element mappers 36.

The resource element mappers 36 determine how primary resource blocks are allocated to each user. Finally, signal generation occurs at 38, pursuant to SC-FDMA. Then each signal is transmitted to the appropriate antenna port in an MMIO system.

[0038] One benefit of layer shifting is to provide additional diversity between the two codewords. The benefit is clear when you consider the previous example. When the layer shifter is applied, some symbols of both codewords will experience the better channel and this will help the system to increase the probability of correct decoding. Therefore, this scheme may have better performance, in some embodiments.

[0039] Finally, as indicated in Figure 5E, two codewords with two layers and two MCSs may be used. Different modulation schemes may be used for different codewords. For example, by using I_MCS for a second transport block to signal two MCSs simultaneously, different modulations can be considered and signaled. Thus, in some embodiments, good channel conditions may be more fully exploited.

[0040] The computer system 130, shown in Figure 4, may include a hard drive 134 and a removable medium 136, coupled by a bus 104 to a chipset core logic 110. The computer system may be any computer system, including a smart mobile device, such as a smart phone, tablet, or a mobile Internet device. A keyboard and mouse 120, or other conventional components, may be coupled to the chipset core logic via bus 108. The core logic may couple to the graphics processor 112, via a bus 105, and the applications processor 100 in one embodiment. The graphics processor 112 may also be coupled by a bus 106 to a frame buffer 114. The frame buffer 114 may be coupled by a bus 107 to a display screen 118, such as a liquid crystal display (LCD) touch screen. In one embodiment, a graphics processor 112 may be a multi-threaded, multi-core parallel processor using single instruction multiple data (SIMD) architecture.

[0041] The chipset logic 110 may include a non-volatile memory port to couple the main memory 132. Also coupled to the logic 110 may be multiple antennas 121,

122 to implement multiple input multiple output (MIMO) in one embodiment. Speakers 124 may also be coupled through logic 110.

[0042] References throughout this specification to “one embodiment” or “an embodiment” mean that a particular feature, structure, or characteristic described in connection with the embodiment is included in at least one implementation encompassed within the present invention. Thus, appearances of the phrase “one embodiment” or “in an embodiment” are not necessarily referring to the same embodiment. Furthermore, the particular features, structures, or characteristics may be instituted in other suitable forms other than the particular embodiment illustrated and all such forms may be encompassed within the claims of the present application.

[0043] While the present invention has been described with respect to a limited number of embodiments, those skilled in the art will appreciate numerous modifications and variations therefrom. It is intended that the appended claims cover all such modifications and variations as fall within the true spirit and scope of this present invention.

What is claimed is:

- 1 1. A method comprising:
2 aperiodically providing channel quality information; and
3 using a physical uplink shared channel having at least two layers to
4 provide said information.
- 1 2. The method of claim 1 including providing channel quality information
2 using two layers with two modulation-coding-schemes.
- 1 3. The method of claim 1 including using at least two codewords.
- 1 4. The method of claim 3 including using link adaptation.
- 1 5. The method of claim 3 including using layer shifting.
- 1 6. The method of claim 3 including using at least two layers with two
2 modulation-coding-schemes.
- 1 7. The method of claim 1 including sending the same codeword over two
2 different layers.
- 1 8. A non-transitory computer readable medium storing instructions to
2 enable a processor to:
3 aperiodically provide channel quality information; and
4 send said information over a physical uplink shared channel having at
5 least two layers.
- 1 9. The medium of claim 8 further storing instructions to provide channel
2 quality information using two layers with two modulation-coding-schemes.
- 1 10. The medium of claim 8 further storing instructions to use at least two
2 codewords.

- 1 11. The medium of claim 10 further storing instructions to use link
2 adaptation.
- 1 12. The medium of claim 10 further storing instructions to use layer
2 shifting.
- 1 13. The medium of claim 10 further storing instructions to use at least two
2 layers with two modulation-coding-schemes.
- 1 14. The medium of claim 8 further storing instructions to send the same
2 codeword over two different layers.
- 1 15. A mobile station comprising:
2 a processor to aperiodically provide channel quality information; and
3 a wireless transceiver to send the information over a physical uplink
4 shared channel having at least two layers.
- 1 16. The station of claim 15 said processor to provide channel quality
2 information using two layers with two modulation coding schemes.
- 1 17. The station of claim 15 said processor to use at least two codewords.
- 1 18. The station of claim 17 said processor to use link adaptation.
- 1 19. The station of claim 17 said processor to use layer shifting.
- 1 20. The station of claim 17 said processor to use at least two layers with
2 two modulation coding schemes.
- 1 21. The station of claim 15 said processor to send the same codeword
2 over two different layers.

- 1 22. The station of claim 15 wherein said station is a user equipment.

1 / 4

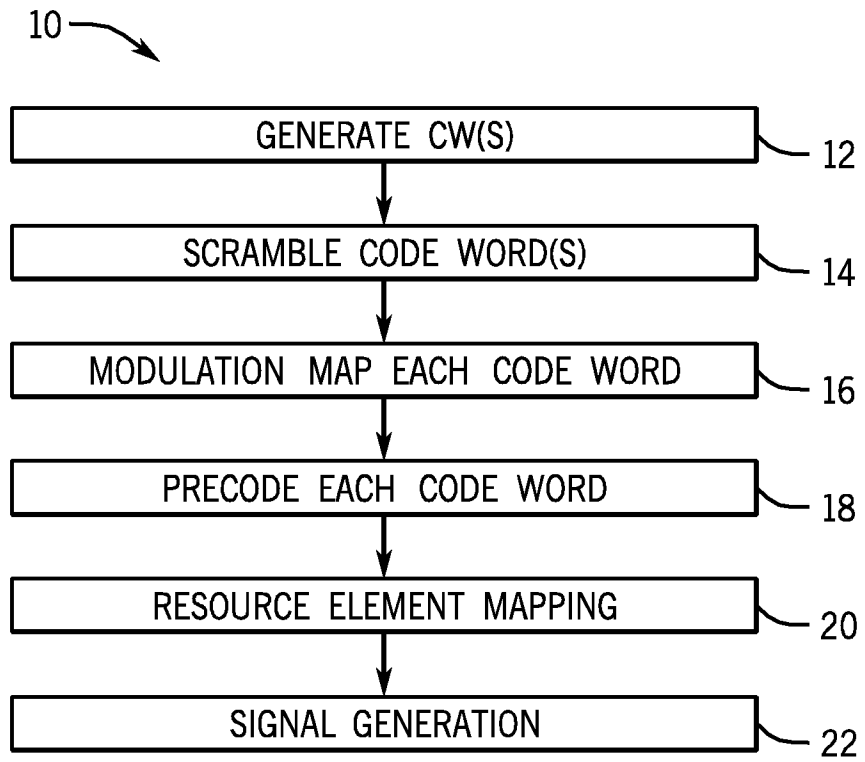


FIG. 1

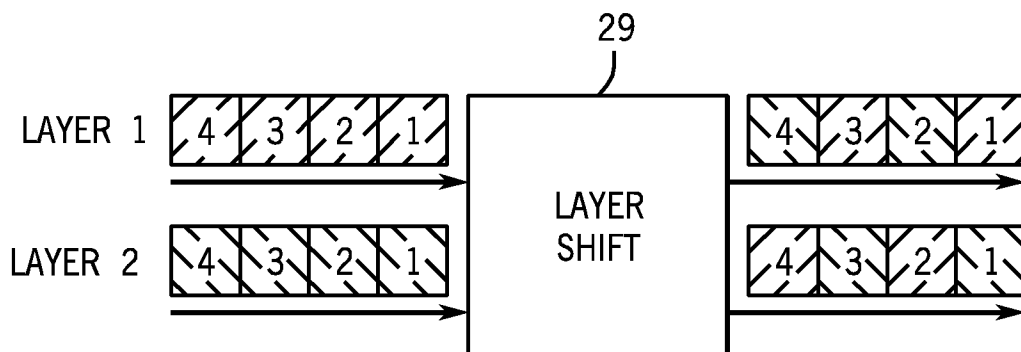


FIG. 3

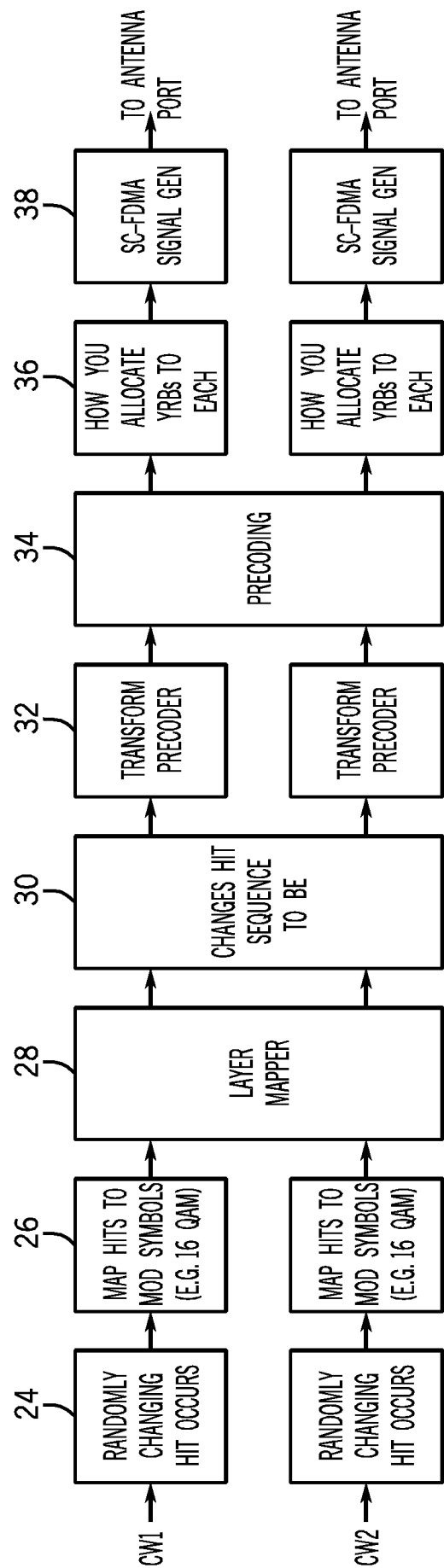


FIG. 2

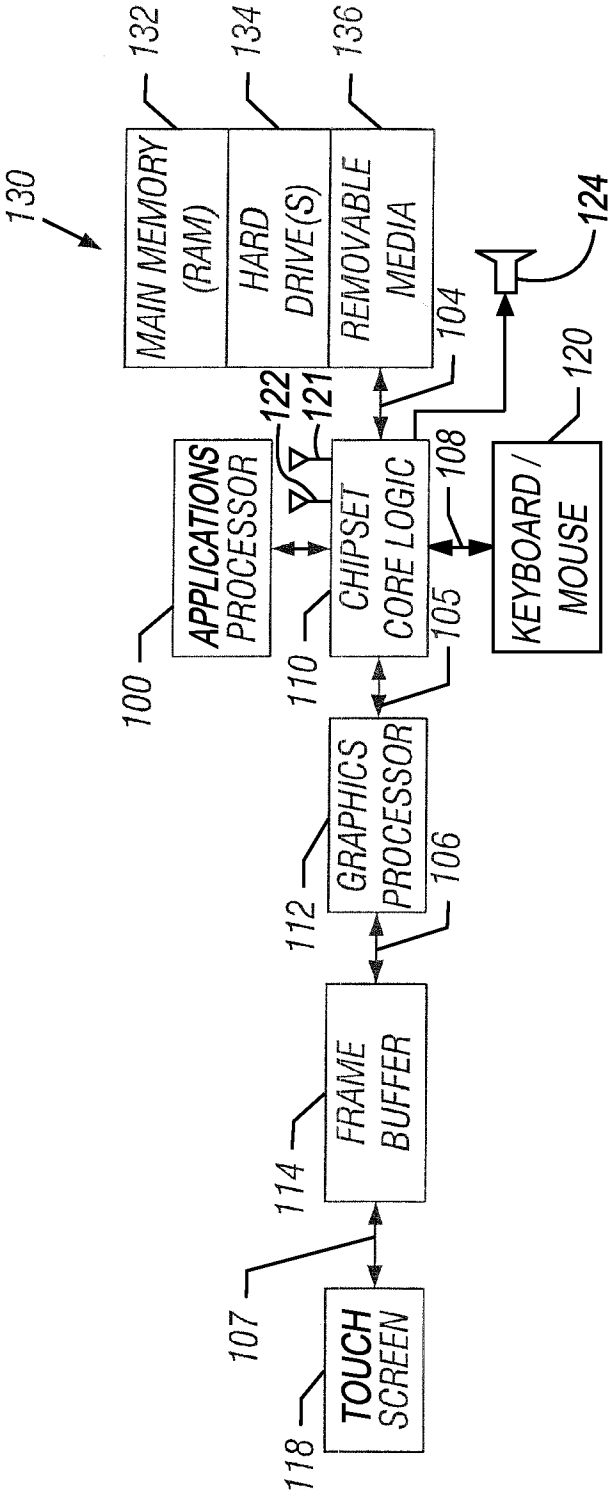
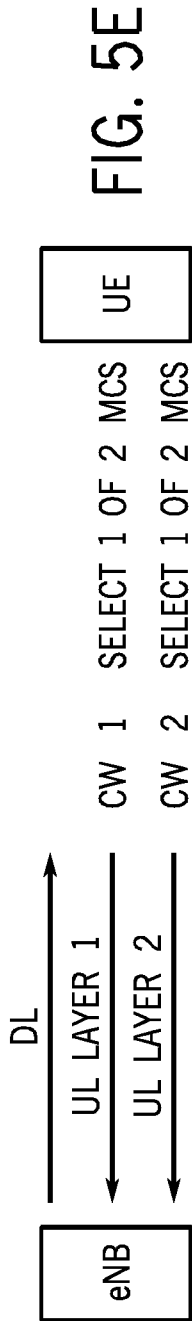
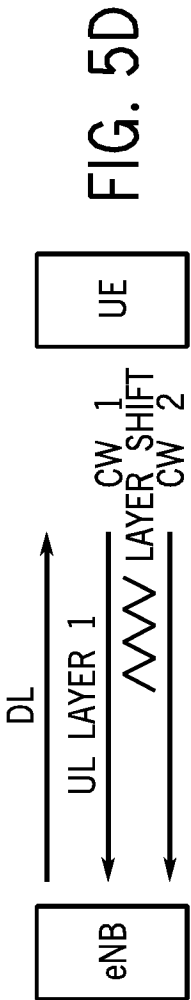
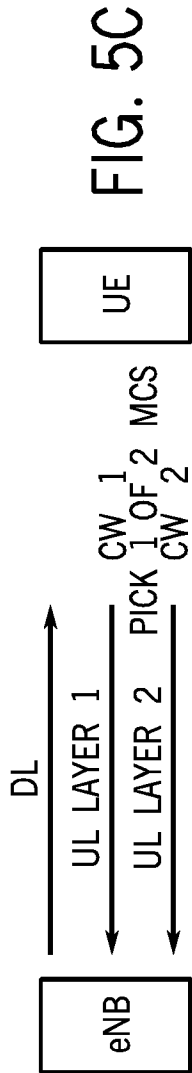
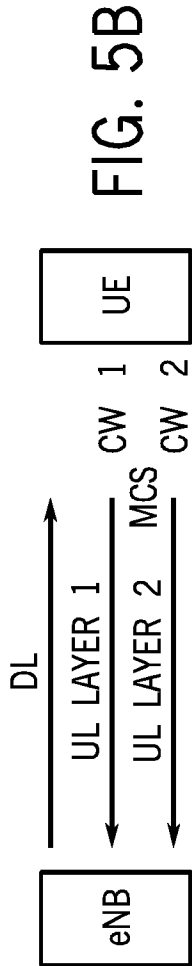
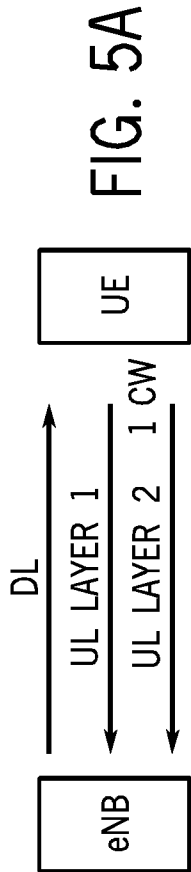


FIG. 4



A. CLASSIFICATION OF SUBJECT MATTER**H04J 11/00(2006.01)i, H04B 7/26(2006.01)i**

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

H04J 11/00; H04W 4/00

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

Korean utility models and applications for utility models

Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

eKOMPASS(KIPO internal) & Keywords: PUSCH, CQI, layer, aperiodic

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X A	US 2010-0329203 A1 (LEE, DAE WON et al.) 30 December 2010 See abstract; paragraphs [61], [100], [142], [148]; claim 1.	1-3,5-10,12-17 ,19-22 4,11,18
X A	HUAWEI, 'Remaining issues of Multiplexing Schemes of control and data in multi-layer PUSCH transmission.' 3GPP TSG RAN WG1 Meeting #61bis, R1-103451, 28 June - 2 July 2010. (Retrieved from the Internet on 20 August 2012: < URL: http://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_61b/Docs >)	1-3,5-10,12-17 ,19-22
A	See sections 3, 4.	4,11,18
X A	TEXAS INSTRUMENTS, 'Data and Control Multiplexing for UL Multi-Antenna Transmission.' 3GPP TSG RAN WG1 60bis, R1-102108, 12-16 April 2010. (Retrieved from the Internet on 20 August 2012: < URL: http://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_60b/Docs >)	1-3,5-10,12-17 ,19-22
A	See section 2.	4,11,18



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents:

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Date of the actual completion of the international search

20 AUGUST 2012 (20.08.2012)

Date of mailing of the international search report

22 AUGUST 2012 (22.08.2012)

Name and mailing address of the ISA/KR

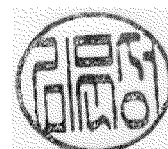
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INTERNATIONAL SEARCH REPORT

International application No.

PCT/US2011/068001

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	3GPP, `3rd Generation Partnership Project; Technical Specification Group Radio Access Network; Evolved Universal Terrestrial Radio Access (E-UTRA); Physical Channels and Modulation (Release 9).` 3GPP TS 36.211 V9.1.0, March 2010. (Retrieved from the Internet on 20 August 2012: < URL: http://www.3gpp.org/ftp/Specs/archive/36_series/36.211 >) See sections 5.3, 5.5, 6.3-6.10.	1-22

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2011/068001Patent document
cited in search reportPublication
datePatent family
member(s)Publication
date

US 2010-0329203 A1

30.12.2010

None