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(54) Title: APPARATUS FOR ENABLING UE-SPECIFIC PDCCH AND UE DEVICE FOR IDENTIFYING SUCH PDCCH

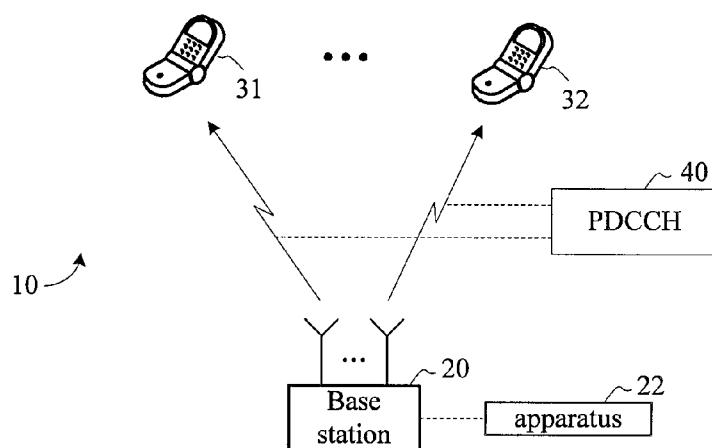


Fig.1

(57) Abstract: The present invention relates to apparatus for enabling UE-specific PDCCH and UE device for identifying such PDCCH. According to one embodiment, an apparatus, which is used in or embedded in a base station, comprises a processor and a memory device associated with the processor, wherein the processor is configured to send DM RSs along with control information by a first CCE of a PDCCH containing a plurality of CCEs. The UE specific PDCCH designs of the present invention have improved coverage and multiplexing capability, as well as good backwards compatibility with the legacy protocols, such as LTE Release 8-10.

APPARATUS FOR ENABLING UE-SPECIFIC PDCCH AND
UE DEVICE FOR IDENTIFYING SUCH PDCCH

FIELD OF THE INVENTION

5 The present invention generally relates to telecommunications and, more particularly, to wireless communication systems.

BACKGROUND OF THE INVENTION

10 In LTE (Long Term Evolution) and/or LTE-A protocols, PDCCH (Physical Downlink Control Channel) has been designed as a cell-specific DL (downlink) control channel to reach all UEs (User equipment) in the coverage area within a cell. PDCCH suffers strong inter-cell interference at the cell edge. The PDCCH coverage and multiplexing capability are in strong demand for enhancement.

15 R-PDCCH has been designed for the Relay backhaul. R-PDCCH has FDM (Frequency Division Multiplexing) design to allow the control channel resource be partitioned in the unit of RB (Resource Block) separated from the data channel. The first slot of R-PDCCH was designed for DL grant and the second slot of the R-PDCCH for UL (uplink) grant. The fixed partition between DL and UL grant is to minimize the decoding delay of the DL grant, which would trigger DL PDSCH (Physical Downlink Sharing Channel) transmission in the specific subframe.

20 The R-PDCCH design simplifies the design of access grant but limits the flexibility and multiplexing capacity.

SUMMARY OF THE INVENTION

25 An object of the present invention is to improve the multiplexing capacity and the coverage performance of a base station, such as a Node B, an eNB (evolved Node B) or the like, with UE-specific PDCCH (U-PDCCH for short) design. Hereinafter, a UE-specific PDCCH is also referred to as user specific PDCCH. The U-PDCCH design targets to group UEs with similar radio channel conditions, e.g. same expected precoding vector or same DL PMI (precoding Matrix Indicator), to share the CCE (control channel

30 element) through multi-layer BF (beamforming). The eNB would group the UEs based on

their CSI (Channel State Information) feedbacks. The UE could decode the U-PDCCH based on the CSI values most recently feedback. The multi-layer BF U-PDCCH design would be similar to MU-MIMO PDSCH design. The BF feature in the U-PDCCH would improve the coverage of the base station and reduce the inter-cell interference from the neighboring cells. The multi-layer spatial multiplexing capability of U-PDCCH design would allow spatial multiplexing of multiple downlink control channel information in the same CCE resource. In order to support multi-layer BF, a UE-specific reference signals need to be sent along with DL control information.

According to an embodiment of the present invention, an apparatus, which is used in a base station, comprises a processor and a memory device associated with the processor, wherein the processor is configured to send DM RSs (demodulation reference signals) along with control information by a specified CCE (e.g. first CCE) of a PDCCH containing a plurality of CCEs. As is known, a base station may be a Node B, an eNB or the like.

According to a design of the present invention, there are three optional formats of a PDCCH for the purpose of more multiplexing capacity, the PDCCH containing two CCEs or four CCEs or eight CCEs, respectively, with at least one of the multiple CCEs, for example the first CCE, being used to carry DM RSs and control information.

According to an additional embodiment of the present invention, the DM RSs of the PDCCH are allocated in at least one REG (Resource Element Group) of said first CCE, while said control information is allocated in at least a first REG of said first CCE. Each DM RS corresponds to a signal beam to a UE. By using OCCs (orthogonal cover code), the same REG(s) could be shared by multiple DM RSs for different UEs. In a more specific manner, most (e.g., eight out of nine) REGs could be allocated to DM RSs, while the other REGs could be allocated to control information. With such configuration, the PDCCH is of good multiplexing capacity.

According to another embodiment of the present invention, a UE (user equipment) device comprises a processor and a memory associated therewith, wherein the processor configured to, in a CONNECTED mode,

- receive and identify an indicator indicating a DL transmission mode supporting multi-layer beamforming along with a user specific PDCCH for DL grant;

- access DL control information using a PDCCH; and
- determine layer mapping information of multi-layer beamforming and MCS level information according to a last reported RI and CQI, if no dynamic control element is detected.

5 According to still another embodiment of the present invention, a UE device comprises a processor and a memory associated therewith, wherein the processor is configured to, in a CONNECTED mode,

- receive and identify an indicator indicating a DL transmission mode supporting multi-layer beamforming along with a user specific PDCCH for DL grant;

10 - access DL control information using a PDCCH; and

- determine layer mapping information of multi-layer beamforming and MCS level information based on dynamic control information in said user specific PDCCH.

BRIEF DESCRIPTION OF THE DRAWINGS

15 The present invention will be better understood from reading the following description of non-limiting embodiments, with reference to the attached drawings, wherein below:

Fig.1 is a schematic diagram of a portion of a MIMO communication system according to an embodiment of the present invention;

20 Fig.2 illustrates three formats of a PDCCH according a design of the present invention;

Fig.3 illustrates the assignment structure of a first CCE of a PDCCH according a design of the present invention;

25 Fig.4 illustrates the framework of a normal subframe according to an embodiment of the present invention;

Fig.5 illustrates the framework of a MBSFN subframe according to an embodiment of the present invention;

Fig.6 illustrates a flowchart of the general procedure of user specific PDCCH assignment at UE side in a CONNECTED mode;

30 Fig.7 illustrates another flowchart of the general procedure of user specific PDCCH

assignment at UE side in a CONNECTED mode.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

With reference to Fig.1, an embodiment of the present invention relates to a MIMO
5 (Multiple Input Multiple Output) system 10 for enabling a UE-specific PDCCH 40 from a
base station 20 the UEs 31 and 32. The system 10 is, for example but not limited to, a
LTE system or a LTE-A system. As is known, the base station 20 may be a Node B, an eNB or
the like. An apparatus 22 used in or embedded in the base station 20 comprises a processor and a
memory device associated with the processor, wherein the processor is configured to send DM
10 RSs along with control information by a first CCE of the PDCCH 40 containing a plurality of
CCEs.

With reference to Fig.2, according a design of the present invention, there are three
optional formats of the PDCCH 40. As defined in the format 1, a UE-specific PDCCH
contains two CCEs; as defined in the format 2, a UE-specific PDCCH contains four CCEs;
15 as defined in the format 3, a UE-specific PDCCH contains eight CCEs. The blank blocks
and the shadow blocks in Fig.2 are only intended to indicate the successive CCEs. In an
exemplary assignment of the present invention, only one of the multiple CCEs of a
UE-specific PDCCH, preferably the first or the last CCE, is used to carry DM RSs and control
information.

20 In an additional embodiment of the present invention, the DM RSs of the PDCCH 40 are
allocated in at least one REG of said first CCE, while said control information is allocated in at
least a first REG of said first CCE. In a more specific manner as illustrated in Fig.3, eight out of
nine REGs of said first CCE could be allocated to DM RSs, while the other REG could be
allocated to control information.

25 Each DM RS corresponds to a signal beam to a UE. By using OCCs (orthogonal cover
code), the same REG(s) could be shared by multiple DM RSs. For example, some DM
RSs are four REs in length for supporting four transmitted antennas, and at most four of
such DM RSs could share a same REG along with respective OCCs of four elements in
length. For another example, some DM RSs are eight REs in length for supporting eight
30 transmitted antennas, and at most eight of such DM RSs could share a same pair of REGs along

with respective OCCs of eight elements in length. With such configuration, the PDCCH 40 is of good multiplexing capacity.

Since a UE may be equipped with multiple receiving antennas, there may be multiple DM RSs and respective OCCs allocated to a same UE. The number of DM RSs and
5 respective OCCs allocated to a UE are determined by a rank of the channel matrix observed by the UE. As will be understood, the multiple DM RSs sharing the same REG or the same pair of REGs may be allocated to a same UE or different UEs.

The assignment of the OCC for each UE could be configured semi-statically through RRC signaling or dynamically through DL control region in a CCE of the PDCCH 40. In
10 an exemplary embodiment of the present invention, the processor of the apparatus 22 is further configured to send OCC assignment information associated with the DM RSs contained in the PDCCH 40 by RRC signaling. In another exemplary embodiment, the processor of the apparatus 22 is further configured to send dynamic OCC assignment information associated with the DM RSs contained in the PDCCH 40 by at least said first REG
15 of said first CCE.

Since the control information contained in the PDCCH 40 may include the dynamic OCC assignment information associated with the DM RSs, UE(s) should decode the control information before decoding the DM RSs. For this purpose, the PDCCH 40 may be precoded except for at least said first REG of said first CCE, in other words, the control information
20 contained in the PDCCH 40 is not precoded.

The dynamic control information may relate to user allocation, MCS (modulation and coding scheme) or rank allocation. In an exemplary embodiment of the present invention, the processor of the apparatus 22 is further configured to send dynamic control information by RRC signaling, wherein said dynamic control information comprises at least one of dynamic user
25 allocation information for multi-user multiplexing in said PDCCH, dynamic MCS allocation information for said PDCCH and dynamic rank allocation information for precoding matrix. The configuration of the dynamic MCS allocation information would allow the base station 20 to advantageously assign the MCS for the UEs with good channel condition.

The PDCCH 40 (U-PDCCH) is precoded at the transmitter of the base station 20.
30 U-PDCCHs for multiple users are spatially multiplexed in the same CCE resources by

base station precoding, as shown in Fig.1. The precoded U-PDCCH is demodulated by using UE-specific RS. Thus a UE needs to support UE-specific RS for U-PDCCH, unlike Rel-8/9/10 UEs which uses CRS (Cell-specific Reference Signal) for PDCCH demodulation. Apart from using UE-specific RS for U-PDCCH, the remaining PDCCH procedure may remain the same as Rel-8/9/10.

Since the user specific PDCCH design uses exact the DL control channel resource allocation numerology and blind detection, the user specific PDCCH could be embedded in the PDCCH region in the normal subframes. Thus, the apparatus 22 of the base station 20 is advantageously capable of allocating user specific PDCCH and legacy PDCCHs, such as those defined in Release 8/9/10, in a mix fashion.

In an additional embodiment of the present invention, the processor of the apparatus 22 is further configured to perform CCE allocation of user specific PDCCH along with legacy PDCCH in a same PDCCH region of a normal subframe. Fig.4 illustrates the framework of such a normal subframe, wherein the diagonal blocks indicate the CCE resources allocated to legacy PCFICH (Physical Control Format Indicator Channel), PHICH (Physical HARQ Indicator Channel) and PDCCH, while the lateral-cut blocks indicate the CCE resources allocated to user specific PDCCH. The UE specific PDCCH CCEs and other legacy control channel CCEs could go together through sub-block interleaver and have the results of interleaved user specific PDCCH. The CCE allocation of the user specific PDCCH is transparent to legacy UEs, such as Release 8/9/10 UEs. The legacy UEs could perform the normal blind decoding and consider the user specific PDCCH as one of the CRC error cases.

In still another embodiment of the present invention, the processor of the apparatus 22 is further configured to allocate the user specific PDCCH in MBSFN (Multicast Broadcast Single Frequency Network) subframes in a non-interleaved fashion. Fig.5 illustrates the framework of such a MBSFN subframe, wherein the diagonal blocks indicate the CCE resources allocated to legacy PCFICH, PHICH and PDCCH, while the lateral-cut blocks indicate the CCE resources allocated to user specific PDCCH. As shown in Fig.5, the base station 20 could allocate a first symbol for legacy PCFICH, PHICH and PDCCH, while allocate multiple symbols for user specific PDCCH without interleaving. The non-interleaved U-PDCCH could be configured by RRC to inform each UE the number of symbols assigned for non-interleaved U-PDCCH and the

starting symbols of PDSCH transmission. The non-interleaved U-PDCCH design would allow the UE to perform subband optimization in the MCS selection. More specifically, the non-interleaved PDCCH would optimize the MCS assignment information in the frequency selective radio channel.

5 Fig.6 illustrates a flowchart of the general procedure of user specific PDCCH assignment at UE side in a CONNECTED mode. More details will be described below in combination with the UE 31, for example.

As shown in Fig.6, the procedure includes three steps 100, 102 and 104.

10 In the step 100, the UE 31 will receive and identify an indicator from higher signaling indicating a DL transmission mode supporting multi-layer beamforming along with a user specific PDCCH for DL grant.

In the step 102, the UE 31 will access DL control information using a PDCCH.

15 In the step 104, the UE 31 will determine layer mapping information of multi-layer beamforming and MCS level information according to a last reported RI and CQI, if no dynamic control element is detected.

In an additional embodiment of the present invention, the UE device 31 comprises a processor and a memory associated therewith, wherein the processor is configured to perform the above-mentioned steps 100, 102 and 104, in a CONNECTED mode.

20 Fig.7 illustrates another flowchart of the general procedure of user specific PDCCH assignment at UE side in a CONNECTED mode. More details will be described below in combination with the UE 32, for example.

As shown in Fig.7, the procedure includes three steps 110, 112 and 114.

25 In the step 110, the UE 32 will receive and identify an indicator from higher layer signaling indicating a DL transmission mode supporting multi-layer beamforming along with a user specific PDCCH for DL grant.

In the step 112, the UE 32 will access DL control information using a PDCCH.

In the step 114, the UE 32 will determine layer mapping information of multi-layer beamforming and MCS level information based on dynamic control information in said user specific PDCCH.

30 In still another embodiment of the present invention, the UE device 32 comprises a

processor and a memory associated therewith, wherein the processor is configured to perform the above-mentioned steps 110, 112 and 114, in a CONNECTED mode.

In one embodiment, the processor of the UE device 31 or 32 is further configured to perform user specific PDCCH blind decoding with C-RNTI (Cell-Radio Network
5 Temporary Identifier) or SPS-C-RNTI (Semi-Persistent Scheduling C-RNTI).

In another embodiment, the processor of the UE device 31 or 32 is further configured to transmit on said user specific PDCCH according to C-RNTI or SPS-C-RNTI.

Throughout the above embodiments, the user specific PDCCH (U-PDCCH) designs have the following features:

- 10 • The allocation of U-PDCCH is transparent to legacy (Release 8-10) UEs when they access the legacy control channels and shared channels.
- The U-PDCCH supports all legacy DCI (Downlink Control Information) formats and additional DCI formats in the future.
- The U-PDCCH reuses as much legacy PDCCH physical layer structure and design,
15 such as CCE and aggregation level, as possible.
- The U-PDCCH is designed to be available for an evolved UE at every subframe and is transparent to legacy UEs.

Thus the above embodiments have good backwards compatibility with the legacy protocols, such as LTE Release 8-10.

20 Other variations to the disclosed embodiments can be understood and effected by those skilled in the art in practicing the claimed invention, from a study of the drawings, the disclosure, and the appended claims. In the claims, the word "comprising" does not exclude other elements or steps, and the indefinite article "a" or "an" does not exclude a plurality. A single unit may fulfill the functions of several items recited in the claims,
25 while multiple functions of a single item recited in the claims could be fulfilled by several units. The mere fact that certain measures are recited in mutually different dependent claims does not indicate that a combination of these measures cannot be used to advantage. Any reference signs in the claims should not be construed as limiting the scope.

Claims

1. An apparatus comprising:
 - a processor; and
 - 5 a memory device associated with the processor;wherein the processor is configured to send DM RSs along with control information by a first CCE of a PDCCH containing a plurality of CCEs.
2. The apparatus of claim 1, wherein said DM RSs are allocated in at least one REG of said
10 first CCE, while said control information is allocated in at least a first REG of said first CCE, each DM RS corresponding to a signal beam.
3. The apparatus of claim 2, wherein at least part of said DM RSs are at least four REs in length and are allocated in a same REG along with respective OCCs.
15
4. The apparatus of claim 2, wherein at least part of said DM RSs are eight REs in length for supporting eight transmitted antenna and are allocated in pairs of REGs along with respective OCCs.
- 20 5. The apparatus of claim 3 or 4, wherein the processor is further configured to:
send OCC assignment information associated with said DM RSs by RRC signaling.
6. The apparatus of claim 3 or 4, wherein the processor is further configured to:
send dynamic OCC assignment information associated with said DM RSs by at least said
25 first REG of said first CCE.
7. The apparatus of claim 2, wherein said PDCCH is precoded except for at least said first REG of said first CCE.
- 30 8. The apparatus of claim 1, wherein the processor is further configured to:

send dynamic control information by RRC signaling, wherein said dynamic control information comprises at least one of dynamic user allocation information for multi-user multiplexing in said PDCCH, dynamic MCS allocation information for said PDCCH and dynamic rank allocation information for precoding matrix.

5

9. The apparatus of claim 1, wherein said PDCCH contains two CCEs, or four CCEs, or eight CCEs.

10. The apparatus of claim 9, wherein the processor is further configured to perform CCE allocation of said PDCCH along with legacy PDCCH in a same PDCCH region of a normal subframe, the CCE allocation of said PDCCH transparent to legacy UEs.

11. The apparatus of claim 9, wherein the processor is configured to allocate said PDCCH in MBSFN subframes in a non-interleaved fashion.

15

12. The apparatus of claim 11, wherein said non-interleaved PDCCH include sub-band MCS assignment information.

13. The apparatus of claim 1, wherein the processor is further configured to allocate said PDCCH in normal and MBSFN subframes.

14. A UE device comprising:
a processor and a memory associated therewith;
wherein the processor is configured to, in a CONNECTED mode,
receive and identify an indicator indicating a DL transmission mode supporting multi-layer beamforming along with a user specific PDCCH for DL grant;
access DL control information using a PDCCH;
determine layer mapping information of multi-layer beamforming and MCS level information according to a last reported RI and CQI, if no dynamic control element is detected.

30

15. A UE device, comprising:

a processor and a memory associated therewith;

wherein the processor is configured to, in a CONNECTED mode,

- 5 receive and identify an indicator indicating a DL transmission mode supporting multi-layer beamforming along with a user specific PDCCH for DL grant;
- access DL control information using a PDCCH;
- determine layer mapping information of multi-layer beamforming and MCS level information based on dynamic control information in said user specific PDCCH.

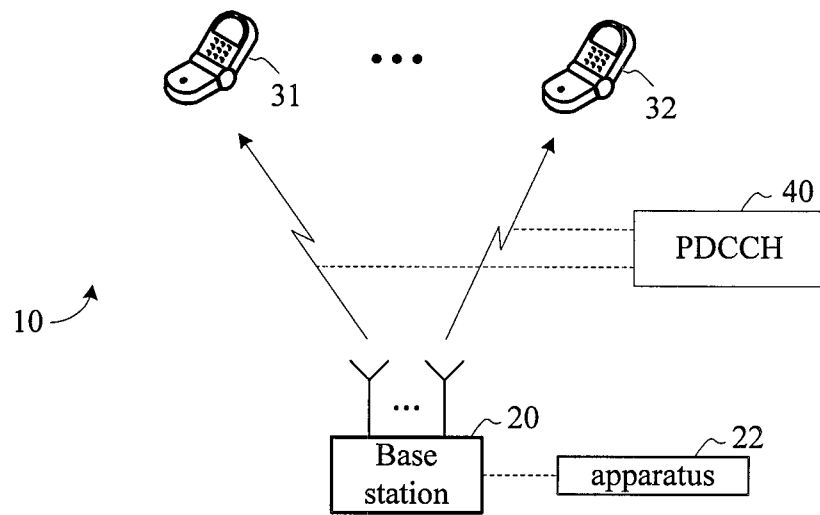


Fig.1

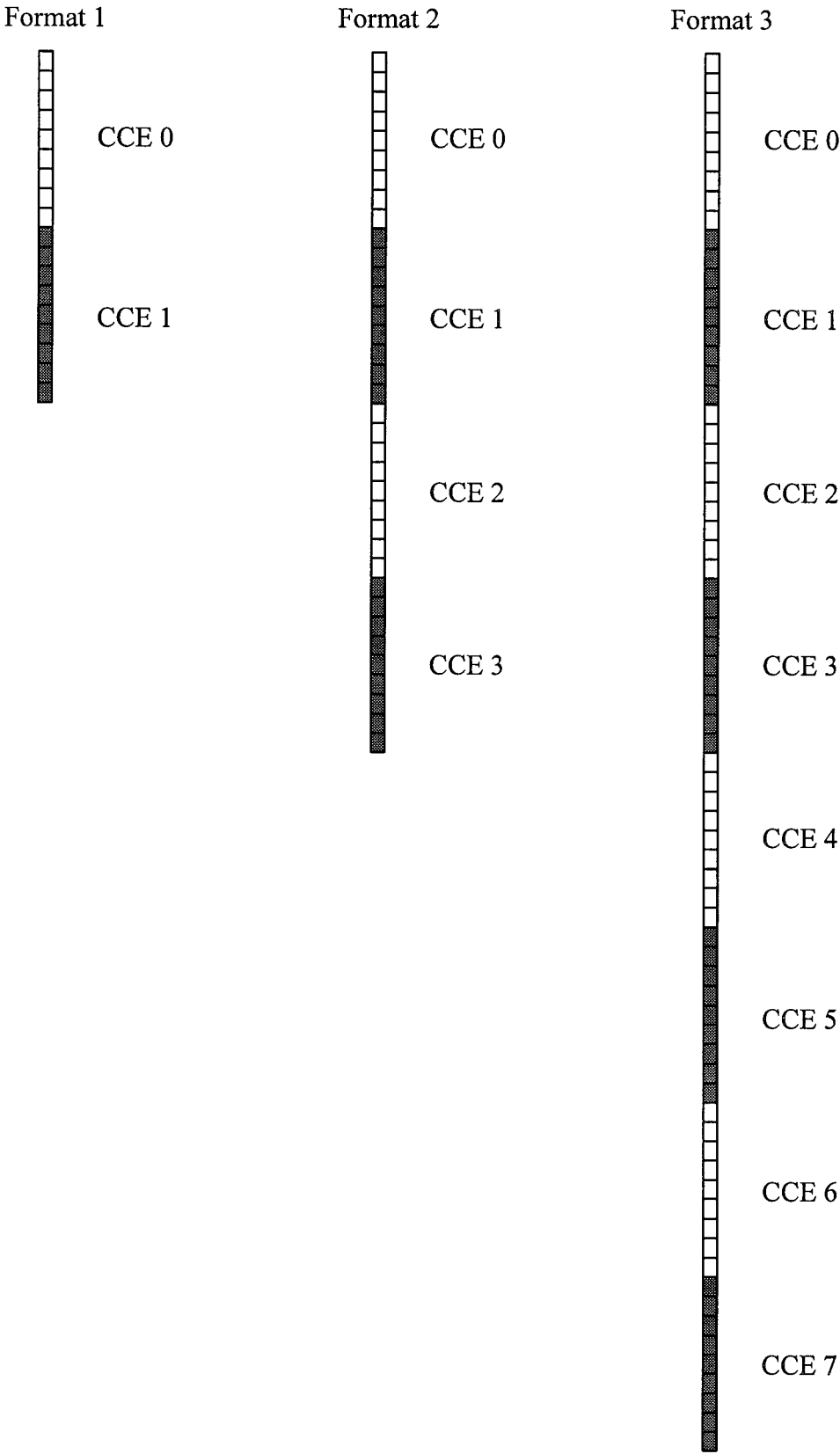


Fig.2

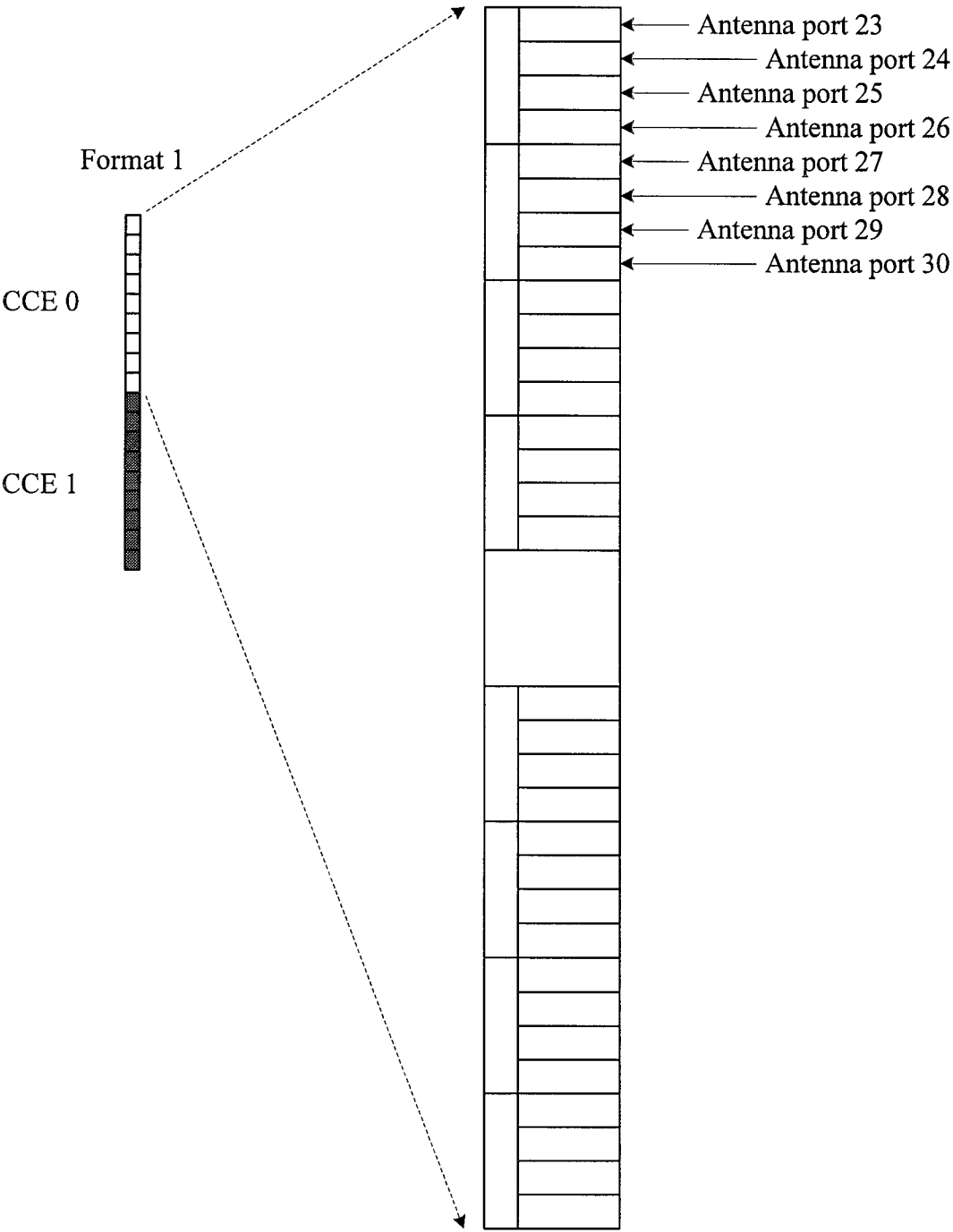


Fig.3

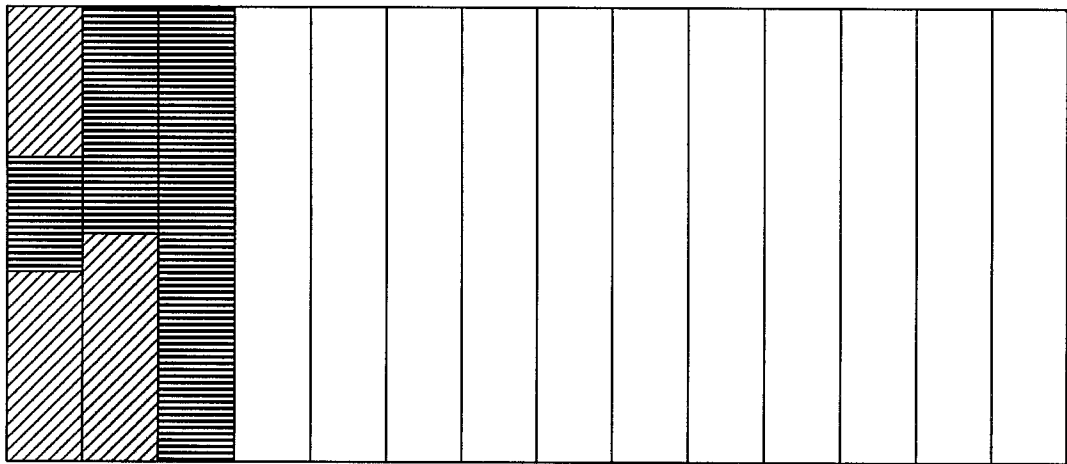


Fig.4

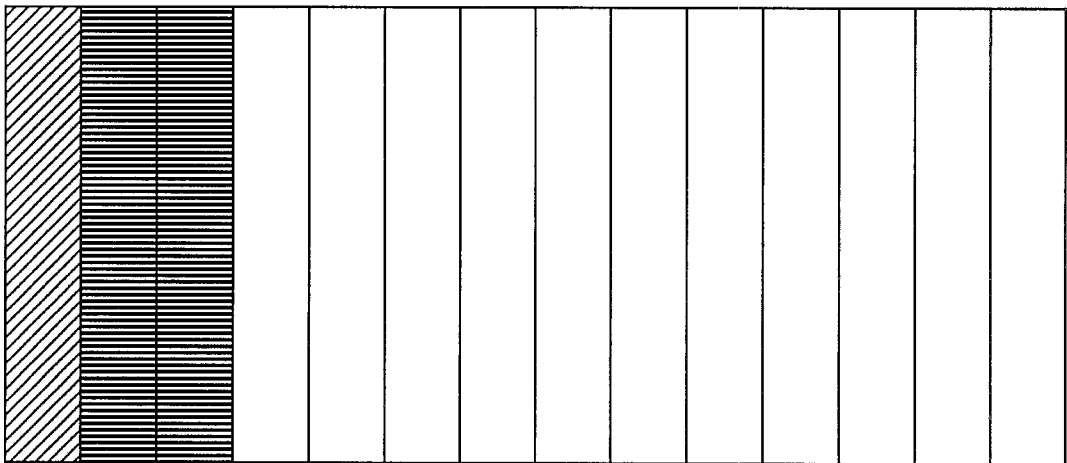


Fig.5

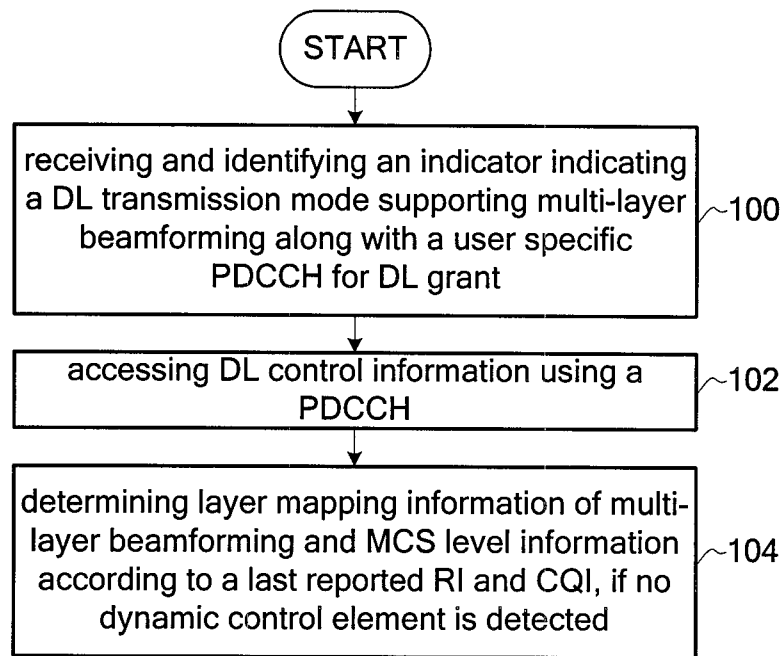


Fig.6

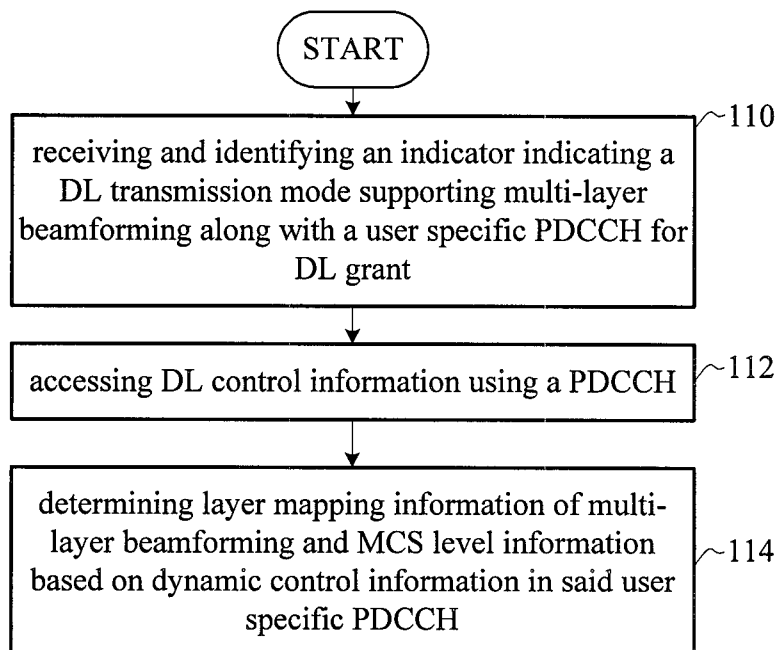


Fig.7

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2011/073281

A. CLASSIFICATION OF SUBJECT MATTER

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)

IPC:H04B,H04W,H04Q,H04L

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

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

WPI, CNPAT, CNABS, CNTXT, CNKI, VEN: DMRS, PDCCH, CCE, REG, control+, information, UE, orthogonal, signal?, allocate+, specific, MCS, MIMO, downlink, grant

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	CN101964676A (ZTE CORPORATION) 02 Feb. 2011 (02.02.2011) the description paragraphs 0011-0041	1, 2, 7, 9, 13
A	the whole document	3-6, 8, 10-12, 14,15
A	WO2010013959A2 (LG ELECTRONICS INC.) 04 Feb. 2010 (04.02.2010) the whole document	1-15
A	WO2010117240A2 (LG ELECTRONICS INC.) 14 Oct. 2010 (14.10.2010) the whole document	1-15

☐ Further documents are listed in the continuation of Box C.☒ See patent family annex.

* Special categories of cited documents:

“A” document defining the general state of the art which is not considered to be of particular relevance

“E” earlier application or patent but published on or after the international filing date

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“O” document referring to an oral disclosure, use, exhibition or other means

“P” document published prior to the international filing date but later than the priority date claimed

“T” later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

“X” document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

“Y” document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

“&” document member of the same patent family

Date of the actual completion of the international search

31 Dec. 2011 (31.12.2011)

Date of mailing of the international search report

19 Jan. 2012 (19.01.2012)Name and mailing address of the ISA/CN
The State Intellectual Property Office, the P.R.China
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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CN2011/073281

Patent Documents referred in the Report	Publication Date	Patent Family	Publication Date
CN101964676A	02.02.2011	WO2011009371A1	27.01.2011
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