

SUMMARY:

[0006] According to ~~certain embodiments~~ an aspect of the invention, a method is described. The method includes indicating an Enhanced Physical Downlink eControl eChannel (EPDCCH) search space by a pair of parameters. The pair of parameters includes a physical resource block index and an explicit control channel element index, the explicit control channel element index identifies a specific control channel element being used within a physical resource block corresponding to the physical resource block index, the explicit control channel element index is determined using the physical resource block index and number of control channel elements being used within the physical resource block corresponding to the physical resource block index, the number of control channel elements for the physical resource block index indicates possible aggregation levels inside the physical resource block corresponding to the physical resource block index, and a same user-specific starting position for the EPDCCH search space is used for each of the aggregation levels being used inside the physical resource block corresponding to the physical resource block index. The method also includes transmitting on the control channel within the search space.

[0007] ~~There is disclosed an~~ An apparatus, according to certain embodiments, includes comprising indicating means for indicating a control channel search space by a pair of parameters. The pair of parameters includes a physical resource block index and an explicit control channel element index. The apparatus also includes transmitting means for transmitting on the control channel within the search space.

[0008] ~~There is disclosed Aa~~ a non-transitory computer readable medium is, in certain embodiments, encoded with instructions that, when executed in hardware, perform a process. The process includes indicating a control channel search space by a pair of parameters. The pair of parameters includes a physical resource block index and an explicit control channel element index. The process also includes transmitting on the control channel within the search space.

[0009] According to another aspect of the invention, an apparatus is described. The ~~in certain embodiments, an~~ apparatus includes at least one processor and at least one memory including computer program code. The at least one memory and the computer program code are configured to, with the at least one processor, cause the apparatus at least to indicate an Enhanced Physical Downlink eControl eChannel (EPDCCH) search space by a pair of parameters. The pair of parameters includes a physical resource block index and an explicit control channel element index, the explicit control channel element index identifies a specific control channel element being used within a physical resource block corresponding to the physical resource block index, the explicit control channel element index is determined

using the physical resource block index and number of control channel elements being used within the physical resource block corresponding to the physical resource block index, the number of control channel elements for the physical resource block index indicates possible aggregation levels inside the physical resource block corresponding to the physical resource block index, and a same user-specific starting position for the EPDCCH search space is used for each of the aggregation levels being used inside the physical resource block corresponding to the physical resource block index. The at least one memory and the computer program code are also configured to, with the at least one processor, cause the apparatus at least to transmit on the control channel within the search space.

[0010] According to yet another aspect of the invention, a method is described. The to-certain embodiments, a method includes processing a received indication of an Enhanced Physical Downlink Control Channel (EPDCCH) search space by a pair of parameters, wherein the pair of parameters includes a physical resource block index and an explicit control channel element index, the explicit control channel element index identifies a specific control channel element being used within a physical resource block corresponding to the physical resource block index, the explicit control channel element index is determined using the physical resource block index and number of control channel elements being used within the physical resource block corresponding to the physical resource block index, the number of control channel elements for the physical resource block index indicates possible aggregation levels inside the physical resource block corresponding to the physical resource block index, and a same user-specific starting position for the EPDCCH search space is used for each of the aggregation levels being used inside the physical resource block corresponding to the physical resource block index. The method also includes attempting blind decoding of the control channel using a search strategy based on the received indication.

[0011] There is disclosed Anan apparatus, according to certain embodiments, includes comprising processing means for processing a received indication of a control channel search space by a pair of parameters, wherein the pair of parameters includes a physical resource block index and an explicit control channel element index. The apparatus also includes decoding means for attempting blind decoding of the control channel using a search strategy based on the received indication.

[0012] There is disclosed Aa non-transitory computer readable medium is, in certain embodiments, encoded

with instructions that, when executed in hardware, perform a process. The process includes processing a received indication of a control channel search space by a pair of parameters, wherein the pair of parameters includes a physical resource block index and an explicit control channel element index. The process also includes attempting blind decoding of the control channel using a search strategy based on the received indication.

[0013] According to yet another aspect of the invention, an apparatus is disclosed. ~~The~~
~~certain embodiments, an~~ apparatus includes at least one processor and at least one memory including computer program code. The at least one memory and the computer program code are configured to, with the at least one processor, cause the apparatus at least to process a received indication of an Enhanced Physical Downlink eControl eChannel (EPDCCH) search space by a pair of parameters, wherein the pair of parameters includes a physical resource block index and an explicit control channel element index, the explicit control channel element index identifies a specific control channel element being used within a physical resource block corresponding to the physical resource block index, the explicit control channel element index is determined using the physical resource block index and number of control channel elements being used within the physical resource block corresponding to the physical resource block index, the number of control channel elements for the physical resource block index indicates possible aggregation levels inside the physical resource block corresponding to the physical resource block index, and a same user-specific starting position for the EPDCCH search space is used for each of the aggregation levels being used inside the physical resource block corresponding to the physical resource block index. The at least one memory and the computer program code are also configured to, with the at least one processor, cause the apparatus at least to attempt blind decoding of the control channel using a search strategy based on the received indication.

[0014] According to yet another aspect of the invention, a method is described. ~~In certain~~
~~embodiments, a~~The method includes deriving an Enhanced Physical Downlink eControl eChannel (EPDCCH) search space based on a set of physical resource blocks and a control channel element identifier, the control channel element index identifies a specific control channel element being used within a physical resource block corresponding to the physical resource block index, the control channel element identifier is determined using a physical resource block index and number of control channel elements being used within the physical resource block corresponding to the physical resource block index, the number of control channel elements for the physical resource block index indicates possible aggregation levels inside the physical resource block corresponding to the physical resource block index, and a same user-specific starting position for the EPDCCH search space is used for each of the aggregation levels being used inside the physical resource block corresponding to the physical resource block index. The control channel search space allows the control channel

to be transmitted with different code rates, transmitted in different physical resource blocks, localized into one physical resource block, or distributed into multiple physical resource blocks.

[0015] There is disclosed Aa non-transitory computer readable medium is, in certain
 5 embodiments, encoded with instructions that, when executed in hardware, perform a
 process. The process includes deriving a control channel search space based on a set of
 physical resource blocks and a control channel element identifier. The control channel
 search space allows the control channel to be transmitted with different code rates,
 transmitted in different physical resource blocks, localized into one physical resource block,
 10 or distributed into multiple physical resource blocks.

[0016] According to yet another aspect of the invention, an apparatus is described. TheAn
 apparatus, ~~according to certain embodiments,~~ includes at least one processor and at least
 one memory including computer program code. The at least one memory and the computer
 program code are configured to, with the at least one processor, cause the apparatus at least
 15 to derive an Enhanced Physical Downlink eControl eChannel (EPDCCH) search space
based on a set of physical resource blocks and a control channel element identifier, the
control channel element index identifies a specific control channel element being used within
a physical resource block corresponding to the physical resource block index, the control
channel element identifier is determined using a physical resource block index and number
 20 of control channel elements being used within the physical resource block corresponding to
the physical resource block index, the number of control channel elements for the physical
resource block index indicates possible aggregation levels inside the physical resource block
corresponding to the physical resource block index, and a same user-specific starting
position for the EPDCCH search space is used for each of the aggregation levels being used
 25 inside the physical resource block corresponding to the physical resource block index. The
 control channel search space allows the control channel to be transmitted with different code
 rates, transmitted in different physical resource blocks, localized into one physical resource
 block, or distributed into multiple physical resource blocks.

[0017] There is disclosed~~According to certain embodiments,~~ an apparatus includes
 30 comprising deriving means for deriving a control channel search space based on a set of
 physical resource blocks and a control

WE CLAIM:

1. A method, comprising:

indicating an Enhanced Physical Downlink Control Channel (EPDCCH)~~a control channel~~
 5 search space by a pair of parameters, wherein the pair of parameters includes a physical resource
 block index and an explicit control channel element index, ~~wherein the explicit control channel~~
 element index identifies a specific control channel element being used within~~associated with~~
 a physical resource block corresponding to the physical resource block index, the explicit
 10 control channel element index is determined using the physical resource block index and
number of control channel elements being used within the physical resource block
corresponding to the physical resource block index, the number of control channel elements
for the physical resource block index indicates possible aggregation levels inside the
physical resource block corresponding to the physical resource block index, and a same
user-specific starting position for the EPDCCH search space is used for each of the
 15 aggregation levels being used inside the physical resource block corresponding to the
physical resource block index; and

transmitting on the control channel within the search space.

2. The method of claim 1, further comprising:

20 implicitly indicating a plurality of code rates by explicitly indicating a single allocated
primary physical resource block.

3. The method of claim 1, wherein the indicating comprises indicating a starting index,
wherein the starting index is configured to inform a user equipment as to which control channel
 25 element index the user equipment is to use as a reference.

4. The method of claim 3, wherein the indicating the starting index comprises indicating a
physical resource block index and offset.

30 5. The method of claim 1, further comprising:

indicating a physical resource block that has no search positions but is to be punctured

out.

62. A method, comprising:

5 processing a received indication of ~~ana~~ Enhanced Physical Downlink eControl
Channel (EPDCCH) search space by a pair of parameters, wherein the pair of parameters
includes a physical resource block index and an explicit control channel element index,
10 ~~wherein the explicit control channel element index identifies a specific control channel~~
~~element being used within~~associated with a physical resource block corresponding to the
physical resource block index, the explicit control channel element index is determined using
the physical resource block index and number of control channel elements being used within
the physical resource block corresponding to the physical resource block index, the number
of control channel elements for the physical resource block index indicates possible
aggregation levels inside the physical resource block corresponding to the physical resource
block index, and a same user-specific starting position for the EPDCCH search space is
15 used for each of the aggregation levels being used inside the physical resource block
corresponding to the physical resource block index; and

attempting ~~blind~~ ~~to decoding~~ ~~decode~~ of the control channel using a search strategy based on the received indication.

73. The method of claim 62, wherein the processing the received indication comprises processing a starting index, wherein the starting index is configured to inform a user equipment as to which control channel element index the user equipment is to use as a reference.

84. The method of claim 73, wherein the processing the starting index comprises processing a physical resource block index and offset.

95. The method of claim 62, further comprising:

processing an indication of a physical resource block that has no search positions but is to be punctured out.

106. The method ~~of any~~ of claim 6s 2-5, further comprising:

limiting candidate physical resource blocks used in the search strategy to a predetermined number of physical resource blocks that is less than a total number of available physical resource blocks.

117. An apparatus, comprising,

at least one processor; and

at least one memory including computer program code,

wherein the at least one memory and the computer program code are configured to, with the at least one processor, cause the apparatus at least to

indicate an Enhanced Physical Downlink Control Channel (EPDCCH) search space by a pair of parameters, wherein the pair of parameters includes a physical resource block index and an explicit control channel element index, wherein the explicit control channel element index identifies a specific control channel element being used
 5 within~~associated with~~ a physical resource block corresponding to the physical resource block index, the explicit control channel element index is determined using the physical resource block index and number of control channel elements being used within the physical resource block corresponding to the physical resource block index, the number of control channel elements for the physical resource block index indicates possible aggregation levels inside
 10 the physical resource block corresponding to the physical resource block index, and a same user-specific starting position for the EPDCCH search space is used for each of the aggregation levels being used inside the physical resource block corresponding to the physical resource block index; and

transmit on the control channel within the search space.

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12. The apparatus of claim 11, wherein the at least one memory and the computer program code are configured to, with the at least one processor, cause the apparatus at least to implicitly indicate a plurality of code rates by explicitly indicating a single allocated primary physical resource block.

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13. The apparatus of claim 11, wherein the at least one memory and the computer program code are configured to, with the at least one processor, cause the apparatus at least to indicate a starting index, wherein the starting index is configured to inform a user equipment as to which control channel element index the user equipment is to use as a
 25 reference.

14. The apparatus of claim 13, wherein the at least one memory and the computer program code are configured to, with the at least one processor, cause the apparatus at least to indicate the starting index by indicating a physical resource block index and offset.

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

least to indicate a physical resource block that has no search positions but is to be punctured out.

168. An apparatus, comprising:

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at least one processor; and

at least one memory including computer program code,

wherein the at least one memory and the computer program code are configured to, with the at least one processor, cause the apparatus at least to

process a received indication of ~~an~~ Enhanced Physical Downlink eControl eChannel (EPDCCH) search space by a pair of parameters, wherein the pair of parameters includes a physical resource block index and an explicit control channel element index, ~~wherein the~~ explicit control channel element index identifies a specific control channel element ~~associated with~~ being used within a physical resource block corresponding to the physical resource block index, the explicit control channel element index is determined using the physical resource block index and number of control channel elements being used within the physical resource block corresponding to the physical resource block index, the number of control channel elements for the physical resource block index indicates possible aggregation levels inside the physical resource block corresponding to the physical resource block index, and a same user-specific starting position for the EPDCCH search space is used for each of the aggregation levels being used inside the physical resource block corresponding to the physical resource block index; and

~~attempt blind to decoding~~ of the control channel using a search strategy based on the received indication.

917. The apparatus of claim 168, wherein the at least one memory and the computer program code are configured to, with the at least one processor, cause the apparatus at least to process a starting index, wherein the starting index is configured to inform a user equipment as to which control channel element index the user equipment is to use as a reference.

~~4018.~~ 918. The apparatus of claim 917, wherein the at least one memory and the computer program code are configured to, with the at least one processor, cause the apparatus at least to process a physical resource block index and offset.

~~4419.~~ 816. The apparatus of claim 816, wherein the at least one memory and the computer program code are configured to, with the at least one processor, cause the apparatus at least to process an indication of a physical resource block that has no search positions but is to be punctured out.

4220. The apparatus of ~~any of claims 8-11~~16, wherein the at least one memory and the computer program code are configured to, with the at least one processor, cause the apparatus at least to limit candidate physical resource blocks used in the search strategy to
5 a predetermined number of physical resource blocks that is less than a total number of available physical resource blocks.

1321. A method, comprising:

deriving ~~aan~~ Enhanced Physical Downlink eControl eChannel (EPDCCH) search space based on a pair of physical resource block index and a control channel element identifier, ~~wherein the explicit control channel element index identifier identifies a specific control channel element associated with~~ being used within a physical resource block corresponding to the physical resource block index, the control channel element identifier is determined using a physical resource block index and number of control channel elements being used within the physical resource block corresponding to the physical resource block index, the number of control channel elements for the physical resource block index indicates possible aggregation levels inside the physical resource block corresponding to the physical resource block index, and a same user-specific starting position for the EPDCCH search space is used for each of the aggregation levels being used inside the physical resource block corresponding to the physical resource block index,

wherein the control channel search space allows the control channel to be transmitted with different code rates, ~~or transmitted in different physical resource blocks, or~~ localized into one physical resource block, or distributed into multiple physical resource blocks.

22. The method of claim 21, wherein parameters defining the search space are signaled directly or partly derived from other parameters.

23. The method of claim 22, wherein the other parameters include at least one of a user equipment identifier and a cell identifier.

1424. An apparatus, comprising:

at least one processor; and

at least one memory including computer program code,

wherein the at least one memory and the computer program code are configured to, with the at least one processor, cause the apparatus at least to

derive ~~ana~~ Enhanced Physical Downlink eControl eChannel (EPDCCH) search space

based on a ~~set~~^{pair} of physical resource blocks ~~index~~ and a control channel element identifier, wherein the ~~explicit control channel element identifier index~~ identifies a specific control channel element being used within ~~associated with~~ a physical resource block corresponding to the physical resource block index, the control channel element identifier is determined using a physical resource block index and number of control channel elements being used within the physical resource block corresponding to the physical resource block index, the number of control channel elements for the physical resource block index indicates possible aggregation levels inside the physical resource block corresponding to the physical resource block index, and a same user-specific starting position for the EPDCCH search space is used for each of the aggregation levels being used inside the physical resource block corresponding to the physical resource block index,

wherein the control channel search space allows the control channel to be transmitted with different code rates, ~~or~~ transmitted in different physical resource blocks, ~~or~~ localized into one physical resource block, or distributed into multiple physical resource blocks.

25. The apparatus of claim 24, wherein parameters defining the search space are signaled directly or partly derived from other parameters.

26. The apparatus of claim 25, wherein the other parameters include at least one of a user equipment identifier and a cell identifier.

~~15. An apparatus, comprising:~~

~~indicating means for indicating a control channel search space by a pair of parameters, wherein the pair of parameters includes a physical resource block index and an explicit control channel element index, wherein the explicit control channel element index identifies a specific control channel element associated with a physical resource block corresponding to the physical resource block index; and~~

~~transmitting means for transmitting on the control channel within the search space.~~

~~16. An apparatus, comprising:~~

processing means for processing a received indication of a control channel search space by a pair of parameters, wherein the pair of parameters includes a physical resource block index and an explicit control channel element index, wherein the explicit control channel element index identifies a specific control channel element associated with a physical resource block corresponding to the physical resource block index; and

attempting means for attempting to decode the control channel based on the received indication.

17. An apparatus, comprising:

deriving means for deriving a control channel search space based on a pair of physical resource block index and a control channel element identifier, wherein the explicit control channel element identifier identifies a specific control channel element associated with a physical resource block corresponding to the physical resource block index,

wherein the control channel search space allows the control channel to be transmitted with different code rates, or transmitted in different physical resource blocks,

or localized into one physical resource block, or distributed into multiple physical resource blocks.

- 5 ~~18. A non-transitory computer-readable medium encoded with instructions that, when executed in hardware, perform a process, the process comprising the method of any claims 2-6.~~