US009722751B2

(12) **United States Patent**
Kim et al.

(10) **Patent No.: US 9,722,751 B2**
(45) **Date of Patent: *Aug. 1, 2017**

(54) **DEVICE AND METHOD FOR MONITORING THE CONTROL CHANNEL IN A MULTICARRIER SYSTEM**

(75) Inventors: **So Yeon Kim**, Anyang-si (KR); **Sung Ho Moon**, Anyang-si (KR); **Jae Hoon Chung**, Anyang-si (KR); **Yeong Hyeon Kwon**, Anyang-si (KR); **Han Gyu Cho**, Anyang-si (KR)

(73) Assignee: **LG Electronics Inc.**, Seoul (KR)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 594 days.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **13/320,512**

(22) PCT Filed: **May 14, 2010**

(86) PCT No.: **PCT/KR2010/003069**

§ 371 (c)(1), (2), (4) Date: **Nov. 14, 2011**

(87) PCT Pub. No.: **WO2010/131928**

PCT Pub. Date: **Nov. 18, 2010**

(65) **Prior Publication Data**

US 2012/0063324 A1 Mar. 15, 2012

Related U.S. Application Data

(60) Provisional application No. 61/178,053, filed on May 14, 2009, provisional application No. 61/285,547, (Continued)

(30) **Foreign Application Priority Data**

May 14, 2010 (KR) 10-2010-0045370

(51) **Int. Cl.**
H04L 1/00 (2006.01)
H04L 5/00 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC ***H04L 5/0053*** (2013.01); ***H04L 5/0007*** (2013.01); ***H04L 27/2647*** (2013.01); *H04L 5/0062* (2013.01); *H04W 24/00* (2013.01)

(58) **Field of Classification Search**
CPC .... H04W 72/042; H04W 72/0406; H04W 24/00; H04W 72/04; H04W 24/10; (Continued)

(56) **References Cited**

U.S. PATENT DOCUMENTS

2010/0034150 A1 2/2010 Wang et al.
2010/0254329 A1* 10/2010 Pan et al. 370/329
(Continued)

FOREIGN PATENT DOCUMENTS

WO 2006/136076 A1 12/2006
WO 2007/035045 A2 3/2007
WO 2008/054099 A1 5/2008

OTHER PUBLICATIONS

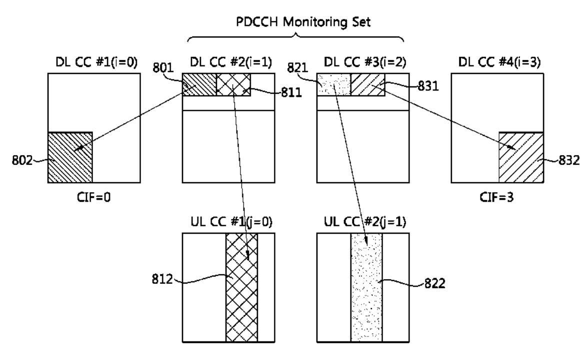
Nortel Networks, "Control channel design for the support of wider bandwidth for LTE-Advanced," 3GPP TSG-RAN WG1 #57, R1-091923, San Francisco, US, May 4-8, 2009, 11 pages.

Primary Examiner — Melanie Jagannathan
Assistant Examiner — Najeebuddin Ansari
(74) *Attorney, Agent, or Firm* — Birch, Stewart, Kolasch & Birch, LLP

(57) **ABSTRACT**

The present invention relates to a method and device for monitoring the control channel in a multicarrier system. Each of a plurality of sub-search spaces corresponds to each of a plurality of scheduled component carriers. The terminal monitors a downlink control channel for a scheduled component carrier corresponding to each of the plurality of sub-search spaces. Each of the plurality of sub-search spaces is defined displaced to the extent that they are offset from each other.

18 Claims, 18 Drawing Sheets



Related U.S. Application Data

filed on Dec. 11, 2009, provisional application No. 61/285,550, filed on Dec. 11, 2009, provisional application No. 61/292,435, filed on Jan. 5, 2010, provisional application No. 61/298,214, filed on Jan. 26, 2010, provisional application No. 61/307,861, filed on Feb. 25, 2010, provisional application No. 61/309,821, filed on Mar. 2, 2010, provisional application No. 61/318,791, filed on Mar. 30, 2010, provisional application No. 61/323,877, filed on Apr. 14, 2010, provisional application No. 61/327,080, filed on Apr. 22, 2010, provisional application No. 61/328,607, filed on Apr. 27, 2010.

(51) **Int. Cl.**
H04L 27/26 (2006.01)
H04W 24/00 (2009.01)

(58) **Field of Classification Search**
CPC H04W 72/00; H04W 28/04; H04W 72/12; H04W 72/1273; H04W 72/1289; H04W 74/002; H04W 28/042; H04W 48/12; H04W 72/02; H04W 72/1278
USPC 370/241, 329, 252
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

2010/0271970	A1*	10/2010	Pan et al.	370/252
2011/0110316	A1*	5/2011	Chen	H04L 5/0053 370/329
2011/0194523	A1*	8/2011	Chung et al.	370/329
2011/0201333	A1*	8/2011	Kwon et al.	455/434
2011/0243090	A1*	10/2011	Grovlen et al.	370/329
2011/0317610	A1*	12/2011	Park et al.	370/312
2012/0008586	A1*	1/2012	Kwon et al.	370/329
2012/0021756	A1*	1/2012	Kwon et al.	455/450
2012/0033643	A1*	2/2012	Noh et al.	370/335
2012/0063351	A1*	3/2012	Kim et al.	370/252
2013/0195039	A1*	8/2013	Pan et al.	370/329

* cited by examiner

FIG. 1
(Background Art)

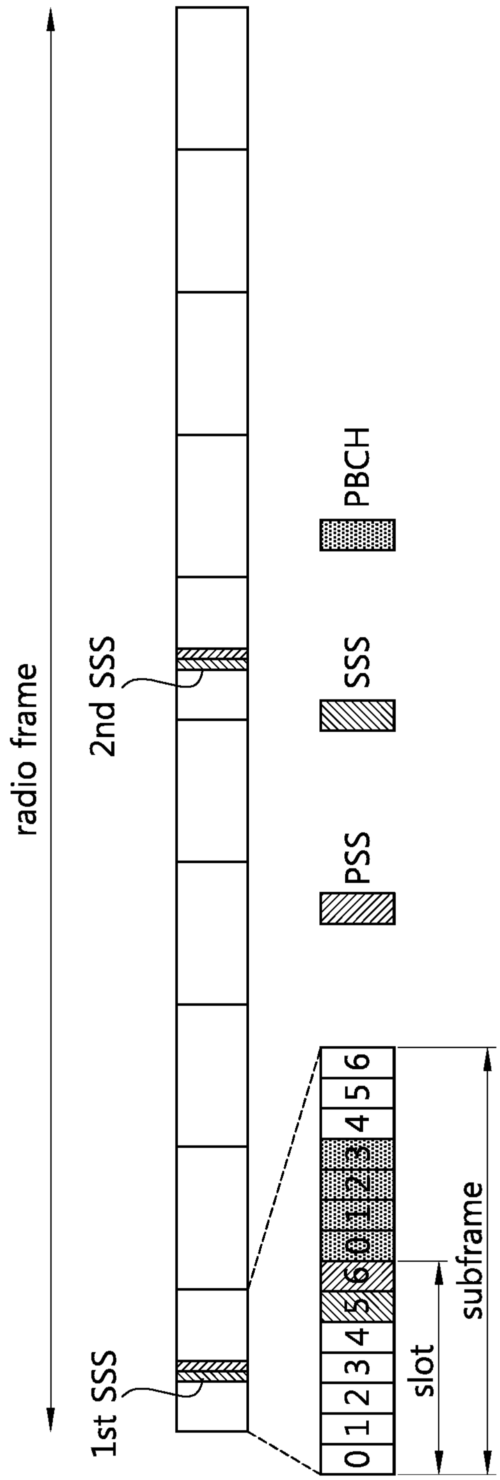


FIG. 2
(Background Art)

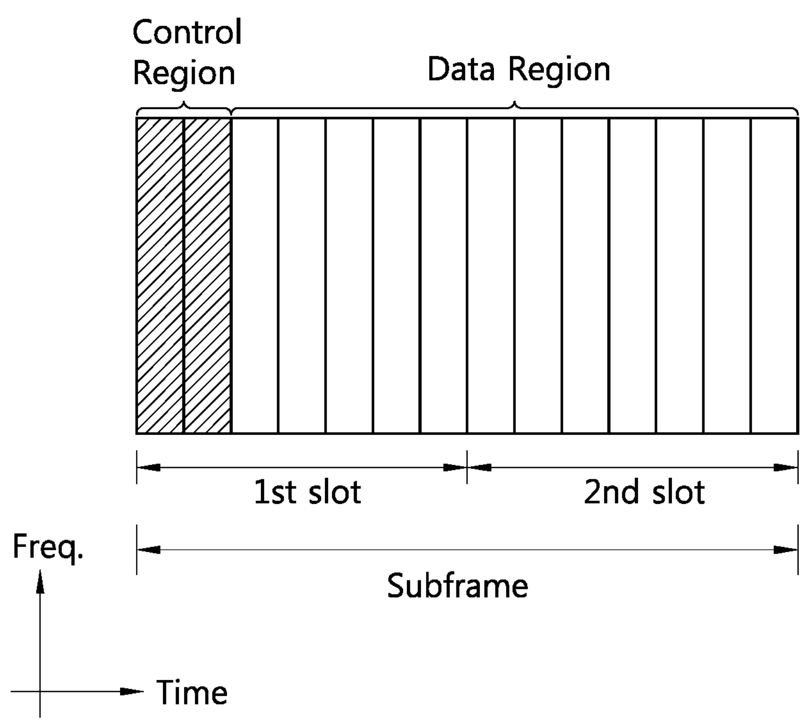


FIG. 3
(Background Art)

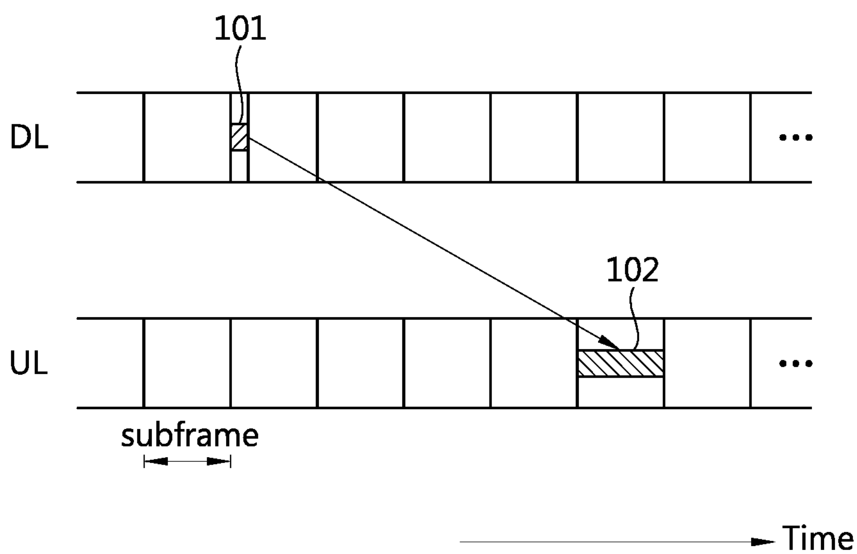


FIG. 4
(Background Art)

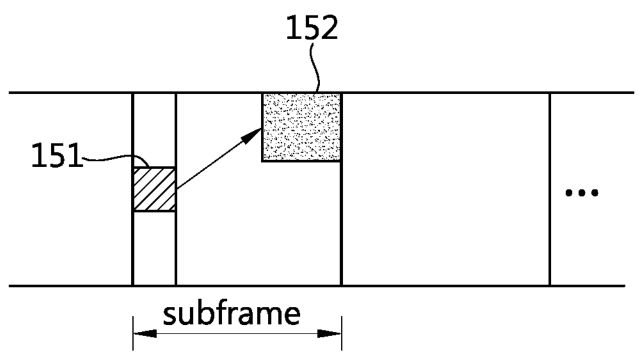


FIG. 5
(Background Art)

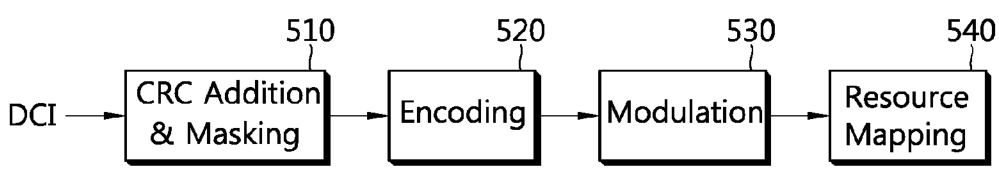


FIG. 6
(Background Art)

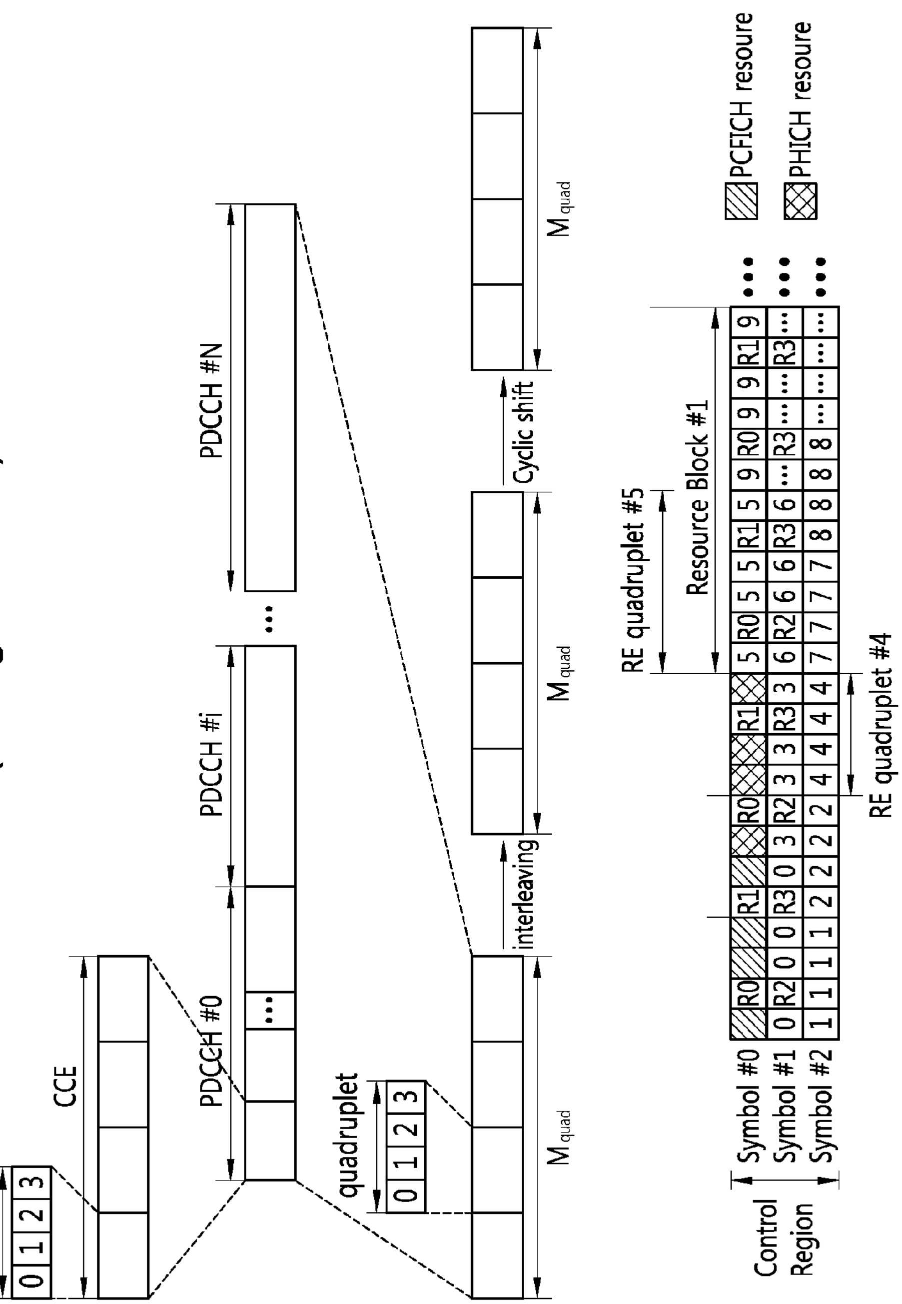


FIG. 7
(Background Art)

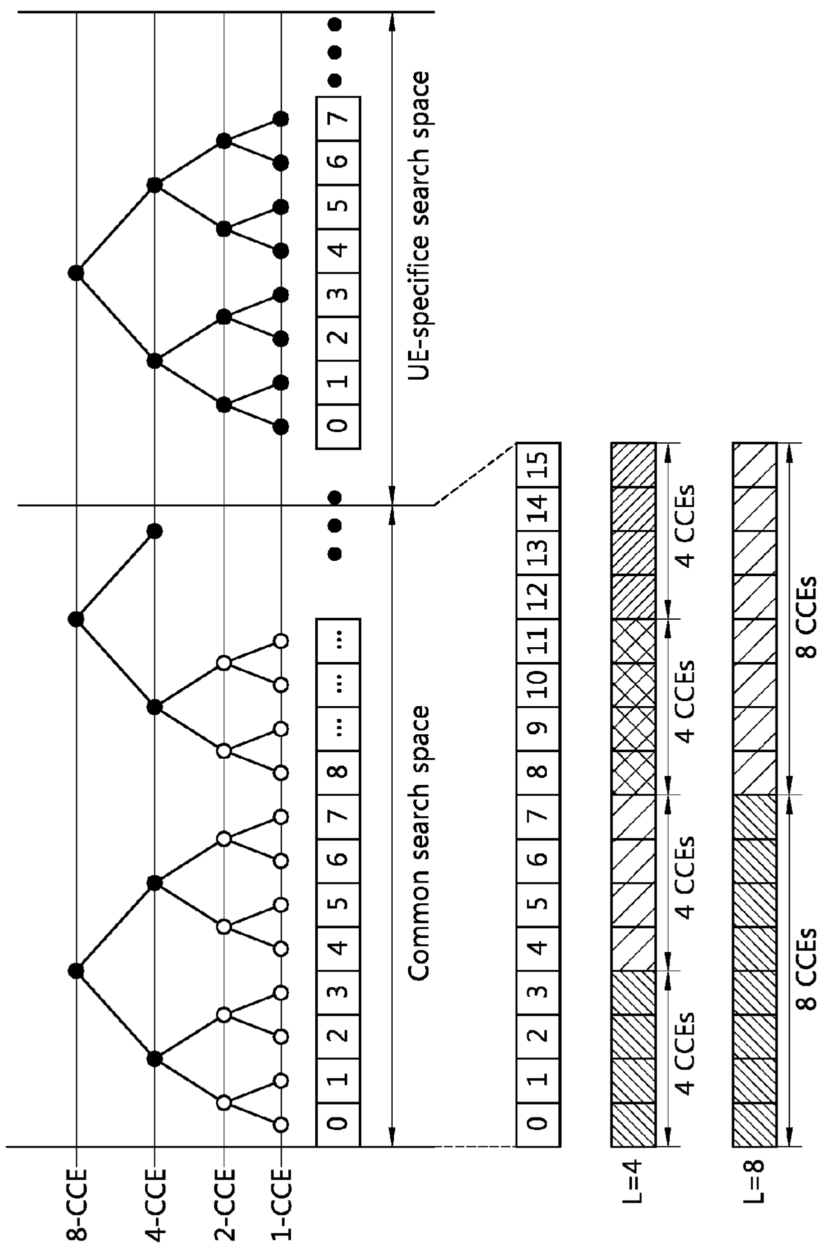


FIG. 8

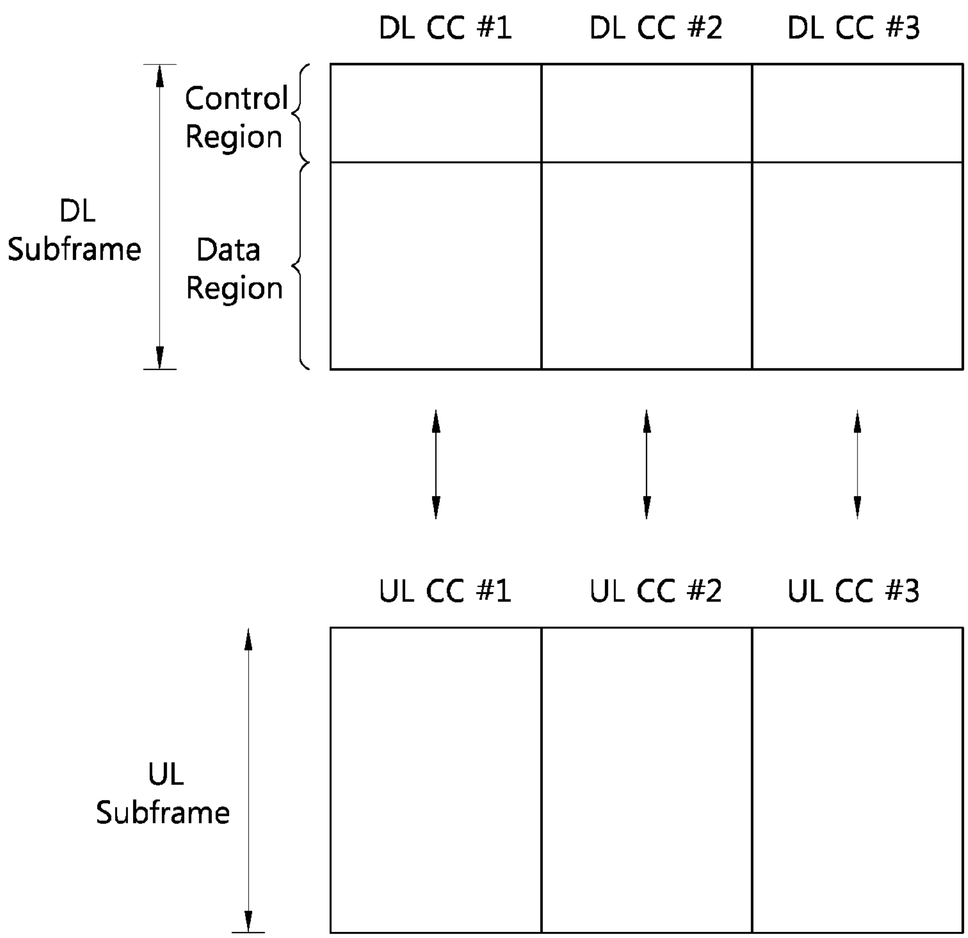

DL CC #1
DL CC #2
DL CC #3
Control Region
Data Region
DL Subframe
UL CC #1
UL CC #2
UL CC #3
UL Subframe

FIG. 9

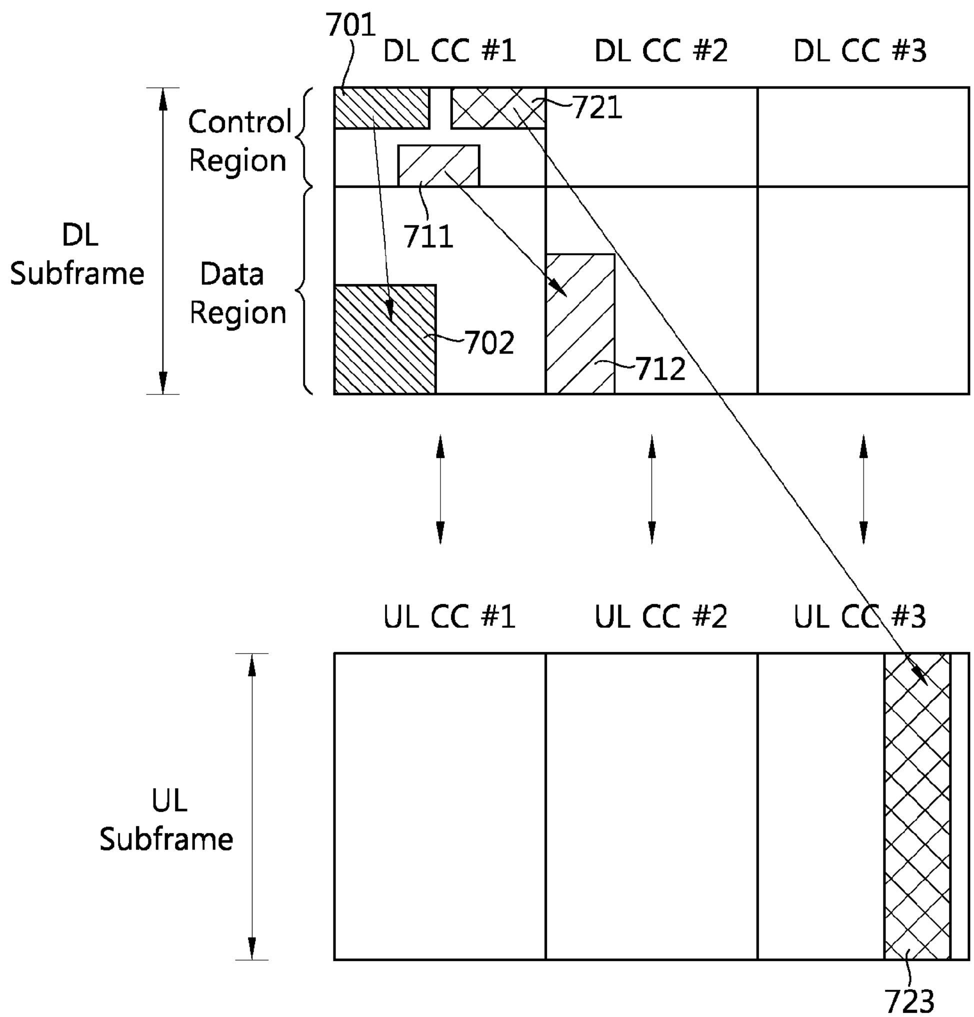

701
DL CC #1
DL CC #2
DL CC #3
721
Control Region
711
DL Subframe
Data Region
702
712
UL CC #1
UL CC #2
UL CC #3
UL Subframe
723

FIG. 10

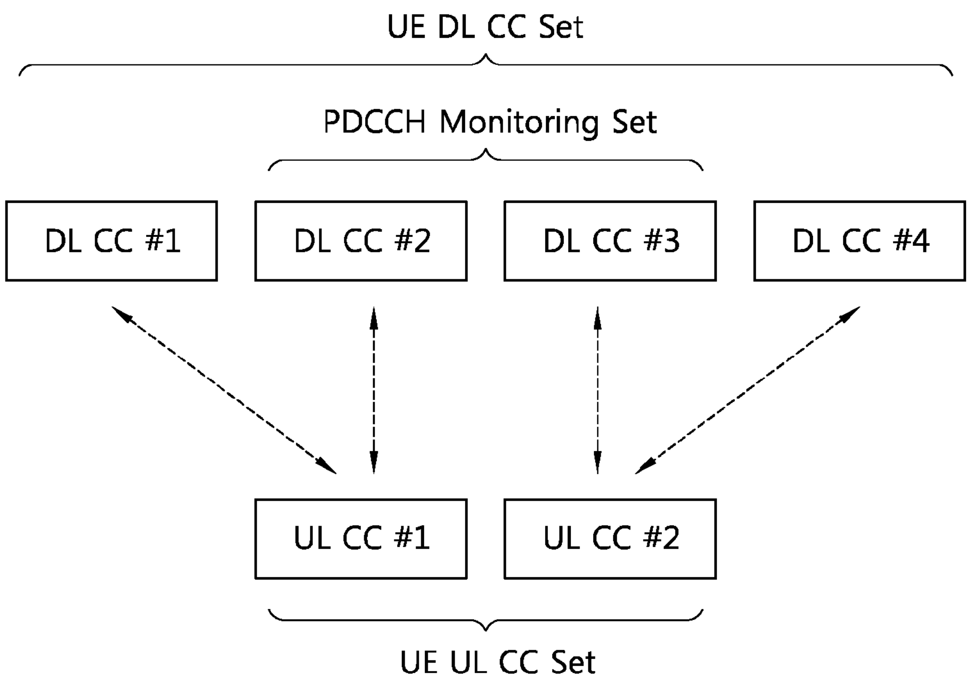

UE DL CC Set
PDCCH Monitoring Set
DL CC #1
DL CC #2
DL CC #3
DL CC #4
UL CC #1
UL CC #2
UE UL CC Set

FIG. 11

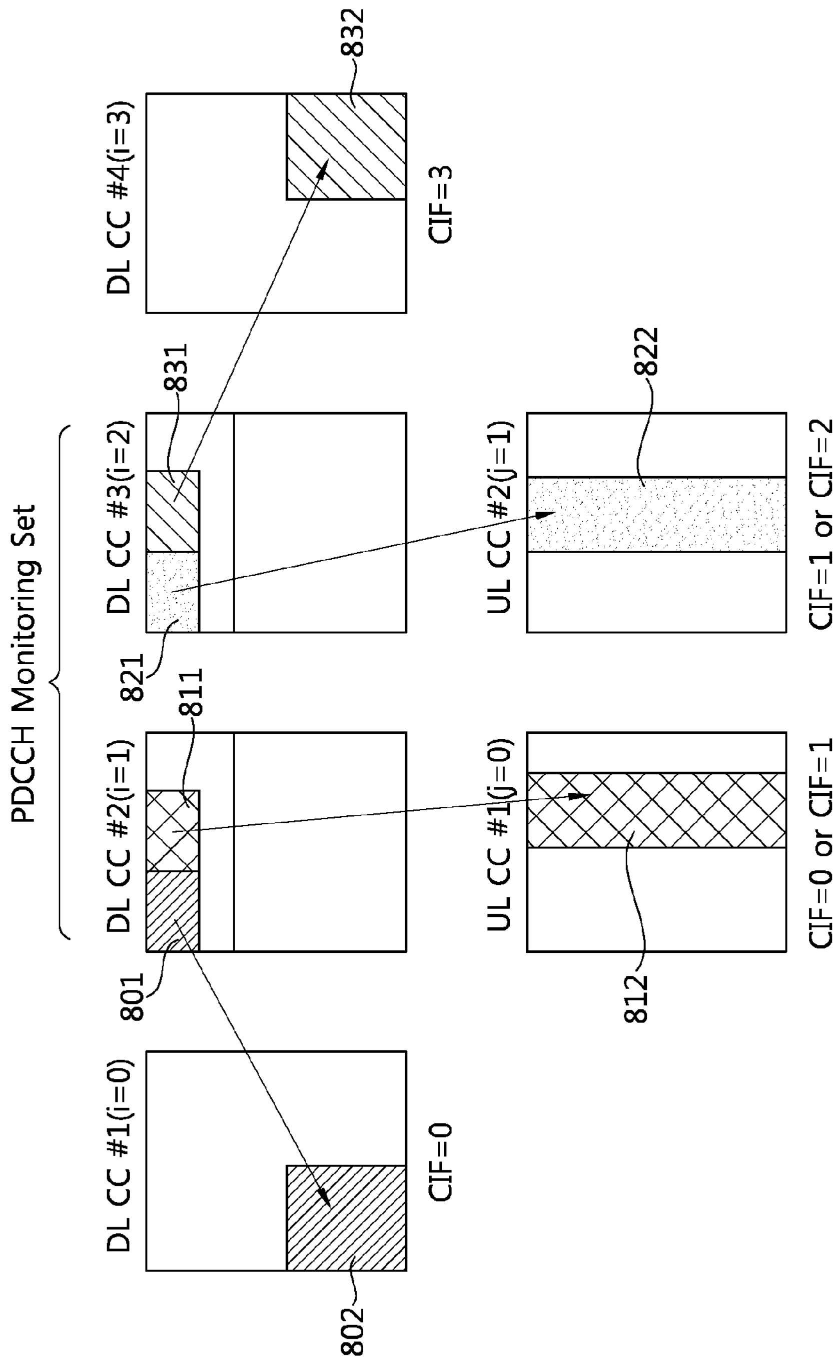

PDCCH Monitoring Set
DL CC #1(i=0)
DL CC #2(i=1)
DL CC #3(i=2)
DL CC #4(i=3)
UL CC #1(j=0)
UL CC #2(j=1)
CIF=0
CIF=3
CIF=0 or CIF=1
CIF=1 or CIF=2
801
802
811
812
821
822
831
832

FIG. 12

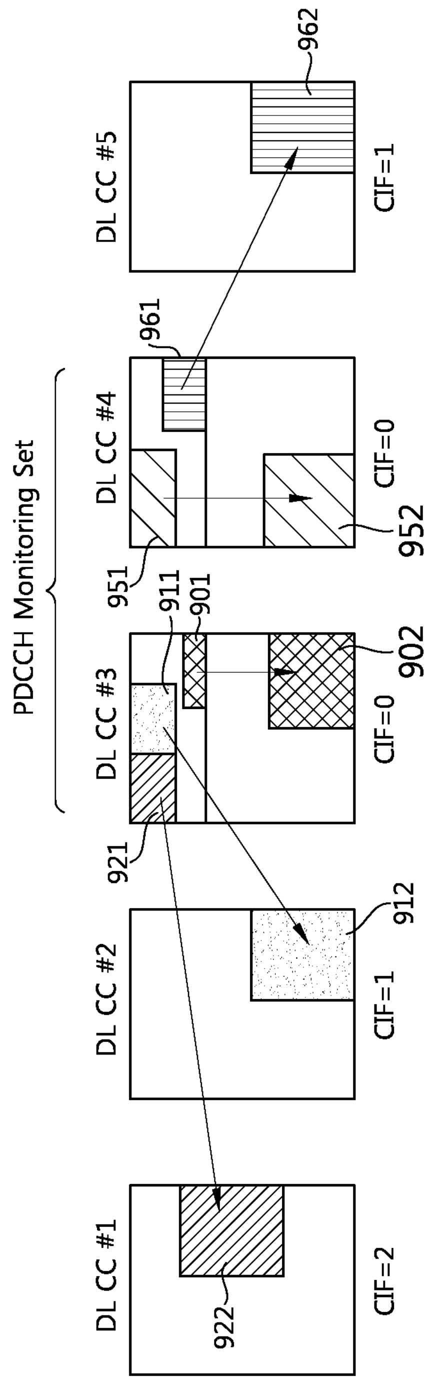

PDCCH Monitoring Set
DL CC #1
DL CC #2
DL CC #3
DL CC #4
DL CC #5
CIF=2
CIF=1
CIF=0
CIF=0
CIF=1
922
921
912
911
901
902
951
952
961
962

FIG. 13

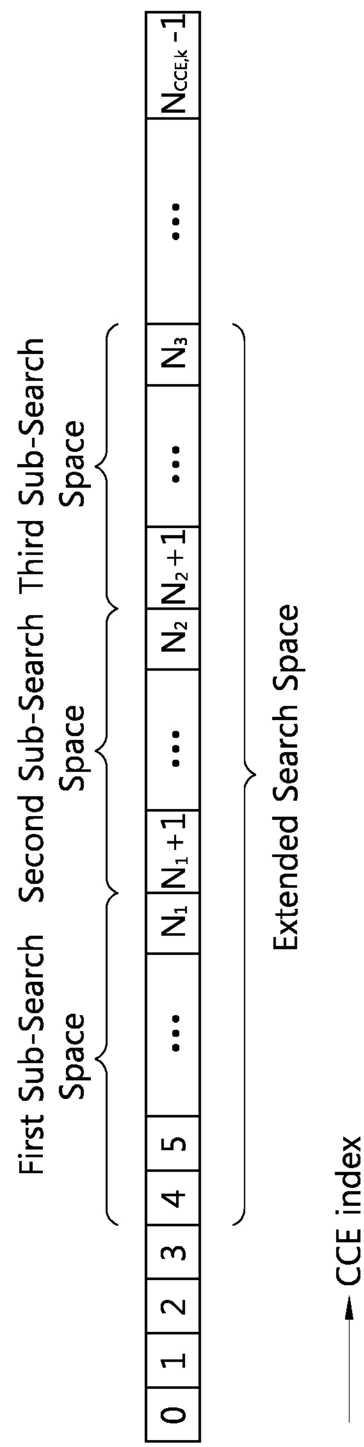

First Sub-Search Space
Second Sub-Search Space
Third Sub-Search Space
0
1
2
3
4
5
...
N_1
N_1+1
...
N_2
N_2+1
...
N_3
...
$N_{CCE,k}-1$
Extended Search Space
CCE index

FIG. 14

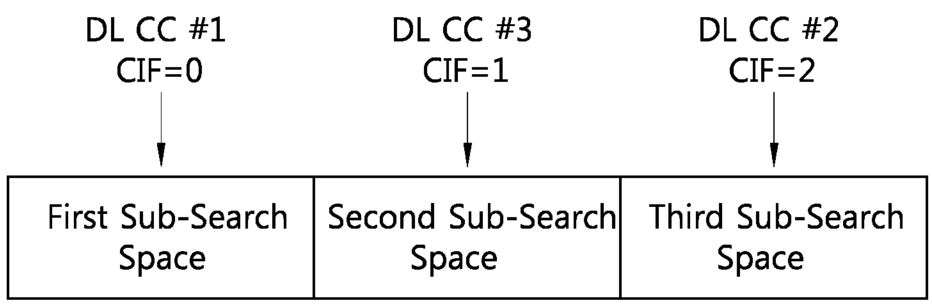
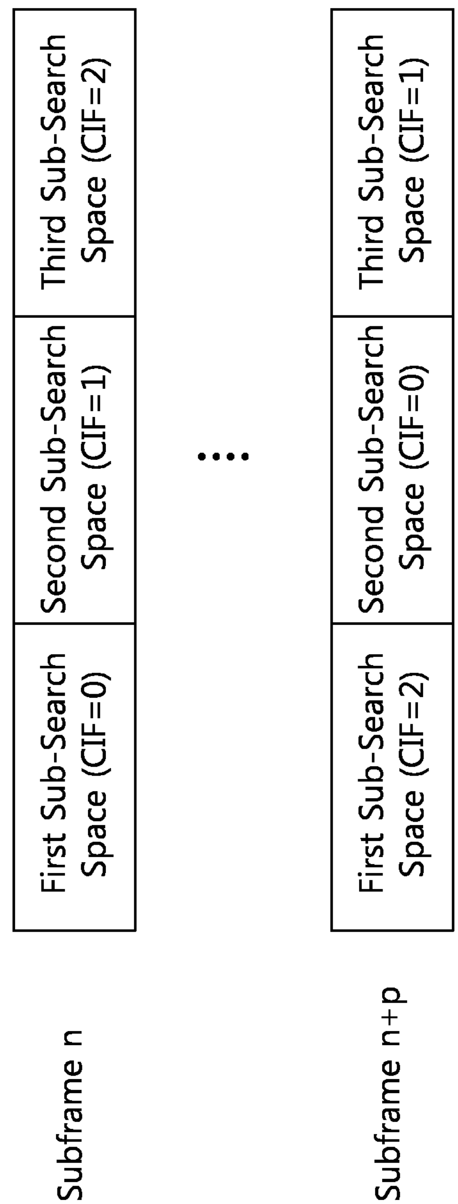

DL CC #1
CIF=0
DL CC #3
CIF=1
DL CC #2
CIF=2
First Sub-Search Space
Second Sub-Search Space
Third Sub-Search Space

FIG. 15



Subframe n
First Sub-Search Space (CIF=0)
Second Sub-Search Space (CIF=1)
Third Sub-Search Space (CIF=2)
....
Subframe n+p
First Sub-Search Space (CIF=2)
Second Sub-Search Space (CIF=0)
Third Sub-Search Space (CIF=1)

FIG. 16

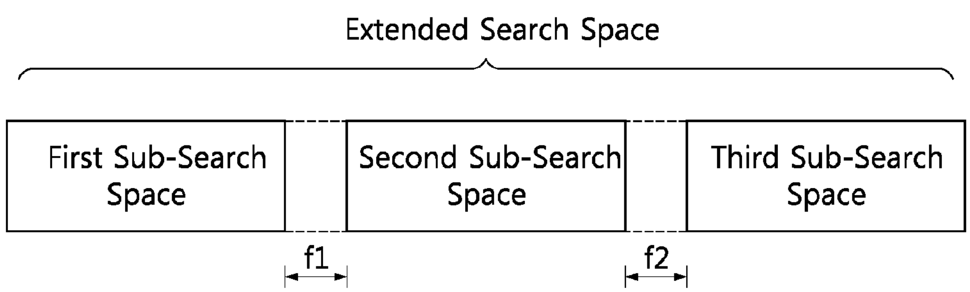

Extended Search Space
First Sub-Search Space
Second Sub-Search Space
Third Sub-Search Space
f1
f2

FIG. 17

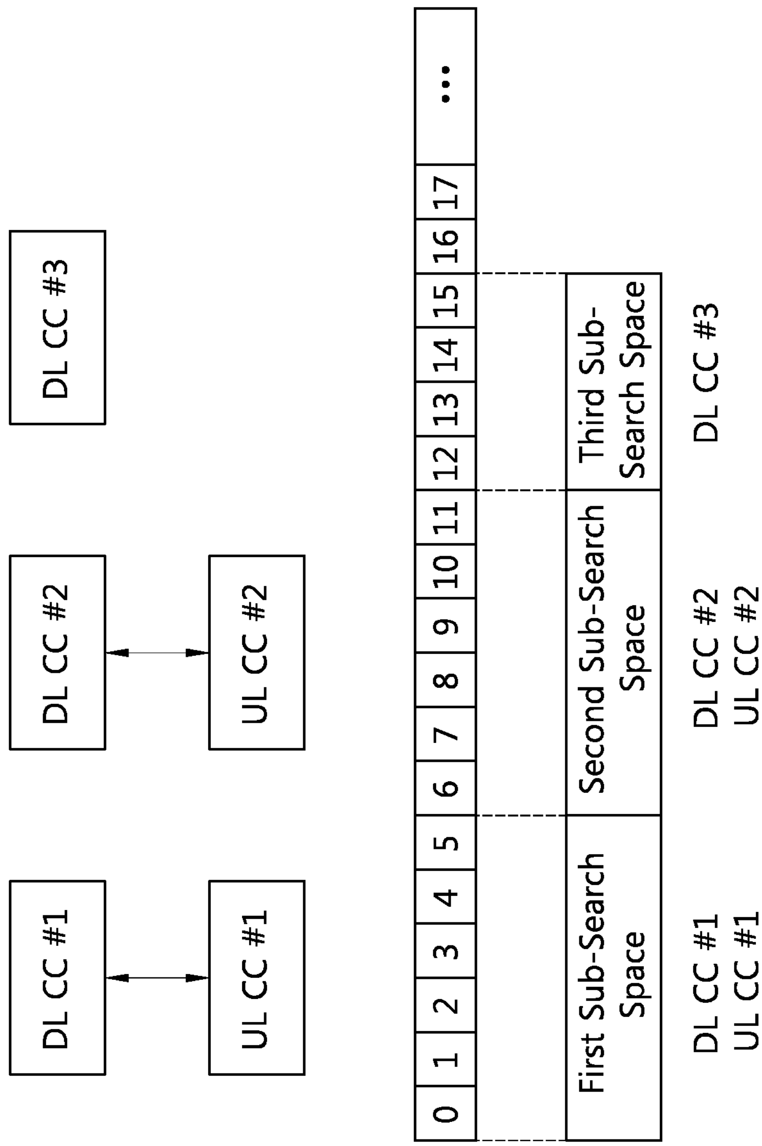
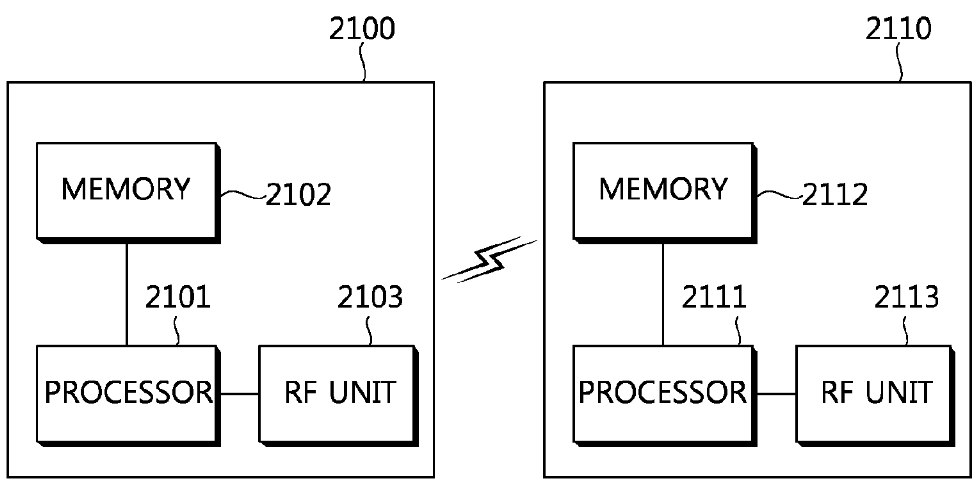

DL CC #1
DL CC #2
DL CC #3
UL CC #1
UL CC #2
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
...
First Sub-Search Space
Second Sub-Search Space
Third Sub-Search Space
DL CC #1
UL CC #1
DL CC #2
UL CC #2
DL CC #3

FIG. 18


2100
MEMORY
2102
2101
2103
PROCESSOR
RF UNIT
2110
MEMORY
2112
2111
2113
PROCESSOR
RF UNIT

DEVICE AND METHOD FOR MONITORING THE CONTROL CHANNEL IN A MULTICARRIER SYSTEM

CROSS REFERENCE TO RELATED APPLICATIONS

This application is a National Phase application of PCT/KR2010/003069 filed on May 14, 2010, which claims the benefit under 35 U.S.C. §119(e) of U.S. Provisional Application No. 61/178,053 filed on May 14, 2009, U.S. Provisional Application No. 61/285,547 filed on Dec. 11, 2009, U.S. Provisional Application No. 61/285,550 filed on Dec. 11, 2009, U.S. Provisional Application No. 61/292,435 filed on Jan. 5, 2010, U.S. Provisional Application No. 61/298,214 filed on Jan. 26, 2010, U.S. Provisional Application No. 61/307,861 filed on Feb. 25, 2010, U.S. Provisional Application No. 61/309,821 filed on Mar. 2, 2010, U.S. Provisional Application No. 61/318,791 field on Mar. 30, 2010, U.S. Provisional Application No. 61/323,877 filed on Apr. 14, 2010, U.S. Provisional Application No. 61/327,080 filed on Apr. 22, 2010, U.S. Provisional Application No. 61/328,607 filed on Apr. 27, 2010, and under 35 U.S.C. §119(a) to Patent Application No. 10-2010-0045370 filed in the Republic of Korea, on May 14, 2010. The entire contents of all of the above applications are hereby incorporated by reference.

TECHNICAL FIELD

The present invention relates to wireless communication. More specifically, the present invention relates to an apparatus and method for monitoring a control channel in a wireless communication system.

BACKGROUND ART

Although bandwidth is set differently between uplink and downlink, only one carrier is generally considered in the conventional wireless communication system. The carrier is defined by a center frequency and a bandwidth. A multiple carrier system uses a plurality of component carriers (CCs) having narrow bandwidth than full bandwidth.

A multiple carrier system can support backward compatibility for legacy systems and also increase data rate significantly through multiple carriers.

Long term evolution (LTE) based on 3rd Generation Partnership Project (3GPP) Technical Specification (TS) Release 8 is a promising, next-generation mobile communication standard. A 3GPP LTE system is a single carrier system supporting only one bandwidth (i.e., one CC) among 1.4, 3, 5, 10, and 20 MHz. However, LTE-Advanced (LTE-A), which is an evolved version of the 3GPP LTE, employs multiple carriers.

In a single carrier system, control channels and data channels are designed based on a single carrier. However, it can be inefficient if a multiple carrier system employs the channel structure of a single carrier system as it is.

DISCLOSURE

Technical Problem

The present invention provides a method and an apparatus for monitoring a control channel in a multiple carrier system.

The present invention also provides a method and an apparatus of transmitting a control channel in a multiple carrier system.

Technical Solution

In an aspect, a method for monitoring a control channel in a multiple carrier system is provided. The method includes determining an extended search space including a plurality of sub-search spaces in a control region of a subframe, each of the plurality of sub-search spaces corresponding to each of a plurality of scheduled component carriers, monitoring a downlink control channel for a scheduled component carrier corresponding to each of the plurality of sub-search spaces, and receiving downlink control information for a scheduled component carrier on a downlink control channel which is successfully decoded, wherein each of the plurality of sub-search spaces is separated from each other by an offset.

The offset may be determined based on an index of the corresponding scheduled component carrier.

The offset may be determined based on a carrier indicator field (CIF) indicating the corresponding scheduled component carrier.

The offset may have a positive or a negative value.

The offset may be determined based on the number of the plurality of scheduled component carriers.

The plurality of sub-search spaces may have the same size.

At least one of the plurality of sub-search spaces may have a different size from that of the remaining sub-search spaces.

In another aspect, a user equipment (UE) for monitoring a control channel in a multiple carrier system is provided. The UE includes a radio frequency unit configured to transmit and receive radio signals, and a processor operatively connected to the radio frequency unit and configured to determine an extended search space including a plurality of sub-search spaces in a control region of a subframe, each of the plurality of sub-search spaces corresponding to each of a plurality of scheduled component carriers, monitor a downlink control channel for a scheduled component carrier corresponding to each of the plurality of sub-search spaces, and receive downlink control information for a scheduled component carrier on a downlink control channel which is successfully decoded, wherein each of the plurality of sub-search spaces is separated from each other by an offset.

Advantageous Effects

Since control channels for multiple component carriers can be scheduled in a single subframe, a probability of control channel blocking can be reduced. Also, by reducing decoding complexity in an extended search space, a burden due to blind decoding and subsequently battery consumption of a user equipment can be reduced.

DESCRIPTION OF DRAWINGS

FIG. **1** illustrates the structure of a radio frame in a 3GPP LTE.

FIG. **2** is a diagram showing the structure of a downlink subframe in a 3GPP LTE.

FIG. **3** is an exemplary diagram showing the transmission of uplink data.

FIG. **4** is an exemplary diagram shown the reception of downlink data.

FIG. **5** is a block diagram showing the construction of a PDCCH.

FIG. **6** is a diagram showing an example of resource mapping of a PDCCH.

FIG. 7 is an exemplary diagram showing the monitoring of a PDCCH.

FIG. 8 is one example of multiple carriers.

FIG. 9 is one example of cross-carrier scheduling.

FIG. 10 is one example of a set of CCs.

FIG. 11 is one example of CIF setting.

FIG. 12 is another example of CIF setting.

FIG. 13 illustrates extended search space comprising multiple sub-search spaces.

FIG. 14 is an example of defining sub-search spaces according to CIF.

FIG. 15 illustrates one example of changing the order of component carriers.

FIG. 16 illustrates an extended search space according to one embodiment of the present invention.

FIG. 17 is an example illustrating an extended search space according to a UL/DL linkage.

FIG. 18 is a block diagram illustrating a wireless communication system in which the embodiments of the present invention are implemented.

MODE FOR INVENTION

A user equipment (UE) can be fixed or mobile, and may be referred to as another terminology, such as a mobile station (MS), a mobile terminal (MT), a user terminal (UT), a subscriber station (SS), a wireless device, a personal digital assistant (PDA), a wireless modem, a handheld device, etc.

A base station generally a fixed station that communicates with the UE and may be referred to as another terminology, such as an evolved node-B (eNB), a base transceiver system (BTS), an access point, etc.

Each base station provides a communication service for a particular geographical region (generally referred to as a cell). A cell can be further divided into a plurality of regions (referred to as sectors).

Hereinafter, downlink (DL) implies communication from the BS to the UE while uplink (UL) from the UE to the BS. In DL, a transmitter may be a part of the BS and a receiver may be a part of the UE. On the other hand, in UL, the transmitter may be a part of the UE and the receiver may be a part of the BS.

FIG. 1 illustrates the structure of a radio frame in a 3GPP LTE. The section 6 of 3GPP TS 36.211 V8.5.0 (2008-12) "Evolved Universal Terrestrial Radio Access (E-UTRA); Physical Channel and Modulation (Release 8)" may be incorporated herein by reference. A radio frame consists of 10 subframes indexed with 0 to 9. One subframe consists of 2 slots. A time required for transmitting one subframe is defined as a transmission time interval (TTI). For example, one subframe may have a length of 1 millisecond (ms), and one slot may have a length of 0.5 ms.

One slot may include a plurality of orthogonal frequency division multiplexing (OFDM) symbols in time domain. Since the 3GPP LTE uses orthogonal frequency division multiple access (OFDMA) in DL, the OFDM symbol is only for expressing one symbol period in the time domain, and there is no limitation in a multiple access scheme or terminologies. For example, the OFDM symbol may also be referred to as another terminology such as a single carrier frequency division multiple access (SC-FDMA) symbol, a symbol duration, etc.

Although it is described that one slot includes 7 OFDM symbols for example, the number of OFDM symbols included in one slot may vary depending on a length of a cyclic prefix (CP). According to 3GPP TS 36.211 V8.5.0 (2008-12), in case of a normal CP, one subframe includes 7 OFDM symbols, and in case of an extended CP, one subframe includes 6 OFDM symbols.

A primary synchronization signal (PSS) is transmitted to the last OFDM symbol of a first (first slot of the first subframe which has an index 0) and an eleventh slot (first slot of the sixth subframe which has an index 5). The PSS is used to obtain OFDM symbol synchronization or slot synchronization, and is related to a physical identity (ID). The primary synchronization code (PSC) is a sequence used for the PSS, and the 3GPP LTE uses three PSCs. One of the three PSCs is transmitted to the PSS according to the cell ID. The same PSC is used for each of the last OFDM symbol of the first and the 11-th slot.

A secondary synchronization signal (SSS) comprises a first SSS and a second SSS. The first SSS and the second SSS are transmitted from an OFDM symbol contiguous with the OFDM symbol to which the PSS is transmitted. The SSS is used for obtaining frame synchronization. The SSS is used for obtaining a cell ID along with the PSS. The first SSS and the second SSS use secondary synchronization codes (SSCs) different from each other. Each of the first SSS and the second SSS includes 31 subcarriers. On SSC has a length of 31 and two SSCs are included in the first SSS and the second SSS.

A physical broadcast channel (PBCH) is transmitted from preceding four OFDM symbols of the second slot of the first subframe. The PBCH carries system information essential for communication between the UE and the BS, and the system information transmitted through the PBCH is referred to as master information block (MIB). On the other hand, the system information transmitted to a physical downlink shared channel (PDSCH) indicated by a physical downlink control channel (PDCCH) is referred to as system information block (SIB).

As specified in the 3GPP TS36.211 V8.5.0 (2008-12), physical channels of the LTE can be classified into a data channel and a control channel, where the data channel includes a physical downlink shared channel (PDSCH) and a physical uplink shared channel (PUSCH); and the control channel includes a physical downlink control channel, a physical control format indicator channel, a physical hybrid-ARQ indicator channel (PHICH), and a physical uplink control channel.

FIG. 2 is a diagram showing the structure of a downlink subframe in a 3GPP LTE. A subframe includes a control region and a data region in time domain. The control region can include up to three preceding OFDM symbols of a first slot in the sub frame. The number of OFDM symbols included in the control region may vary. A PDCCH is allocated to the control region while a PDSCH is allocated to the data region.

A resource block (RB) is a resource allocation unit, and includes a plurality of subcarriers in one slot. For example, if one slot includes seven OFDM symbols in the time domain and an RB includes 12 subcarriers in the frequency domain, one RB can include 7*12 resource elements (REs).

A PCFICH transmitted from a first OFDM symbol of the subframe carries a control format indicator (CFI) regarding the number of OFDM symbols (i.e., the size of the control region) used for transmission of control channels in the subframe. The UE first receives the CFI over the PCFICH and then monitors the PDCCH.

A PHICH carries an positive-acknowledgement (ACK)/negative-acknowledgement (NACK) signal for uplink hybrid automatic repeat request (HARQ). The ACK/NACK signal for uplink data transmitted by the UE is transmitted on the PHICH.

Control information transmitted through the PDCCH is referred to as downlink control information (DCI). The DCI may include resource allocation of the PDSCH (this is referred to as a downlink grant), resource allocation of a PUSCH (this is referred to as an uplink grant), a set of transmit power control commands for individual UEs in any UE group and/or activation of a voice over Internet protocol (VoIP).

FIG. **3** is an exemplary diagram showing the transmission of uplink data. A UE receives an uplink resource assignment on a PDCCH **101** by monitoring PDCCHs in a downlink subframe. The UE transmits an uplink data packet on a PUSCH **102** which can be constructed by using the uplink resource assignment.

FIG. **4** is an exemplary diagram showing the reception of downlink data. A UE receives a downlink data packet on a PDSCH **152** indicated by a PDCCH **151**. The UE receives a downlink resource assignment on the PDCCH **151** by monitoring PDCCHs in a downlink subframe. The UE receives the downlink data packet on the PDSCH **152** indicated by the downlink resource assignment.

FIG. **5** is a block diagram showing a structure of a PDCCH. A BS determines a PDCCH format according to DCI to be transmitted to a UE. Thereafter, the BS attaches a cyclic redundancy check (CRC) to the DCI, and masks a unique identifier (referred to as a radio network temporary identifier (RNTI)) to the CRC according to an owner or usage of the PDCCH (block **510**).

If the PDCCH is for a specific UE, a unique identifier (e.g., cell-RNTI (C-RNTI)) of the UE may be masked to the CRC. Alternatively, if the PDCCH is for a paging message, a paging indication identifier (e.g., paging-RNTI (P-RNTI)) may be masked to the CRC. If the PDCCH is for system information, a system information identifier (e.g., system information-RNTI (SI-RNTI)) may be masked to the CRC. To indicate a random access response that is a response for transmission of a random access preamble of the UE, a random access-RNTI (RA-RNTI) may be masked to the CRC.

When the C-RNTI is used, the PDCCH carries control information for a specific UE (this is referred to as UE-specific control information), and when other RNTIs are used, the PDCCH carries common control information received by all or a plurality of UEs in a cell.

The CRC-attached DCI is encoded to generate coded data (block **520**). Encoding includes channel encoding and rate matching.

The coded data is modulated to generate modulation symbols (block **530**).

The modulation symbols are mapped to physical resource elements (REs) (block **540**). The modulation symbols are respectively mapped to the REs.

FIG. **6** shows exemplary resource mapping of a PDCCH. This can refer to the section 6.8 of 3GPP TS 36.211 V8.5.0 (2008-12). R**0** denotes a reference signal of a first antenna, R**1** denotes a reference signal of a second antenna, R**2** denotes a reference signal of a third antenna, and R**3** denotes a reference signal of a fourth antenna.

A control region in a subframe includes a plurality of control channel elements (CCEs). The CCE is a logical allocation unit used to provide the PDCCH with a coding rate depending on a radio channel state, and corresponds to a plurality of resource element groups (REGs). An REG includes a plurality of resource elements. According to a relationship between the number of CCEs and the coding rate provided by the CCEs, a PDCCH format and a possible number of bits of the PDCCH are determined.

One REG (indicated by a quadruple in FIG. **6**) includes 4 REs. One CCE includes 9 REGs. The number of CCEs used to configure one PDCCH may be selected from a set {1, 2, 4, 8}. Each element of the set {1, 2, 4, 8} is referred to as a CCE aggregation level.

A control channel including one or more CCEs performs interleaving in unit of REG unit, and is mapped to a physical resource after performing cyclic shift based on a cell identifier (ID).

FIG. **7** shows exemplary monitoring of a PDCCH. This can refer to the section 9 of 3GPP TS 36.213 V8.5.0 (2008-12). The 3GPP LTE uses blind decoding for PDCCH detection. In the blind decoding, a specific identifier is de-masked from a CRC of a PDCCH (referred to as a candidate PDCCH), and then CRC error checking is performed to determine whether the PDCCH is a control channel of an entity performing the blind decoding. A UE has no information about which position in the control region the PCDDH of the UE is transmitted from and which CCE aggregation level or DCI format is used for the transmission.

A plurality of PDCCHs can be transmitted in one subframe. A UE monitors a plurality of PDCCHs in every subframe. Monitoring is an operation of attempting PDCCH decoding by the UE according to a format of the monitored PDCCH.

The 3GPP LTE uses a search space to reduce an overload caused by blind decoding. The search space may be referred to as a monitoring set of CCEs for PDCCH. The UE monitors the PDCCH in the corresponding search space.

The search space is classified into a common search space and a UE-specific search space. The common search space is a space for searching for a PDCCH having common control information and consists of 16 CCEs indexed with 0 to 15. The common search space supports a PDCCH having CCE aggregation levels of {4, 8}. In the common search space, however, a PDCCH for UE-specific control information (e.g. DCI format 0, 1A) can also be transmitted. The UE-specific search space supports a PDCCH having CCE aggregation levels of {1, 2, 4, 8}.

Table 1 shows the number of PDCCH candidates to be monitored by a UE.

TABLE 1

Search Space Type	Aggregation level L	Size [In CCEs]	Number of PDCCH candidates	DCI formats
UE-specific	1	6	6	0, 1, 1A, 1B,
	2	12	6	1D, 2, 2A
	4	8	2	
	8	16	2	
Common	4	16	4	0, 1A, 1C,
	8	16	2	3/3A

The size of the search space is defined in the Table 1, and the starting position of the search space is different between the UE-specific search space and common search space. The starting position of the common search space is fixed regardless of subframe, but the starting position of the UE-specific search space may be determined every subframe and may be obtained based on a UE's identifier (e.g., C-RNTI), a CCE aggregation level and/or the slot number in the subframe. The UE-specific search space may be overlapped with the common search space if the starting position of the UE-specific search space is in the common search space.

In a aggregation level L∈{1,2,3,4}, a search space $S^{(L)}_k$ is defined as a set of PDCCH candidates. A CCE corresponding to a PDCCH candidate m of the search space S(L)k is expressed as shown:

$$L\cdot\{(Y_k+m) \bmod \lfloor N_{CCE,k}/L\rfloor\}+i, \qquad \text{[Equation 1]}$$

where i=0, 1, . . . , L−1, m=0, . . . , $M^{(L)}-1$ and $N_{CCE,k}$ is the total number of CCEs that can be used for transmission of PDCCHs in the control region of a subframe k. The control region includes a set of CCEs numbered from 0 to $N_{CCE,k}-1$. $M^{(L)}$ is the number of PDCCH candidates from a CCE aggregation level L in a given search space. In a common search space, Y_k is set to zero for two aggregation levels of L=4 and L=8. In the UE-specific search space of the aggregation level L, the variable Y_k is defined as shown:

$$Y_k=(A \cdot Y_{k-1}) \bmod D, \quad \text{[Equation 2]}$$

where $Y_{-1}=n_{RNTI}\neq 0$; A=39827; D=65537; k=floor(n_s/2); and n_s is the slot number in a radio frame.

When the UE monitors the PDCCH by using a C-RNTI, the DCI format and the search space to be monitored are determined according to a transmission mode of the PDSCH. The following table shows an example of PDCCH monitoring where a C-RNTI is allocated.

TABLE 2

Transmission mode	DCI Format	Search Space	Transmission mode of PDSCH according to PDCCH
Mode 1	DCI Format 1A	Common and UE-Specific	Single antenna port, port 0
	DCI Format 1	UE-Specific	Single antenna port, port 1
Mode 2	DCI Format 1A	Common and UE-Specific	Transmit diversity
	DCI Format 1	UE-Specific	Transmit diversity
Mode 3	DCI Format 1A	Common and UE-Specific	Transmit diversity
	DCI Format 2A	UE-Specific	CDD (Cyclic Delay Diversity) or Transmit diversity
Mode 4	DCI Format 1A	Common and UE-Specific	Transmit diversity
	DCI Format 2	UE-Specific	Closed-loop spatial multiplexing
Mode 5	DCI Format 1A	Common and UE-Specific	Transmit diversity
	DCI Format 1D	UE-Specific	MU-MIMO (Multi-user Multiple Input Multiple Output)
Mode 6	DCI Format 1A	Common and UE-Specific	Transmit diversity
	DCI Format 1B	UE-Specific	Closed-loop spatial multiplexing
Mode 7	DCI Format 1A	Common and UE-Specific	If the number of PBCH transmission ports is 1, single antenna port, port 0; otherwise, transmit diversity
	DCI Format 1	UE-Specific	Single antenna port, port 5
Mode 8	DCI Format 1A	Common and UE-Specific	If the number of PBCH transmission ports is 1, single antenna port, port 0; otherwise, transmit diversity
	DCI Format 2B	UE-Specific	Dual layer transmission (port 7 or 8) or single antenna port, port 7 or 8

Table 3 illustrates the usage of DCI format.

TABLE 3

DCI Format	Description
DCI Format 0	Used for PUSCH scheduling
DCI Format 1	Used for scheduling of one PDSCH codeword
DCI Format 1A	Used for compact scheduling of one PDSCH codeword and random access process
DCI Format 1B	Used for compact scheduling of one PDSCH codeword having free-coding information
DCI Format 1C	Used for very compact scheduling of one PDSCH codeword
DCI Format 1D	Used for compact scheduling of one PDSCH codeword having free-coding and power offset information
DCI Format 2	Used for PDSCH scheduling of UEs configured as closed loop spatial multiplexing
DCI Format 2A	Used for PDSCH scheduling of UEs configured as open-loop spatial multiplexing
DCI Format 3	Used for transmission of TPC command of PUCCH and PUSCH having two-bit power adjustment
DCI Format 3A	Used for transmission of TPC command of PUCCH and PPUSCH having one-bit power adjustment

Now, a multiple carrier system will be described.

The 3GPP LTE system supports a case where downlink bandwidth and uplink bandwidth are set differently under the premise that one component carrier (CC) is used. This implies that the 3GPP LTE is supported only for a case where the downlink bandwidth and the uplink bandwidth are equal to or different from each other in a situation where one CC is defined for each of a downlink and an uplink. For example, the 3GPP LTE may support up to 20 MHz, and supports only one CC for the uplink and the downlink even if the uplink bandwidth and the downlink bandwidth may be different from each other.

Spectrum aggregation (also referred to as bandwidth aggregation or carrier aggregation) is for supporting a plurality of CCs. The spectrum aggregation is introduced to support an increasing throughput, to prevent cost rising caused by introduction of a broadband radio frequency (RF) device, and to ensure compatibility with legacy systems. For example, when five CCs are assigned with a granularity of a carrier unit having bandwidth of 20 MHz, bandwidth of up to 100 MHz can be supported.

The spectrum aggregation can be classified into contiguous spectrum aggregation achieved between consecutive carriers in frequency domain and non-contiguous spectrum aggregation achieved between discontinuous carriers. The number of carriers aggregated in downlink may be different from the number of carriers aggregated in uplink. Symmetric aggregation is achieved when the number of downlink carriers is equal to the number of uplink carriers. Asymmetric aggregation is achieved when the number of downlink carriers is different from the number of uplink carriers.

CCs may have different sizes (i.e., bandwidths). For example, when five CCs are used to configure a band of 70 MHz, the band can be composed of 5 MHz carrier (CC #0)+20 MHz carrier (CC #1)+20 MHz carrier (CC #2)+20 MHz carrier (CC #3)+5 MHz carrier (CC #4).

FIG. **8** is one example of multiple carriers. The example shows three DL CCs and UL CCs respectively, but is not limited to the number above. Each DL CC transmits a PDCCH and a PDSCH independently; and each UL CC transmits a PUCCH and a PUSCH independently.

Hereinafter, a multiple carrier system implies a system supporting multiple carriers based on spectrum aggregation. In a multiple carrier system, contiguous spectrum aggregation and/or non-contiguous spectrum aggregation can be used; also, either of symmetric aggregation and asymmetric aggregation can be used.

In a multiple carrier system, a linkage can be defined between a DL CC and a UL CC. A linkage can be configured through EARFCN information included in downlink system information and is configured by using a fixed relationship between DL/UL Tx/Rx separation. A linkage implies a relationship mapping between a DL CC through which a

PDCCH carrying a UL grant is transmitted and a UL CC using the UL grant. Also, a linkage may imply a relationship mapping between a DL CC (or UL CC) through which data for HARQ are transmitted and a UL CC (or DL CC) through which HARQ ACK/NACK signal is transmitted. A BS can inform a UE of linkage information as part of a upper layer message such as RRC message or as part of system information. The linkage between a DL CC and a UL CC can be fixed but can be varied between cells/UEs.

Separate coding refers to a case where a PDCCH can carry control information regarding a resource assignment for a PDSCH/PUSCH corresponding to one carrier. That is, the PDCCH and the PDSCH; and the PDCCH and the PUSCH correspond to each other in the one-to-one manner. Joint coding refers to a case where one PDCCH can carry a resource assignment for PDSCHs/PUSCHs of a plurality of CCs. One PDCCH can be transmitted through one CC or through a plurality of CCs.

For clarity, PDCCH-PDSCH relation for downlink transmission is disclosed herein for separate coding but the present invention can be applied to PDCCH-PUSCH relationship for uplink transmission.

In a multiple carrier system, two methods can be used for CC scheduling.

In a first method, a pair of PDCCH-PDSCH is transmitted from one CC. This CC is referred to as a self-scheduling CC, which implies that a UL CC through which a PUSCH is transmitted becomes a CC linked to a DL CC through which the corresponding PDCCH is transmitted. In other words, the PDCCH either allocates a PDSCH resource on the same CC or allocates a PUSCH resource on the linked UL CC.

In a second method, independently of a DL CC through which a PDCCH is transmitted, determined is a DL CC through which a PDSCH is transmitted or a UL CC through which a PUSCH is transmitted. That is, the PDCCH and the PDSCH are transmitted from separate DL CCs or a PUSCH is transmitted through a UL CC not linked to the DL CC through which the PDCCH is transmitted, which is referred to as cross-carrier scheduling. The CC through which the PDCCH is transmitted is called a PDCCH cross-carrier, a monitoring cross-carrier, or a scheduling cross-carrier; the CC through which the PDSCH/PUSCH is transmitted is called a PDSCH/PUSCH cross-carrier or a scheduled cross-carrier.

Cross-carrier scheduling can be activated/deactivated for each UE and a cross-carrier scheduling activated UE can receive DCI in which a CIF is included. The UE can figure out which scheduled CC the control information is about, to which the PDCCH received from a CIF included in the DCI correspond.

A DL-UL linkage predefined by the cross-carrier scheduling can be overridden. That is, the cross-carrier scheduling can be used to schedule a different CC rather than the linked CC irrespective of the DL-UL linkage.

FIG. **9** is one example of cross-carrier scheduling. It is assumed that DL CC #1 is linked to UL CC #1; DL CC #2 is linked to UL CC #2; and DL CC #3 is linked to UL CC #3.

A first PDCCH **701** of DL CC #1 carries DCI about a PDSCH **702** of the same DL CC #1. A second PDCCH **711** of the DL CC #1 carries DCI about a PDSCH **712** of DL CC #2. A third PDCCH **721** of the DL CC #1 carries DCI about a PUSCH **722** of UL CC #3 which is not set up for linkage.

For cross-carrier scheduling, the DCI of a PDCCH can include a carrier indicator field (CIF). A CIF indicates a DL CC or a UL CC scheduled through the DCI. For example, the second PDCCH **711** can include a CIF indicating the DL CC #2. The third PDCCH **721** can include a CIF indicating the UL CC #3.

Also, the CIF of the third PDCCH **721** can take a CIF value corresponding to a DL CC rather than the CIF value corresponding to a UL CC. In other words, as the CIF of the third PDCCH **721** indicates the DL CC #3 linked to the UL CC #3, the PUSCH can indirectly indicate a scheduled UL CC #3. It is because if the DCI of a PDCCH includes PUSCH scheduling and the CIF indicates a DL CC, a UE can determine that the above situation corresponds to the PUSCH scheduling on a UL CC linked to a DL CC. Therefore, by using a CIF having a limited bit length (e.g., a CIF having three-bit length), a larger number of CCs can be indicated than a method for informing of all the DL/UL CCs.

A UE using cross-carrier scheduling is required to monitor a PDCCH of a plurality of scheduled CCs with respect to the same DCI format in a control region of one scheduling CC. For example, if a plurality of DL CCs have different transmission modes, each DL CC can monitor a plurality of PDCCHs having different DCI formats. Even if the same transmission mode is used for the plurality of DL CCs, as long as the bandwidth of each DL CC varies from one another, the size of payload of the DCI format is different under the same DCI format and a plurality of PDCCHs can be monitored.

Consequently, if cross-carrier scheduling is possible, a UE is required to monitor a PDCCH for a plurality of DCI in the control region of a monitoring CC according to the transmission mode and/or the bandwidth of each CC. Therefore, it is required to construct a search space which can support the PDCCH monitoring and to monitor the PDCCH.

First, in a multiple carrier system, the following terminologies are defined.

A UE DL CC set: a set of DL CCs scheduled for a UE to receive a PDSCH.

A UE UL CC set: a set of UL CCs scheduled for a UE to transmit a PUSCH.

A PDCCH monitoring set: A set of at least one DL CC performing PDCCH monitoring. A PDCCH monitoring set may be the same as the UE DL CC set or a subset of the UE DL CC set. A PDCCH monitoring set can include at least one of DL CCs in the UE DL CC set. Similarly, a PDCCH monitoring set can be defined separately independent of the UE DL CC set. A DL CC included in the PDCCH monitoring set can be configured such that self-scheduling for a linked UL CC is always possible.

The UE DL CC set, the UE UL CC set, and the PDCCH monitoring set can be configured to be cell-specific or UE-specific.

FIG. **10** is one example of a set of CCs. It is assumed that four DL CCs (DL CC #1, #2, #3, #4) from the UE DL CC set are allocated to a UE; two UL CCs (UL CC #1, #2) from the UE UL CC set are allocated to the UE; and two DL CCs (DL CC #2, #3) from the PDCCH monitoring set are allocated to the UE.

The DL CC #2 in the PDCCH monitoring set transmits a PDCCH about a PDSCH of the DL CC #1/#2 in the UE DL CC set and a PDCCH about a PUSCH of the UL CC #1 in the UE UL CC set. The DL CC #3 in the PDCCH monitoring set transmits a PDCCH about a PDSCH of the DL CC #3/#4 in the UE DL CC set and a PDCCH about a PUSCH of the UL CC #2 in the UE UL CC set.

A linkage can be established among CCs included in the UE DL CC set, the UE UL CC set, and the PDCCH monitoring set. In the example of FIG. **10**, a PDCCH-

PDSCH linkage is established between a scheduling CC, DL CC #2 and a scheduled CC, DL CC #1; and a PDCCH-PUSCH linkage is established between DL CC #2 and UL CC #1. Also, a PDCCH-PDSCH linkage is established between a scheduling CC, DL CC #3 and a scheduled CC, DL CC #4; and a PDCCH-PUSCH linkage is established between DL CC #3 and UL CC #2. A BS can inform the UE of information about the scheduling CC or the PDCCH-PDSCH/PUSCH linkage information through cell-specific signaling or terminal-specific signaling.

On the other hand, for the respective DL CCs in the PDCCH monitoring set, a DL CC and a UL CC may not be linked to each other. After linking a DL CC in the PDCCH monitoring set to a DL CC in the UE DL CC set, a UL CC for PUSCH transmission can be limited to a UL CC linked to a DL CC in the UE DL CC set.

A CIF can be set differently according to linkage of the UE DL CC set, the UE UL CC set, and the PDCCH monitoring set.

FIG. **11** is one example of CIF setting. The example shows four DL CCs indexed with 0 to 3, denoted by i. The example also includes two UL CCs indexed with 0 and 1, denoted by j. Linkage for the UE DL CC set, the UE UL CC set, and the PDCCH monitoring set is the same as the example of FIG. **10**.

A first PDCCH **801** of the DL CC #2 indicates the PDSCH **802** of the DL CC #1. The CIF in the first PDCCH **801** is 0, indicating the index of the DL CC #1.

A second PDCCH **811** of the DL CC #2 indicates the PUSCH **812** of the UL CC #1. The CIF in the second PDCCH **811** is 0, indicating the index of the UL CC #1. If DLCC and ULCC have a CIF value independent of each other, the CIF value is configured to be 0 to indicate the UL CC #1. Additionally, a flag field indicating whether a received DCI is a downlink grant or a uplink grant can be included in the second PDCCH **811**. Similarly, the CIF in the second PDCCH **811** may indicate the DL CC linked to the UL CC #1. Since the UL CC #1 is linked to the DL CC #1 or the DL CC #2 herein, the CIF in the second PDCCH **811** is either zero, indicating the DL CC #1 linked to the UL CC #1 or one, indicating the DL CC #2 linked to the UL CC #1. A UE can figure out that the second PDCCH **811** includes a uplink grant and corresponds to a PDCCH about the UL CC #1 linked to the DL CC #1 or the DL CC #2.

If the CIF is configured to indicate a DL CC linked to a UL CC, the CIF doesn't have to indicate the index of the UL CC but is configured to always indicate the index of the DL CC. Therefore, it may be argued that the index of a UL CC is determined according the index of a linked DL CC. A UE can figure out whether the CIF indicates a DL CC or a DL CC linked to a UL CC according to whether a resource assignment in the PDCCH is a downlink grant or a uplink grant.

A first PDCCH **821** of the DL CC #3 indicates a PDSCH **822** of the UL CC #2. The CIF in the first PDCCH **821** is set to be 1, indicating the index of the UL CC #2; or it can be set to be 2 (or 3), indicating the DL CC #3 (or the DL CC #4) linked to the UL CC #2.

A second PDCCH **831** of the DL CC #3 indicates a PDSCH **832** of the DL CC #4. The CIF in the first PDCCH **831** is 3, indicating the index of the DL CC #4.

FIG. **12** is another example of CIF setting. FIG. **12** includes five DL CCs and a PDCCH monitoring set includes DL CC #3 and DL CC #4. Different from the embodiment of FIG. **11**, the CIF has a relative index value with respect to a monitoring CC through which a PDCCH is transmitted. In other words, different from the embodiment of FIG. **11**, where the CIF value for a DL CC #1, #2, #3, and #4 was assigned 0, 1, 2, and 3 independent of a monitoring CC through which the PDCCH is transmitted and the PDCCH-PDSCH/PUSCH linkage, a relative CIF value is assigned to each DL CC with respect to the monitoring CC.

A scheduled DL CC linked to the DL CC #3 is DL CC #1, DL CC #2, and DL CC #3. DL CC #3, #1, and #2 are assigned with 0, 1, and 2, respectively as an index for CIF. The scheduled DL CC linked to the DL CC #4 is DL CC #4 and DL CC #5. Therefore, the DL CC #4 and #5 are assigned with 0 and 1 as an index for CIF.

In the figure, the CIF value is assigned to each scheduling CC in the ascending order with respect to a monitoring CC, but the CIF can also be assigned in the descending order.

A first PDCCH **901** of the DL CC #3 indicates a PDSCH **902** of the DL CC #3. The CIF in the first PDCCH **901** is 0. A second PDCCH **911** of the DL CC #3 indicates a PDSCH **912** of the DL CC #2. The CIF in the second PDCCH **911** is 1. A third PDCCH **921** of the DL CC #3 indicates a PDSCH **922** of the DL CC #1. The CIF in the third PDCCH **921** is 2.

A first PDCCH **951** of the DL CC #4 indicates a PDSCH **952** of the DL CC #4. The CIF in the PDCCH **951** is 0. A second PDCCH **961** of the DL CC #4 indicates a PDSCH **962** of the DL CC #5. The CIF in the second PDCCH **961** is 1.

By setting the CIF value with respect to a monitoring CC, the CIF can indicate all the DL CCs with a smaller number of bits than the number of bits representing the total number of DL CCs.

As described above, a method for assigning a CIF value independently for a PDCCH monitoring CC and a DL-UL linkage provides an advantage that much more CCs can be indicated by using a CIF having a limited bit length.

A monitoring CC can also be used as a reference for the CIF to indicate a UL CC for a PUSCH. In a similar way, the UL CC can be indicated indirectly as the CIF indicates a DL CC linked as described above.

Now, an extended search space according to an embodiment of the present invention will be described.

As shown in Table 1, in the 3GPP LTE system, a UE-specific search space defines six PDCCH candidates for each of the aggregation levels 1 and 2; and defines two PDCCH candidates for each of the aggregation levels 4 and 8. A common search space defines four PDCCH candidates for the aggregation level 4 and two PDCCH candidates for the aggregation level 8. This configuration is based on a single carrier and assumes that case where the same CC is used for transmission of the PDCCH-PDSCH.

In a multiple carrier system capable of cross-carrier scheduling, since multiple PDCCHs to be received by one UE can be transmitted through a single DL CC, chances are that the multiple PDCCHs may not be scheduled or a PDCCH blocking probability becomes high if only the number of existing PDCCH candidates is considered. It is because the number of PDCCHs that can be transmitted to a single DL CC is limited due to the number of PDCCH candidates although a more number of PDCCHs should be transmitted than the existing 3GPP LTE. Accordingly, flexibility for scheduling multiple PDCCHs may be degraded and the PDCCH blocking probability may be increased. The PDCCH blocking probability denotes a probability that PDCCH scheduling is not performed as search spaces for multiple UEs overlap.

Moreover, in a multi-cell environment such as a heterogeneous network, if a PDCCH-less CC is incorporated for interference coordination, it is probable that a large number of PDCCHs are concentrated on a particular DL CC. Thus, it may be difficult to accommodate scheduling a larger number of PDCCHs in a control region for a given size of a search space.

In a multiple carrier system, an extended search space is disclosed for extending the size of an insufficient search space when cross-carrier scheduling is employed.

If cross-carrier scheduling is used, multiple PDCCHs for one UE can be transmitted from a single DL CC. To secure a UE-specific search space needed for this purpose, size of the search space can be increased by increasing the number of PDCCH candidates for each aggregation level, which is referred to as an extended search space compared with the previous search space.

The following Tables 4 and 5 show examples of an increased search space.

TABLE 4

Search Space Type	Aggregation Level L	Size [in CCEs]	Number of PDCCH candidates
UE-specific	1	12	12
	2	24	12
	4	16	4
	8	32	4

TABLE 5

Search Space Type	Aggregation Level L	Size [in CCEs]	Number of PDCCH candidates
UE-specific	1	10	10
	2	20	10
	4	12	3
	8	24	3

In the above tables, the number of PDCCH candidates and size of the search space are examples introduced only for the description of embodiments.

Increase in the number of PDCCH candidates implies that an increased search space is provided. The increase of the number of PDCCH candidates for each aggregation level can be varied depending on carrier aggregation capability of each UE, blind decoding capability, and configuration due to a UE category and/or an upper layer.

Size of a search space can be varied according to UE-specific signaling such as RRC message and/or carrier allocation information. Alternatively, size of a search space can be varied according to the number of DL CCs included in a UE DL CC set, the number of UL CCs included in a UE UL CC set, and DL-UL linkage. Size of a search space can be varied depending on whether a particular DL CC can transmit both of a uplink grant and a downlink grant; or whether only one of the two grants can be transmitted.

Now, it is assumed that the number of DL CCs in a UE DL CC set is N, and the number of UL CCs in a UE UL CC set is M. ABS can inform a UE of N and M through RRC signaling.

Table 6 is one example where size of a search space is varied.

TABLE 6

Search Space Type	Aggregation Level L	Size [in CCEs]	Number of PDCCH candidates
UE-specific	1	1 × 6 × C	6 × C
	2	2 × 6 × C	6 × C
	4	4 × 6 × C	2 × C
	8	8 × 6 × C	2 × C

The C can be defined based on N and M. For example, C can be set to be the larger of N and M. As another example, if N≥M is always satisfied, a relationship of C=N can be established. In yet another example, C can be determined such as C=N+M. In still another example, C can be determined to be dependent on at least one of carrier aggregation capability, blind decoding capability, and a UE category.

Table 7 is one example where size of a search space is varied by using arbitrary parameters i and j.

TABLE 7

Search Space Type	Aggregation Level L	Size [in CCEs]	Number of PDCCH candidates
UE-specific	1	1 × i × C	i × C
	2	2 × i × C	i × C
	4	4 × j × C	j × C
	8	8 × j × C	j × C

The i and j can be determined to be dependent on at least one of carrier aggregation capability, blind decoding capability, and a UE category.

If it is assumed that a PDCCH monitoring set, a linked UE DL CC set, and/or a UE UL CC set are available, an extended search space can be defined more efficiently based on linkage.

If it is assumed that Qm is the total number of CCs in a PDCCH monitoring set; Qd is the total number of CCs in a UE DL CC set; and Qu is the total number of CCs in a UE UL CC set; and q is a CC index in the PDCCH monitoring set, q=0, 1, . . . , Qm−1.

Table 8 is one example where size of a search space is varied by using a parameter X.

TABLE 8

Search Space Type	Aggregation Level L	Size [in CCEs]	Number of PDCCH candidates
UE-specific	1	1 × 6 × X	6 × X
	2	2 × 6 × X	6 × X
	4	4 × 2 × X	2 × X
	8	8 × 2 × X	2 × X

X can be defined such that X=round(Qd/Qm), X=ceil(Qd/Qm), or X=floor(Qd/Qm). round(x) is a function that rounds off to the nearest integer. ceil(x) is a function that returns the minimum value from integers larger than or equal to x. floor(x) is a function that returns the maximum value from integers smaller than or equal to x.

Table 9 is one example where size of a search space is varied by using arbitrary parameters i and j.

TABLE 9

Search Space Type	Aggregation Level L	Size [in CCEs]	Number of PDCCH candidates
UE-specific	1	1 × i × X	i × X
	2	2 × i × X	i × X
	4	4 × j × X	j × X
	8	8 × j × X	j × X

The i and j are constants used to define an extended search space.

X can be defined for each monitoring CC in a PDCCH monitoring set. Now, it is assumed that X of a monitoring CC having an index q is Xq. Xq may be the number of PDSCH CCs that can be scheduled by the q-th PDCCH CC.

X in the Table 8 and 9 can be replaced with Xq. Xq can be expressed by the number of DL CCs linked to a monitoring CC having an index q or the number of UL CCs linked to a monitoring CC having an index q. For example, in the configuration of a CC set shown in FIG. **11**, a monitoring CC corresponds to DL CC #2 and DL CC #3. If q=0 and 1, respectively, X_1=2 and X_2=2. In configuration of a CC set shown in FIG. **12**, the monitoring CC is DL Cc #3 and DL CC #4. If q=0 and 1, respectively, X_1=3 and X_2=2.

Also, Xq can be defined by a DL CC that can be scheduled by a monitoring CC having an index q or a UL CC linkage. If it is assumed that X^dq is the number of DL CCs that can be scheduled by a monitoring CC having an index q; and X^uq is the number of UL CCs that can be scheduled by a monitoring CC having an index q, Xq can be defined such that Xq=X^dq+X^uq. Also, Xq can be determined to be the larger of X^dq and X^uq. In the configuration of a CC set shown in FIG. **11**, $X^d{}_0$=2, $X^u{}_0$=1, $X^d{}_1$=2, and $X^u{}_1$=1.

By adjusting the number of PDCCH candidates based on the parameter Xq for a monitoring CC, size of an extended search space can be adjusted according to the number of PDCCHs scheduled in the control region.

Size of an extended search space can be expressed by $C \cdot M^{(L)} \cdot L$. C is the number of scheduled CCs that can be scheduled at a PDCCH monitoring CC and $M^{(L)}$ is the number of PDCCH candidates in a CCE aggregation level L.

Now, a method for dividing a search space according to each CC in an extended search space will be described.

An extended search space is a UE-specific search space and its starting point can be defined the same as the existing 3GPP LTE. Since a UE in an extended search space monitors multiple PDCCHs for multiple CCs, the extended search space can be divided for each CC, which is called a sub-search space.

A sub-search space is a search space belonging to the extended search space and used for a UE to monitor a PDCCH for each CC. One sub-search space can be defined for a DL CC and a UL CC linked with each other or separate sub-search space can be defined for the DL CC and the UL CC.

FIG. **13** illustrates extended search space comprising multiple sub-search spaces. Now, it is assumed that an extended search space starts from a CCE having an index 4 from among CCE columns of the k-th subframe.

The extended search space comprises a first sub-search space, a second sub-search space, and a third sub-search space. N_1, N_2, and N_3 are CCE indices determined according to the size of each sub-search space. Each sub-search space is consecutive. Therefore, if it is assumed that a starting point of the foremost, first sub-search space (which is referred to as a reference sub-search space) coincides with the starting point of the extended search space and a UE knows the size of each sub-search space, starting points of the second and the third sub-search space can be known.

A starting point of an extended search space can be defined by Eqs. 1 and 2 in the same as the existing 3GPP LTE. A starting point of a reference sub-search space can be the same as that of the extended search space.

The starting point of the extended search space and the number of sub-search spaces are only examples and are not limited to the above description. An extended search space can comprise multiple sub-search spaces.

A BS can inform a UE of the information about a CC corresponding to each sub-search space. However, this may cause signaling overhead.

Therefore, in the disclosed method, sub-search spaces are defined according to a predetermined order of CCs. To this purpose, it is necessary to define a CC corresponding to a foremost, reference sub-search space in an extended search space.

A reference CC may correspond to a CC having the lowest CC index among scheduled CCs or a CC indicated with the lowest CIF. Also, a reference CC can correspond to a self-scheduling CC or a primary CC. The primary CC may correspond to a CC indicated as a primary CC among multiple CCs; or a CC through which fundamental system information is transmitted, being known to both of a BS and a UE as a primary CC.

After a reference sub-search space for a reference CC is defined, sub-search spaces for the remaining CCs can be defined sequentially with respect to the reference CC.

If a CC having the smallest CC index is defined as a reference CC among scheduled CCs, sub-search spaces for each scheduled CC can be defined in the ascending order of CC index.

If a self-scheduling CC or a primary CC is defined as a reference CC, a sub-search space for a CC having the smallest CC index among the remaining scheduled CCs is positioned to the next of the reference sub-search space and sub-search spaces for the remaining scheduled CCs can be defined in the ascending order of CC index.

A CC index can correspond to a CIF. As shown in FIG. **11**, a CIF can correspond to a CC index in a UE DL CC set or a UE UL CC set. Similarly, as shown in FIG. **12**, the CIF can correspond to a relative index with respect to a monitoring CC through which a PDCCH is transmitted.

FIG. **14** is an example of defining sub-search spaces according to CIF. Since DL CC #1 is a reference CC and CIF=0, a first search space is allocated. Since CIF of DL CC #3 is 1, a second search space is allocated. Since CIF of DL CC #2 is 2, which is the highest, a third search space is allocated.

In the case that a sub-search space is defined based on CIF, the CIF value mapped according to a setting of the CIF for a particular CC can be varied. Therefore, by allowing the positions of sub-search spaces for various scheduled CCs allocated to one UE to vary, overlapping of the positions of sub-search spaces repeatedly for particular CCs about a particular UE can be avoided.

In the above example, sub-search spaces are allocated in the ascending order of CCE index or CIF, but the sub-search spaces can also be allocated in the descending order of the CCE index or the CIF.

A reference CC may not be fixed, changing periodically or according to a predetermined pattern specified by a BS. Also, the order of CCs allocated to sub-search spaces can be changed periodically or according to a predetermined pattern specified by a BS. For example, at the initial stage, sub-search spaces are defined in the ascending order of the CC index and the CC index is cyclically shifted one by one in the next subframe.

FIG. **15** illustrates one example of changing the order of component carriers. For a subframe n, a CC with CIF=0 is designated as a reference CC and sub-search spaces are defined in the ascending order of CIF. In the next subframe n+p (p is an integer such that p≥1), CIF is cyclically shifted to the left one by one, thus defining sub-search spaces in the order of CIF=2, 0, 1.

When consecutive sub-search spaces are used, a reference sub-search space $S^{(L)}{}_{k,0}$ can be defined as follows by using equations 1 and 2.

$$S_{k,0}^{(L)}=L\cdot\{(Y_k+m)\bmod\lfloor N_{CCE,k}/L\rfloor\}+i \qquad \text{[Equation 3]}$$

A sub-search space $S^{(L)}_{k,p}$ except for the reference sub-search space can be defined as follows.

$$S_{k,p}^{(L)}=S_{k,0}^{(L)}+p\cdot L\cdot M^{(L)} \text{ or } S_{k,p}^{(L)}=S_{k,0}^{(L)}+P\cdot\cdot M^{(L)} \quad \text{[Equation 4]}$$

Here, P is the number of scheduled CC by a monitoring CC, where p=0, 1, . . . , P−1; L is a CCE aggregation level; $M^{(L)}$ is the number of PDCCH candidates at a CCE aggregation level L.

On the other hand, a sub-search space $S^{(L)}_{k,p}$ can be defined as follows.

$$S_{k,p}^{(L)}=L\cdot\{(Y_{k,p}+m)\bmod \lfloor N_{CCE,k}/L\rfloor\}+i \quad \text{[Equation 5]}$$

where

$$Y_{k,p}=S_{k,p-1}^{(L)}(m=M^{(L)}-1,i=L-1)+1.$$

When search spaces are constructed for the case of cross-carrier scheduling by using consecutive search spaces, the entire search space can be defined by the following equation.

$$S_{k}^{(L)}=L\cdot\{(Y_{k}+m\cdot P)\bmod \lfloor N_{CCE,k}/L\rfloor\}+i \quad \text{[Equation 6]}$$

Although the embodiment above indicates sub-search spaces, sub-search spaces within an extended search space may not be consecutive. That is, by defining an offset between sub-search spaces, each sub-search space may be separated from each other by the offset.

FIG. **16** illustrates an extended search space according to one embodiment of the present invention.

An extended search space comprises a first sub-search space, a second sub-search space, and a third sub-search space. The second sub-search space is defined being separated from the first sub-search space by a first offset f1; and the third sub-search space is defined being separated from the second sub-search space by a second offset f2.

Now, it is assumed that a starting point of an extended search space is a CCE indexed with 20 and size of each sub-search space at a CCE aggregation level 1 is 6 CCE and an offset is 3. If a starting point of a first sub-search space is the same as that of the extended search space, the first sub-search space corresponds to CCEs indexed with 20 to 25. A second sub-search space corresponds to CCEs indexed with 28 to 33. A third sub-search space corresponds to CCEs indexed with 36 to 41.

In this example, an offset corresponds to a space ranging from the end point of the previous sub-search space to the start point of the next sub-search space, but is not limited to the above. An offset can indicate a space ranging from one reference (e.g., start point of the extended search space) to the start point or the end point of the corresponding sub-search space. On the other hand, the offset may be represented as ranging from the start point of the previous sub-search space to the start point of the next sub-search space.

An offset can be a negative integer rather than a positive integer. A negative offset implies that at least two consecutive sub-search space can overlap with each other. A BS can inform a UE based on carrier capability and blind decoding capability of the UE about whether an offset is positive or negative.

If payload size of a DCI format is the same for each CC, an offset can be so configured that a part or the whole of a sub-search space is overlapped. If payload size of a DCI format is different, an offset can be so configured that a sub-search space is not overlapped.

An offset can be the same for each sub-search space or for each CC. On the other hand, a different offset can be configured for each sub-search space or CC.

An offset can be configured differently for each CCE aggregation level and can be set to be the same independently of a CCE aggregation level.

Construction of multiple sub-search spaces using an offset has an advantage in that a separate start point of a sub-search space should not necessarily be defined and a UE can employ an existing procedure for setting search spaces as it is. Also, by adjusting an offset, it can be so configured that a sub-search space is not overlapped or the whole or a part of a sub-search space can be overlapped.

CC index of a CC corresponding to a sub-search space can be used through an offset, which is made possible by assigning a different offset to each sub-search space.

CIF of a CC corresponding to a sub-search space can be used through an offset, which is made possible by assigning a different offset to each sub-search space.

A BS can inform a UE about an offset through RRC signaling or control information on a PDCCH. A BS, by taking account of scheduling of multiple UEs, can adjust the offset so that blocking against a search space is minimized.

An offset can be determined based on the size (i.e., the number of CCEs available for PDCCH transmission) of a control region within a subframe. For example, if size of a control region is increased, an offset is made large correspondingly while the offset is set to have a negative value if the size of the control region is not sufficiently large.

An offset can be determined based on the number of DL CCs belonging to a UE DL CC set and/or the number of UL CCs belonging to a UE UL CC set.

An offset can be determined based on the number of monitoring DL CCs belonging to a PDCCH monitoring set.

An offset can be determined by a relationship $f1=N_{CCE,k}/X1$. $N_{CCE,k}$ is the total number of CCEs of a monitoring CC within a control region of a subframe k and X1 is the number of scheduled CCs which can be scheduled in the monitoring CC. On the other hand, an offset can have an arbitrary value from 0~f1. An offset can be set to be a prime number larger than f1.

An offset can be determined by a relationship $f2=N_{CCE,k}/X2$. $N_{CCE,k}$ is the total number of CCEs of a monitoring CC within a control region of a subframe k and X2 is the number of scheduled CCs which can be scheduled within a cell. On the other hand, an offset can have an arbitrary value from 0~f2. An offset can be set to be a prime number larger than f2.

An offset can be varied in units of a subframe or it can be varied when the number of scheduled CCs is changed.

An offset can be determined based on an identifier (UE ID) of a UE (e.g., C-RNTI). An offset can be determined as UE ID+CC index, UE ID+CIF, UE ID mod CC index, UE ID mod CIF, UE ID mod X1, UE ID mod X2, etc.

An offset can be determined based on a subframe number (SFN) of a subframe through which a PDCCH is transmitted. SFN is a number of a subframe within a radio frame.

An offset can be determined based on a combination of UE ID and SFN.

An offset can be determined based on at least one from among UE ID, carrier specific information, and SFN. For example, the offset can be determined such as UE ID+CC index, UE ID+CIF+SFN, etc.

An offset can be determined by $N_{CCE,k}$/(LL*LS). LL is the size (e.g., LL=16 in the 3GPP LTE) of the largest CCE aggregation level among CCE aggregation levels available and LS is the number (e.g., LS=2) by which the largest CCE aggregation level can be allocated.

An offset can be generated based on a generation sequence. A generation sequence can use a random sequence and information such as UE ID, CC index, CIF, SFN, and $N_{CCE,k}$ can be used for initialization of the generation sequence.

The following shows an example of constructing a sub-search space by using an offset. Now, it is assumed that an offset for a p-th sub-search space is f_p and the number of PDCCH candidates in the p-th sub-search space is $M^{(L)}_p$. Y_k is a start point of a reference sub-search space and can be given from EQ. 2. If the start point Y_k of the reference sub-search space is selected as a reference, a start point $Y_{k,p}$ of the p-th sub-search space in a k-th subframe can be expressed in various ways as follows.

$$Y_{k,p}=[\{(A\cdot Y_{k-1})\bmod D\}+f_p] \bmod D \text{ or}$$

$$Y_{k,p}=(Y_k+f_p)\bmod D \text{ or}$$

$$Y_{k,p}=\{Y_k+(M_p^{(L)}-1)+f_p\} \bmod D \text{ or}$$

$$Y_{k,p}=[\{(A\cdot Y_{k-1})\bmod D\}\cdot f_p] \bmod D \text{ or}$$

$$Y_{k,p}=(Y_k\cdot f_p)\bmod D \text{ or}$$

$$Y_{k,p}=[\{Y^k+(M_p^{(L)}-1)\}\cdot f_p] \bmod D \quad \text{Equation 7}$$

Here, Y_{k-1}, A, and D can have the same value as in the existing 3GPP LTE or can have different values.

On the other hand, if a start point $Y_{k,p-1}$ of a previous sub-search space is selected as a reference, a start point $Y_{k,p}$ of a p-th sub-search space in a k-th subframe can be expressed in various ways as follows.

$$Y_{k,p}=[\{(A\cdot Y_{k-1,p})\bmod D\}+f_p] \bmod D \text{ or}$$

$$Y_{k,p}=[\{(A\cdot Y_{k-1,p-1})\bmod D\}+f_p] \bmod D \text{ or}$$

$$Y_{k,p}=(Y_{k,p-1}+f_p)\bmod D \text{ or}$$

$$Y_{k,p}=\{Y_{k,p-1}+(M_p^{(L)}-1)+f_p\} \bmod D \text{ or}$$

$$Y_{k,p}=[\{(A\cdot Y_{k-1,p})\bmod D\}\cdot f_p] \bmod D \text{ or}$$

$$Y_{k,p}=[\{(A\cdot Y_{k-1,p-1})\bmod D\}\cdot f_p] \bmod D \text{ or}$$

$$Y_{k,p}=(Y_{k,p-1}\cdot f_p)\bmod D \text{ or}$$

$$Y_{k,p}=[\{Y_{k,p-1}+(M_p^{(L)}-1)\}\cdot f_p] \bmod D \quad \text{[Equation 8]}$$

Expression derived from equations 7 and 8 by removing the last 'mod D' are equally possible.

Based on a start point of equations 7 and 8, a p-th sub-search space $S^{(L)}_{k,p}$ can be expressed as follows.

$$S_{k,p}^{(L)}=L\cdot\{(Y_{k,p}+m)\bmod \lfloor N_{CCE,k}/L\rfloor\}+i \quad \text{[Equation 9]}$$

If a reference sub-search space is defined as EQs. 1 and 2, a start point of a p-th sub-search space based on an offset can be defined as shown in EQs. 7 and 8 while the sub-search space can be defined as shown in EQ. 9.

If a sub-search space is defined by using an offset, a reference sub-search space $S^{(L)}_{k,0}$ can be defined as follows.

$$S_{k,0}^{(L)}=L\cdot\{(Y_k+m)\bmod \lfloor N_{CCE,k}/L\rfloor\}+i \quad \text{[Equation 10]}$$

An arbitrary (p−1)-th sub-search space $S^{(L)}_{k,p-1}$ rather than a reference sub-search space can be defined as follows.

$$S_{k,p-1}^{(L)}=L\cdot\{(Y_{k,p-1}+m)\bmod \lfloor N_{CCE,k}/L\rfloor\}+i \quad \text{[Equation 11]}$$

A p-th sub-search space $S^{(L)}_{k,p}$ from the (p−1)-th sub-search space can be defined by using an offset f_p as follows.

$$S_{k,p}^{(L)}=L\cdot\{(Y_{k,p}+m)\bmod \lfloor N_{CCE,k}/L\rfloor\}+i \quad \text{[Equation 12]}$$

Here, $Y_{k,p}=S_{k,p-1}^{(L)}(m=M^{(L)}-1, i=L-1)+f_p$.

Here, size of each sub-search space within an extended search space can be set to be the same with each other. However, the size of each sub-search space can be set differently according to the bandwidth of a CC corresponding to a sub-search space, linkage with a UL CC, payload size of the same DCI format, etc.

Now, a method for setting size of each sub-search space will be described.

The size of a sub-search space can be determined to be a value obtained by dividing the size of an extended search space by a particular parameter. For example, if the size of an extended search space is 12 CCE and the extended search space includes two sub-search spaces (i.e., two scheduled CCs), each sub-search space includes six CCEs. Here, a start point of each sub-search space can be determined from a start point of a reference sub-search space as described above. If a start point of a reference sub-search space corresponds to CCE index 0, the reference sub-search space includes CCEs indexed with 0 to 5 and the next sub-search space includes CCEs indexed with 6 to 11. Once an offset is determined, a start point of the next sub-search space may be larger or smaller than CCE index 6.

As shown in Table 6, when an extended search space is defined by {6×C, 6×C, 2×C, 2×C} PDCCH candidates for the respective CCE aggregation levels of {1, 2, 4, 8}, a start point of a p-th (p>1) sub-search space can be selected as ($Y_{k,p-1}$+6*c) or ($Y_{k,p-1}$+2*c) according to a CCE aggregation level. $Y_{k,p-1}$ is a start point of a (p−1)-th sub-search space and $Y_{k,0}$ is a start point of an extended search space (or a start point of a reference sub-search space), where c=0, 1, . . . , C−1.

On the other hand, as shown in Table 7, when an extended search space is defined by {i×C, i×C, j×C, j×C} PDCCH candidates for the respective CCE aggregation levels of {1, 2, 4, 8}, a start point of a p-th sub-search space can be selected as ($Y_{k,p-1}$+i*c) or ($Y_{k,p-1}$+j*c) according to a CCE aggregation level.

The above can be applied in the same way to an extended search space defined by Tables 8 and 9.

The above can be equally applied to a case when an offset f is assigned to each sub-search space. In the example of Table 7, a start point of a p-th sub-search space can be selected as ($Y_{k,p-1}$+f+i*c) or ($Y_{k,p-1}$+f+j*c).

To give a more specific example, it is assumed that an extended search space includes two sub-search spaces. It is further assumed that an extended search space includes {12, 12, 4, 4} CCE columns for CCE aggregation levels of {1, 2, 4, 8} and a start point of an extended search space for each CCE aggregation level corresponds to CCE index of {0, 4, 10, 20} among the whole of CCE columns.

At CCE aggregation level L=1, an extended search space includes CCEs indexed with 0 to 11. If two sub-search spaces are consecutive, a first sub-search space includes CCEs indexed with 0 to 5 while a second sub-search space includes CCEs indexed with 6 to 11. If an offset f is determined, the first sub-search space includes CCEs indexed with 0 to 5 and the second sub-search space includes CCEs indexed with 6+f to 11+f.

At CCE aggregation level L=2, an extended search space includes CCEs indexed with 4 to 15. If two sub-search spaces are consecutive, a first sub-search space includes CCEs indexed with 4 to 9 while a second sub-search space includes CCEs indexed with 10 to 15. If an offset f is determined, the first sub-search space includes CCEs indexed with 4 to 9 and the second sub-search space includes CCEs indexed with 10+f to 15+f.

At CCE aggregation level L=4, an extended search space includes CCEs indexed with 10 to 13. If two sub-search spaces are consecutive, a first sub-search space includes CCEs indexed with 10 to 11 while a second sub-search space includes CCEs indexed with 12 to 13. If an offset f is determined, the first sub-search space includes CCEs indexed with 10 to 11 and the second sub-search space includes CCEs indexed with 12+f to 13+f.

At CCE aggregation level L=8, an extended search space includes CCEs indexed with 20 to 23. If two sub-search spaces are consecutive, a first sub-search space includes CCEs indexed with 20 to 21 while a second sub-search space includes CCEs indexed with 22 to 23. If an offset f is determined, the first sub-search space includes CCEs indexed with 20 to 21 and the second sub-search space includes CCEs indexed with 22+f to 23+f.

As shown in Table 3, in the 3GPP LTE, DCI format for a uplink grant used for PUSCH scheduling is referred to as DCI format 0. Payload size of DCI format 0 is always the same as DCI format 1A for a downlink grant. Therefore, in the DCI format 0 and the DCI format 1A, a flag is included for differentiating the DCI format 0 and the DCI format 1A. The DCI format 0 and the DCI format 1A are decoded blindly in the same search space. That is, different DCI formats are monitored within one search space.

To support multiple carriers, a new DCI format can be defined in addition to the DCI format of Table 3. And bandwidth or transmission mode of each CC can be defined independently. Therefore, when an extended search space is designed, it is necessary to take account of a uplink grant and a downlink grant monitored in the same search space.

FIG. **17** is an example illustrating an extended search space according to a UL/DL linkage. Now it is assumed that an extended search space includes a first, a second, and a third sub-search space and the start point is CCE index 0.

DL CC #1 is linked to UL CC #1 and DL CC #2 is linked to UL CC #2. No UL CC is linked to DL CC #3.

A first sub-search space is used to monitor PDCCH for a downlink grant for DL CC #1 and a uplink grant for UL CC #1.

A second sub-search space is used to monitor PDCCH for a downlink grant for DL CC #2 and a uplink grant for UL CC #2.

A third sub-search space is used to monitor PDCCH for a downlink grant for DL CC #3.

In the same way as the 3GPP LTE, it is so configured that a downlink grant and a uplink grant can all be monitored in one sub-search space. However, among multiple DL CCs, some DL CC may not be linked to UL CC. Since the third sub-search space is intended for DL CC #3 which is not linked to Ul CC, it is not necessary for a UE to monitor PDCCH for a uplink grant.

The size of a sub-search space used for monitoring both of a downlink grant and a uplink grant may be different from the size of a sub-search space used for monitoring a downlink grant (or uplink grant) only. For example, although the size of the first sub-search space is the same as that of the second sub-search space, the size of the third sub-search space is made to be smaller than that of the first and the second sub-search space.

Since only the downlink grant can be scheduled in the third sub-search space, reducing the size causes no burden on the scheduling of a BS. Also, due to the reduced size of a search space, burden on blind decoding of a UE can be reduced.

So far, it has been assumed that the size of the first and the second sub-search space is 6 CCE and the size of the third sub-search space is 4 CCE. However, size of a sub-search space and the number of sub-search spaces within an extended search space are not limited to the above description.

The above embodiments describe communication between a BS and a UE. In the case where a relay is involved, too, technical principles of the present invention can be applied to the communication between a BS and the relay and/or communication between the relay and a UE. If the present invention is applied to the communication between a BS and a relay, the relay can perform the function of a UE. If the present invention is applied to the communication between a relay and a UE, the relay can perform the function of a BS. Unless otherwise indicated, a UE can function as a UE or a relay.

FIG. **18** is a block diagram illustrating a wireless communication system in which the embodiments of the present invention are implemented. The embodiment of an extended search space described above can be implemented by a BS and a UE.

A BS **2100** comprises a processor **2101**, a memory **2102**, and a radio frequency (RF) unit **2103**.

A processor **2101** implements a disclosed function, a disclosed procedure, and/or a disclosed method. In the embodiment described above, operation of a BS can be implemented by the processor **2101**. The processor **2101** can support operation for multiple carriers and configure a downlink physical channel in the extended search space described above.

A memory **2102**, being connected to the processor **2101**, stores protocol or parameters for operation of multiple carriers. An RF unit **2103**, being connected to the processor **2101**, transmits and/or receives radio signals.

A UE **2110** comprises a processor **2111**, a memory **2112**, and an RF unit **2113**.

The processor **2111** implements a disclosed function, a disclosed procedure, and/or a disclosed method. The operation of a UE in the embodiment described above can be implemented by the processor **2111**. The processor **2111** can support operation of multiple carriers and monitor a PDCCH about multiple CCs in an extended search space.

A memory **2112**, being connected to the processor **2111**, stores protocol or parameters for operation of multiple carriers. An RF unit **2113**, being connected to the processor **2111**, transmits and/or receives radio signals.

The processor **2101**, **2111** can include application-specific integrated circuit (ASIC), other chipsets, logical circuits and/or a data processing apparatus. The memory **2102**, **2112** can include read-only memory (ROM), random access memory (RAM), a flash memory, a memory card, storage medium and/or other storage devices. The RF unit **2103**, **2113** can include a baseband circuit for processing radio signals. If embodiments are implemented by software, the techniques described above can be implemented in a module (procedures, functions, etc.) which carries out the functions described above. A module can be stored in the memory **2102**, **2112** and can be carried out by the processor **2101**, **2111**. The memory **2102**, **2112** can be installed inside or outside the processor **2101**, **2111** and can be connected to the processor **2101**, **2111** through various well-known means.

In the above exemplary systems, although the methods have been described on the basis of the flowcharts using a series of the steps or blocks, the present invention is not limited to the sequence of the steps, and some of the steps may be performed at different sequences from the remaining steps or may be performed simultaneously with the remaining steps. Furthermore, those skilled in the art will understand that the steps shown in the flowcharts are not exclusive and may include other steps or one or more steps of the flowcharts may be deleted without affecting the scope of the present invention.

The above-described embodiments include various aspects of examples. Although all possible combinations for describing the various aspects may not be described, those skilled in the art may appreciate that other combinations are possible. Accordingly, the present invention should be construed to include all other replacements, modifications, and changes which fall within the scope of the claims.

The invention claimed is:

1. A method for monitoring a control channel in a multiple carrier system, the method performed by one user equipment (UE), the method comprising:

receiving information related to a carrier indicator field (CIF) which indicates at least one specific component carrier among a plurality of component carriers;

determining whether the CIF is configured;

determining a plurality of search spaces in a control region of a subframe based on the determination that the CIF is configured,

wherein the plurality of search spaces exist in the at least one specific component carrier among the plurality of component carriers;

monitoring a downlink control channel within each of the plurality of search spaces; and

receiving downlink control information for the at least one specific component carrier on the downlink control channel which is successfully decoded,

wherein each of the plurality of search spaces for monitoring the downlink control channel is determined by a respective offset,

wherein the respective offset is generated based on the CIF which indicates the at least one specific component carrier, and

wherein offsets for the plurality of search spaces are different from each other.

2. The method of claim **1**, wherein the respective offset has a positive or a negative value.

3. The method of claim **1**, wherein the respective offset is generated further based on a number of the plurality of component carriers.

4. The method of claim **1**, wherein the plurality of search spaces all have the same size.

5. The method of claim **1**, wherein at least one of the plurality of search spaces has a size different from a size of all remaining ones of the plurality of search spaces.

6. The method of claim **5**, wherein the at least one of the plurality of search spaces is used for monitoring a downlink grant or an uplink grant.

7. The method of claim **6**, wherein the at least one of the plurality of search spaces is smaller than the remaining ones of the plurality of search spaces.

8. The method of claim **5**, wherein the remaining ones of the plurality of search spaces are used for monitoring a downlink grant and an uplink grant.

9. The method of claim **1**, wherein the determining of the plurality of search spaces includes determining control channel elements (CCEs) for the plurality of search spaces.

10. The method of claim **1**, further comprising:

receiving a cross-carrier scheduling configuration indicating that the at least one specific component carrier carries the downlink control channel.

11. The method of claim **10**, wherein the at least one specific component carrier corresponds to a physical downlink control channel (PDCCH)-less carrier.

12. The method of claim **1**, further comprising:

receiving information on a physical downlink control channel (PDCCH) monitoring set which indicates at least one of the plurality of component carriers on which the UE has to perform the monitoring.

13. A user equipment (UE) for monitoring a control channel in a multiple carrier system, the UE comprising:

a radio frequency unit configured to transmit and receive radio signals; and

a processor operatively connected to the radio frequency unit and configured to:

receive information related to a carrier indicator field (CIF) which indicates at least one specific component carrier among a plurality of component carriers;

determine whether the CIF is configured;

determine a plurality of search spaces in a control region of a subframe based on the determination that the CIF is configured,

wherein the plurality of search spaces exist in the at least one specific component carrier among the plurality of component carriers;

monitor a downlink control channel within each of the plurality of search spaces; and

receive downlink control information for the at least one specific component carrier on the downlink control channel which is successfully decoded,

wherein each of the plurality of search spaces for monitoring the downlink control channel is determined by a respective offset,

wherein the respective offset is generated based on the CIF which indicates the at least one specific component carrier, and

wherein offsets for the plurality of search spaces are different from each other.

14. The UE of claim **13**, wherein the plurality of search spaces all have the same size.

15. The UE of claim **13**, wherein at least one of the plurality of search spaces has a size different from a size of all remaining ones of the plurality of search spaces.

16. The UE of claim **13**, wherein the processor is further configured to receive a cross-carrier scheduling configuration indicating that the at least one specific component carrier carries the downlink control channel.

17. The UE of claim **16**, wherein the at least one specific component carrier corresponds to a physical downlink control channel (PDCCH)-less carrier.

18. The UE of claim **13**, wherein the processor is further configured to receive information on a physical downlink control channel (PDCCH) monitoring set which indicates at least one of the plurality of component carriers on which the UE has to perform the monitoring.

* * * * *