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WO 2012/053715 A1 **WO 2010/085909 A1**
US 20110194536 A1 **US 20090060088 A1**

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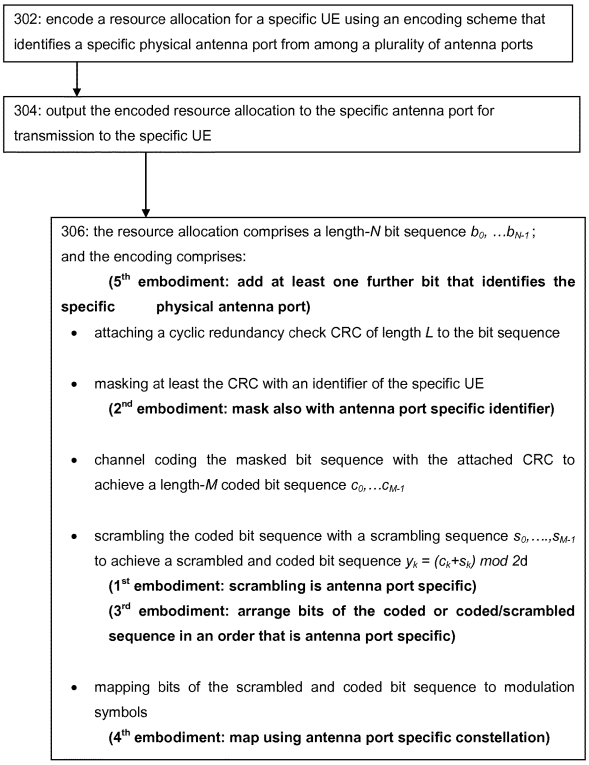
INT CL **H04B, H04L, H04W**
Other: **WPI EPODOC TXTE INSPEC XP3GPP**

(54) Title of the Invention: **Method and apparatus for configuring a resource allaocation**
Abstract Title: **Identifying a specific antenna port using a CRC masking encoding scheme**

(57) A resource allocation for a specific user equipment (UE) is encoded using an encoding scheme that identifies a specific antenna port from among a plurality of antenna ports; and the encoded resource allocation is output to the specific antenna port for transmission to the specific UE. The encoding scheme comprises attaching a cyclic redundancy check (CRC) and masking it with an identifier of the specific UE. The UE blindly detects its control channel and determines its resource allocation by decoding the control channel using a decoding scheme that identifies a specific antenna port from among the plurality of transmit antenna ports. In various embodiments, the scheme is in scrambling or masking (using an ID of the antenna port or UE); by the order of bits when encoding, port specific mapping constellations, and adding bits that give the port index.



302: encode a resource allocation for a specific UE using an encoding scheme that identifies a specific physical antenna port from among a plurality of antenna ports

304: output the encoded resource allocation to the specific antenna port for transmission to the specific UE

306: the resource allocation comprises a length-*N* bit sequence $b_0, \ldots b_{N-1}$; and the encoding comprises:

(5th embodiment: add at least one further bit that identifies the specific physical antenna port)

- attaching a cyclic redundancy check CRC of length *L* to the bit sequence
- masking at least the CRC with an identifier of the specific UE
  (2nd embodiment: mask also with antenna port specific identifier)
- channel coding the masked bit sequence with the attached CRC to achieve a length-*M* coded bit sequence $c_0, \ldots c_{M-1}$
- scrambling the coded bit sequence with a scrambling sequence $s_0, \ldots, s_{M-1}$ to achieve a scrambled and coded bit sequence $y_k = (c_k + s_k) \bmod 2$d
  (1st embodiment: scrambling is antenna port specific)
  (3rd embodiment: arrange bits of the coded or coded/scrambled sequence in an order that is antenna port specific)
- mapping bits of the scrambled and coded bit sequence to modulation symbols
  (4th embodiment: map using antenna port specific constellation)

Figure 3

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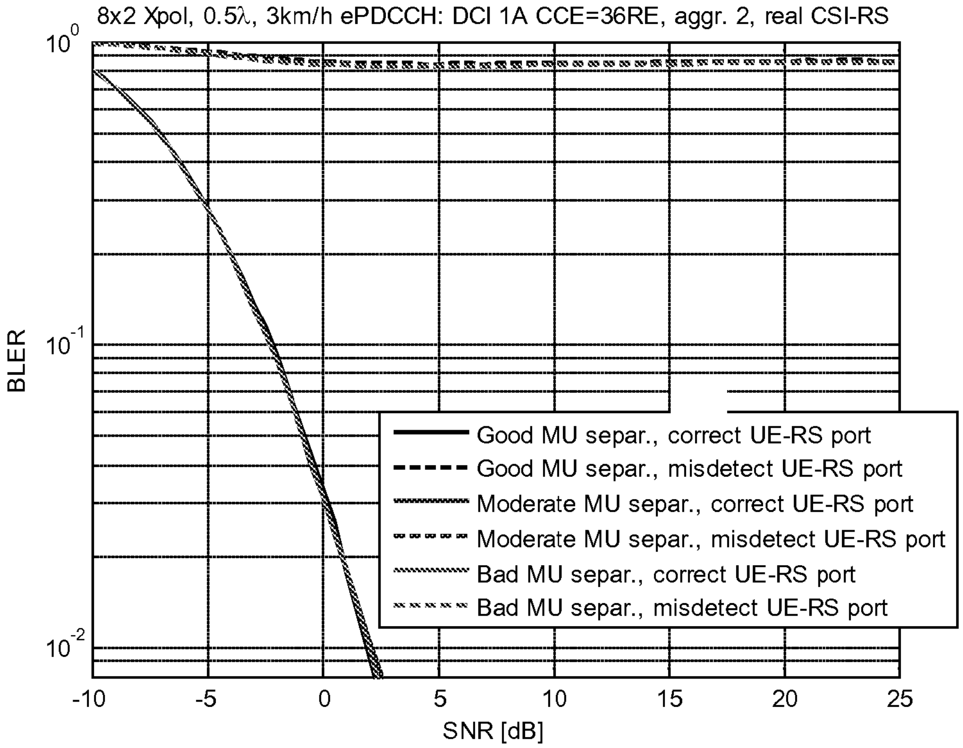


Figure 1

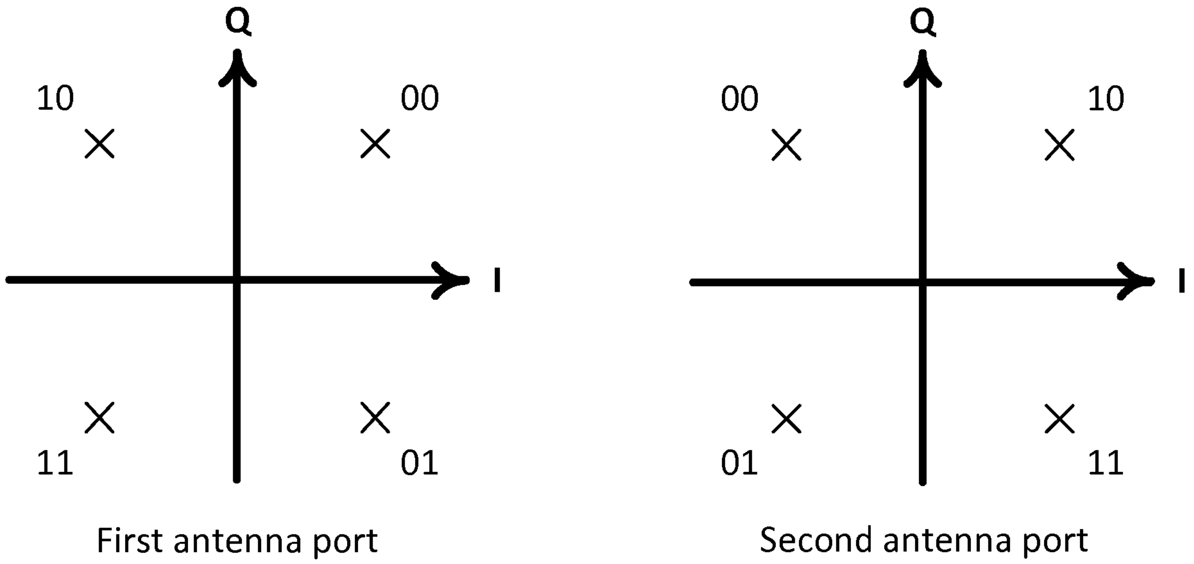
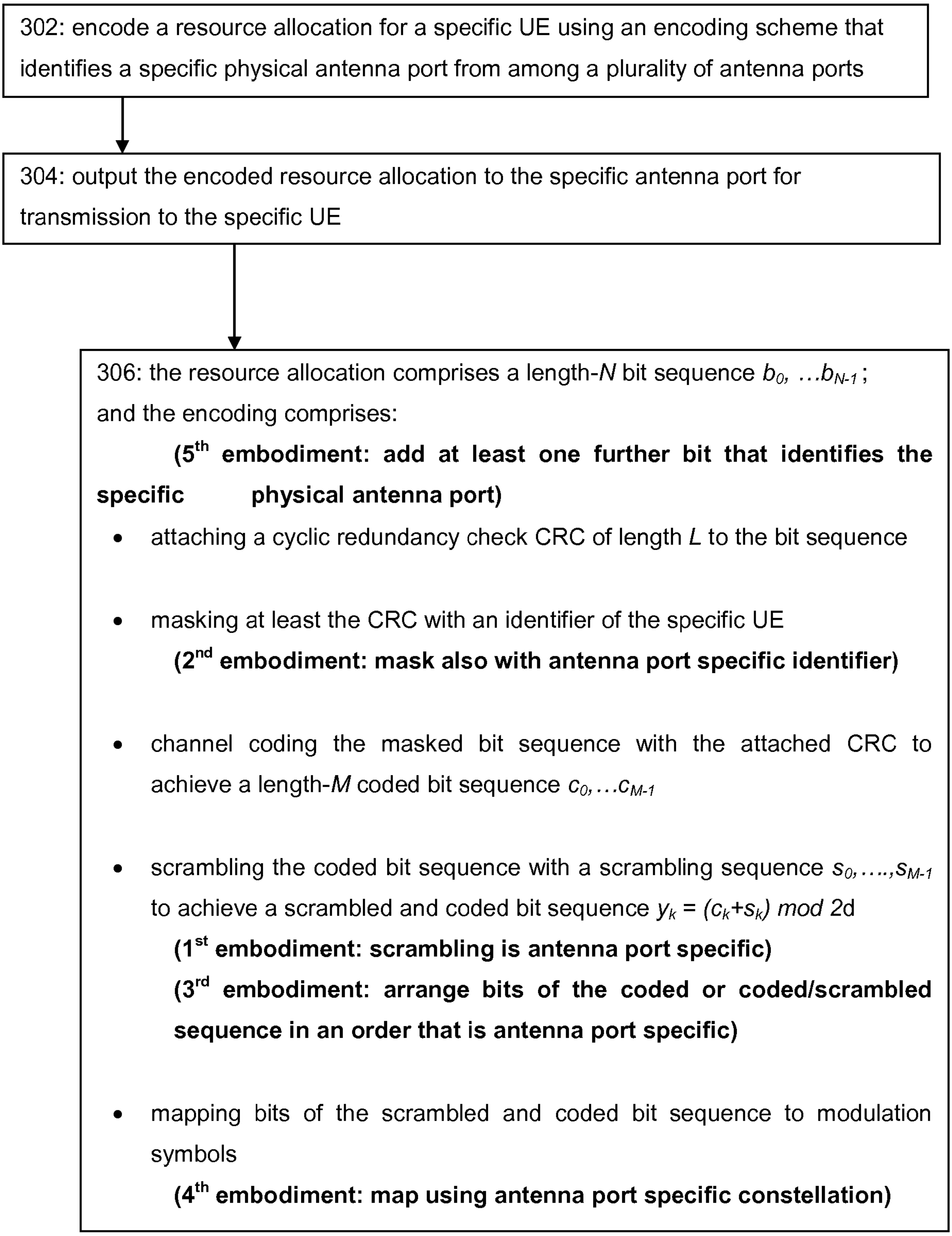


Figure 2



302: encode a resource allocation for a specific UE using an encoding scheme that identifies a specific physical antenna port from among a plurality of antenna ports

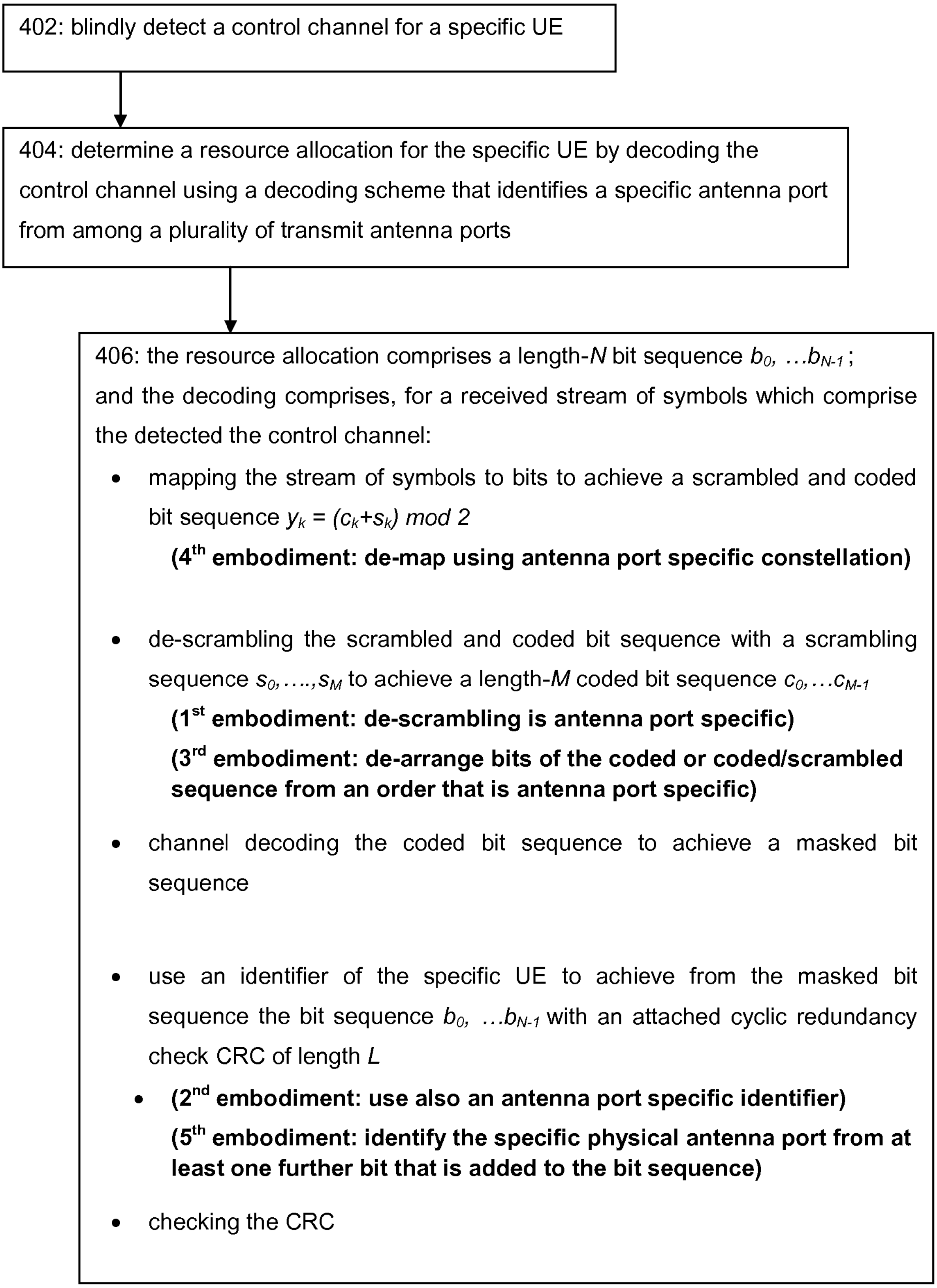
304: output the encoded resource allocation to the specific antenna port for transmission to the specific UE

306: the resource allocation comprises a length-N bit sequence $b_0, \ldots b_{N-1}$;
and the encoding comprises:

(5th embodiment: add at least one further bit that identifies the specific physical antenna port)

- attaching a cyclic redundancy check CRC of length L to the bit sequence
- masking at least the CRC with an identifier of the specific UE
  (2nd embodiment: mask also with antenna port specific identifier)
- channel coding the masked bit sequence with the attached CRC to achieve a length-M coded bit sequence $c_0, \ldots c_{M-1}$
- scrambling the coded bit sequence with a scrambling sequence $s_0, \ldots, s_{M-1}$ to achieve a scrambled and coded bit sequence $y_k = (c_k+s_k)\ mod\ 2$d
  (1st embodiment: scrambling is antenna port specific)
  (3rd embodiment: arrange bits of the coded or coded/scrambled sequence in an order that is antenna port specific)
- mapping bits of the scrambled and coded bit sequence to modulation symbols
  (4th embodiment: map using antenna port specific constellation)

Figure 3



402: blindly detect a control channel for a specific UE

404: determine a resource allocation for the specific UE by decoding the control channel using a decoding scheme that identifies a specific antenna port from among a plurality of transmit antenna ports

406: the resource allocation comprises a length-N bit sequence $b_0, \ldots b_{N-1}$;
and the decoding comprises, for a received stream of symbols which comprise the detected the control channel:

- mapping the stream of symbols to bits to achieve a scrambled and coded bit sequence $y_k = (c_k+s_k) \bmod 2$
  (4th embodiment: de-map using antenna port specific constellation)
- de-scrambling the scrambled and coded bit sequence with a scrambling sequence $s_0,\ldots,s_M$ to achieve a length-M coded bit sequence $c_0,\ldots c_{M-1}$
  (1st embodiment: de-scrambling is antenna port specific)
  (3rd embodiment: de-arrange bits of the coded or coded/scrambled sequence from an order that is antenna port specific)
- channel decoding the coded bit sequence to achieve a masked bit sequence
- use an identifier of the specific UE to achieve from the masked bit sequence the bit sequence $b_0, \ldots b_{N-1}$ with an attached cyclic redundancy check CRC of length L
  - **(2nd embodiment: use also an antenna port specific identifier)**
    (5th embodiment: identify the specific physical antenna port from at least one further bit that is added to the bit sequence)
- checking the CRC

Figure 4

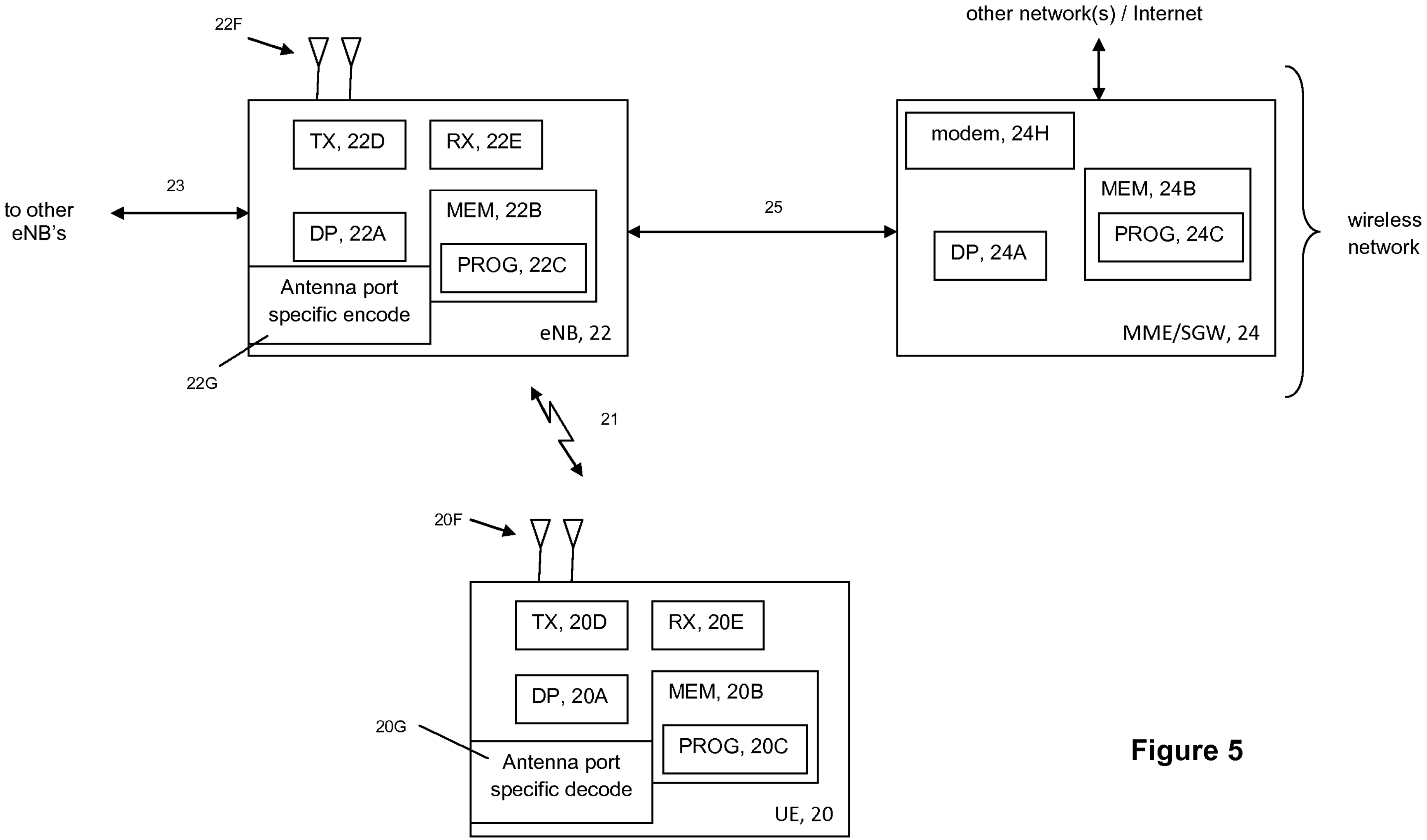

22F
other network(s) / Internet
TX, 22D
RX, 22E
modem, 24H
23
to other
eNB's
DP, 22A
MEM, 22B
PROG, 22C
25
MEM, 24B
PROG, 24C
DP, 24A
wireless
network
Antenna port
specific encode
eNB, 22
MME/SGW, 24
22G
21
20F
TX, 20D
RX, 20E
DP, 20A
MEM, 20B
PROG, 20C
20G
Antenna port
specific decode
UE, 20

Figure 5

Method and apparatus for configuring a resource allocation

Technical Field

The exemplary and non-limiting embodiments of this invention relate generally to wireless communication systems, methods, devices and computer programs for configuring a resource allocation; more specifically, embodiments relate to arranging control signaling such that a UE receiving a control channel (such as an E-PDCCH in the LTE system) will not successfully decode the control channel using an incorrect port configuration the UE assumes for the eNB.

Background

Abbreviations used in this description and/or in the referenced drawings are defined below following the Detailed Description section.

These teachings relate to substantially reducing the relatively high probability that currently exists for a UE to decode the E-PDCCH using an incorrect assumption of the eNB's antenna port configuration, yet the decoding still passes the CRC and so the UE believes it has the correct port configuration. The problem arises in part because the E-PDCCH supports UE-specific RSs which are precoded and so the eNB's antenna port configuration for the E-PDCCH is not necessarily fixed, whereas the conventional PDCCH uses cell-wide (broadcasted) CRSs which are not precoded and the eNB's port configuration for transmitting it is static in the cell.

For the UE's blind decoding of the E-PDCCH, each decoding attempt assumes a certain resource mapping and antenna port(s) for a given E-PDCCH format (size). If the CRC passes for a given blind decoding attempt the UE assumes the decoding is successful. As will be explained below with reference to Figure 1, passing the CRC does not necessarily mean that the antenna port configuration assumed for the 'successful' decoding of the E-PDCCH was an accurate description of what the eNB actually used to transmit it. Some situations exist (for example under MU-MIMO scheduling) in which the control message could be successfully received with two different assumptions on the utilized antenna port. When receiving from the wrong antenna port, the UE-RS cover code can be de-spread with an incorrect cover code corresponding to a different antenna port; for example the UE should normally decode antenna port AP7 with the cover code [+1,+1] but may instead attempt decoding AP8 with the cover code [+1,-1]. Despite the very low quality of the resulting channel estimate, the robust channel coding (low coding rate) together with QPSK modulation used for control information makes it possible to successfully decode the E-PDCCH using an incorrect assumption of the antenna port the eNB assigned to the UE for that transmission.

Figure 1 is a diagram of block error rate BLER (vertical axis) on a control channel versus signal to noise ratio SNR (horizontal axis) showing disparity between decoding with a correct demodulation RS port selection (solid lines) and an incorrect port selection (dashed lines). The inventors have conducted a link level study showing there is roughly a 15% probability of successfully decoding the control message using an incorrect assumption of the antenna port in a MU-MIMO configuration. The UEs in the simulation from which the Figure 1 data was obtained were assigned with the same UE-RS sequences, in order to preserve the orthogonality between the antenna ports. Significantly, it is not possible to assign the UEs with different UE-RS sequences without losing the orthogonality of the antenna port multiplexing. It does not appear that the 15% mis-detection probability can be appreciably decreased by changing the multi-user pairing or the UE-RS sequences.

A mis-detection probability on the order of 15% is substantial, meaning the UE's blind decoding cannot guarantee that the E-PDCCH antenna port is unambiguously detected. This problem is exacerbated when other information is implicitly linked to the antenna port configuration for transmitting the E-PDCCH. For example, the resource allocation on the PUCCH on which the UE is supposed to transmit its ACK/NACK may depend on the antenna port used to transmit the E-PDCCH. Similar implicit linkage from the PDCCH is already in use for Release 8 ACK/NACK resource allocation on the PUCCH, but as noted above the port configuration in Releases 8-10 is fixed so the potential for mis-detection is negligible. Figure 1 shows the mis-detection potential for the E-PDCCH is not trivial. If the antenna port is mis-detected the UE would transmit its ACK/NACK on the wrong channel, causing interference to some other UE as well as causing the eNB to miss the

UE's ACK/NACK transmission since it is not on the correct PUCCH resource. The uplink ACK/NACK resource allocation is but one example of information that could be linked to the antenna port used for the E-PDCCH; other information can be implicitly linked to that port configuration and may be in further development of LTE Release 11 or later since all aspects of the E-PDCCH are not yet resolved in the 3GPP.

What is needed is a way for the UE to avoid UE-RS port misdetection during the E-PDCCH blind decoding process.

Summary

In a first exemplary embodiment there is a method comprising: encoding a resource allocation for a specific user equipment using an encoding scheme that identifies a specific antenna port from among a plurality of antenna ports; and outputting the encoded resource allocation to the specific antenna port for transmission to the specific user equipment. In a preferred arrangement the first embodiment is performed by an eNB node.

In a second exemplary embodiment there is an apparatus comprising a processing system, which may be embodied by at least one processor and at least one memory storing a computer program. The processing system is arranged to cause the apparatus to: encode a resource allocation for a specific user equipment using an encoding scheme that identifies a specific antenna port from among a plurality of antenna ports; and output the encoded resource allocation to the specific antenna port for transmission to the specific user equipment.

In a third exemplary embodiment there is a computer readable memory comprising a set of instructions, which, when executed by a computing system, causes the computing system to perform the steps of: encoding a resource allocation for a specific user equipment using an encoding scheme that identifies a specific antenna port from among a plurality of antenna ports; and outputting the encoded resource allocation to the specific antenna port for transmission to the specific user equipment.

In a fourth exemplary embodiment there is a method comprising: blindly detecting a control channel for a specific user equipment; and determining a resource allocation for the specific user equipment by decoding the control channel using a decoding scheme that identifies a specific antenna port from among a plurality of transmit antenna ports. In a preferred arrangement, the fourth embodiment is performed by a user equipment.

In a fifth exemplary embodiment there is an apparatus comprising a processing system, which may be embodied by at least one processor and at least one memory storing a computer program. The processing system is arranged to cause the apparatus to: blindly detect a control channel for a specific user equipment; and determine a resource allocation for the specific user equipment by decoding the control channel using a decoding scheme that identifies a specific antenna port from among a plurality of transmit antenna ports.

In a sixth exemplary embodiment there is a computer readable memory comprising a set of instructions, which, when executed by a computing system, causes the computing system to perform the steps of blindly detecting a control channel for a specific user equipment; and determining a resource allocation for the specific user equipment by decoding the control channel using a decoding scheme that identifies a specific antenna port from among a plurality of transmit antenna ports.

These and other embodiments and aspects are detailed below with particularity.

Brief Description of the Drawings

Figure 1 is a diagram of block error rate BLER on a control channel versus signal to noise ratio SNR showing disparity between decoding with a correct demodulation reference signal port selection (solid lines) and an incorrect port selection (dashed lines).

Figure 2 illustrates two constellations which different antennas use for their respective bit to QPSK mapping according to an exemplary fourth embodiment of the invention.

Figure 3 is a logic flow diagram that illustrates from the perspective of the network/eNB the operation of a method, and a result of execution of computer program instructions embodied on a computer readable memory, in accordance with an exemplary embodiment of this invention.

Figure 4 is a logic flow diagram that illustrates from the perspective of the UE the operation of a method, and a result of execution of computer program instructions embodied on a computer readable memory, in accordance with an exemplary embodiment of this invention.

Figure 5 is a simplified block diagram of a UE and an eNB which are exemplary electronic devices suitable for use in practicing the exemplary embodiments of the invention.

Detailed Description

The following examples are in the specific context of the LTE/LTE-Advanced systems (for example, Release 11 and later) but these teachings are more broadly applicable to any wireless radio system which employs radio resource grants from the network to the UEs. These examples consider only a single UE but it will be understood the description applies for all such UEs being scheduled for radio resources according to the teachings described for one UE.

Following is a more detailed exposition of the problem summarized in the background section above which Figure 1 quantifies. Release 10 of the 3GPP LTE specification includes features related to downlink and uplink MIMO, relays, bandwidth extension via carrier aggregation and enhanced inter-cell interference coordination (eICIC). While Release 10 is finalized, ongoing development of the Release 11 specifications include downlink MIMO enhancements, one portion of which is downlink control signaling enhancements. Current downlink control signaling is based on common reference signals (CRS) which are not precoded and are broadcasted over the entire cell. When multiple antennas are in use, transmit diversity is used. Specifically, space-frequency block code (SFBC) is used for the case of 2 transmit antennas and SFBC-frequency switched transmit diversity (FSTD) is used for the case of 4 transmit antennas. Mapping of the control channels to resource elements (REs) is fixed and based on the cell ID. The 3GPP is working to enhance the physical downlink control channel (PDCCH) such that more advanced multi-antenna schemes could be used, such as closed-loop single-user (SU-) MIMO or multi-user (MU-) MIMO or even coordinated multi-point transmission (CoMP). Another goal is to allow more flexibility in mapping to the resource elements in order to improve inter-cell interference coordination possibilities for control channels, which may provide benefits when enhanced inter-cell coordination (eICIC) techniques are in use in a heterogeneous network environment.

In LTE Releases 8-10, the downlink control information (DCI) is transmitted on the physical downlink control channel (PDCCH) which gives the UE its UL and DL resource allocations/assignments for data. The PDCCH is transmitted on the same set of antenna ports as the physical broadcast channel (PBCH), which is why the eNB's antenna port configuration for sending the PDCCH is cell-specific and static. Specifically, the PDCCH transmission mode is either single-antenna port transmission or transmit diversity, depending on the number of antenna ports configured at the eNB. Mapping of logical antenna ports to physical transmit antennas is standard transparent and implementation specific. The radio channel frequency response for the UE's demodulation of the PDCCH is estimated from the CRSs associated to the eNB's antenna ports.

LTE Release-11 adds a new scheduling channel E-PDCCH, which will partly resemble the relay-PDCCH (R-PDCCH) specified in Release 10 for relay nodes in that it will most likely support UE-specific reference signals (UE-RS) and be mapped to the PDSCH region of the subframe. It will be possible to transmit the E-PDCCH with spatial multiplexing using antenna ports with UE-RS. The E-PDCCH is expected to support multi-user MIMO, and/or (in contrast to the R-PDCCH) to multiplex DCIs to several UEs within one PRB pair. While the reader may imply that the term UE-specific RS means each is to be used by a single UE, it is to be noted that this is not necessary as in principle nothing forbids the eNB to configure multiple UEs with the same RS in which case also UE-specific RS could be in fact shared by multiple UEs. The distinction is that CRSs are cell-wide and UE-RSs are UE specific even if they are not UE unique.

The CRSs are not precoded whereas the UE-RSs are, and the underlying precoding decisions have an effect on the antenna port that is used for the transmission of the E-PDCCH to a given UE. For example, the eNB may make one type of precoding/scheduling decision when it uses MU-MIMO and another for SU-MIMO. Therefore the antenna port configuration of the E-PDCCH transmission cannot be static to preserve precoding/scheduling flexibility at the eNB. Therefore the UE must use blind decoding attempts in order to find the correct antenna port (among multiple possible UE-RS ports) that the eNB used for transmitting the E-PDCCH to this specific UE. Similarly, if multiple DCIs are mapped to the same PRB pair, the UE may have to blindly search for the correct phase reference for demodulation among multiple possible UE-RS ports.

In the UE's blind decoding it assumes that its E-PDCCH is carried by a certain block of resource elements, according to UE's search space. The UE assumes that part of the resource elements carry the precoded UE-specific RSs, and also must assume a certain antenna port (or multiple ports if antenna diversity or spatial multiplexing is utilized) to create a channel estimate. This antenna port assumption affects how the resource elements are selected and how the orthogonal cover code of the UE-RS is de-spread. The channel estimate is used for demodulating the expected E-PDCCH resource elements.

LTE Release 10 specifications provide at section 5.3.3.2 of 3GPP TS36.212, MULTIPLEXING AND CHANNEL CODING (Release 10), v10.3.0 (2011-09) that the CRC of the PDCCH is scrambled with the UE identity, specifically the UE's radio network temporary identifier RNTI. But the PDCCH uses CRSs and not UE-specific RSs as does the E-PDCCH. That same specification also provides at section 5.3.1.1 that the CRC of the master information blocks (MIBs) is scrambled with a bit mask which depends on the number of transmit antenna ports at the eNB. But the MIBs are broadcast over the PBCH and so are common throughout the whole cell, unlike the E-PDCCH which gives to specific UEs their resource allocations.

Prior to the bit-masking noted above being adopted in LTE Release 10, following are a few of the competing suggestions for addressing PBCH mis-detection. Document R1-074642 by Nortel entitled THE RELIABILITY IMPROVEMENT OF THE BLIND DETECTION OF THE ANTENNA CONFIGURATION (3GPP TSG-RAN1 meeting #51; Jeju Island, South Korea; 5-9 November 2007) offered four different approaches to mitigate mis-detection of the PBCH: change the resource element mapping of the

PBCH depending on the number of transmit antennas; apply a scrambling sequence which depends on the number of transmit antennas; modify the Alamouti transmission format to reduce similarities between the different transmit diversity schemes; and use some type of reliability measure in the decoding of the PBCH (for example, different versions of the PBCH corresponding to the different transmit antenna configurations are decoded and some decoding reliability measurement is used to select one having the strongest reliability).

Document R1-080324 by Nokia Siemens Networks, Nokia, China Mobile and Huawei entitled ISSUES WITH PBCH-BASED BLIND ANTENNA CONFIGURATION DETECTION (3GPP TSG-RAN1 meeting #51bis; Sevilla, Spain; 14-18 January 2008) suggested CRC masking of the PBCH that depends on the antenna configuration; and a new mapping of the PBCH to the resource elements (starting in the first OFDM symbol of the second slot).

Document R1-080944 by Nokia Siemens Networks and Nokia entitled CRC MASK SELECTION FOR PBCH (3GPP TSG WG1 meeting #52; Sorrento, Italy; 11-15 February 2008) considered how the CRC mask would be selected when the CRC mask of the PBCH depends on the antenna configuration.

United States Patent Application Publication 2009/0176463 entitled METHOD AND APPARATUS FOR CONVEYING ANTENNA CONFIGURATION INFORMATION discloses how to convey information regarding the antenna configuration and/or the transmission diversity scheme to a mobile device recipient. In particular, such information can be conveyed by mapping a PBCH within a sub-frame so as to include CRSs indicative of different antenna configurations or transmission diversity schemes or by CRC masking.

United States Patent Application Publication 2010/0323637, entitled METHOD AND APPARATUS FOR CONVEYING ANTENNA CONFIGURATION INFORMATION VIA MASKING describes that the set of CRC masks can be determined based upon the Hamming distances between the masks and bit diversities between the masks, where each of the masks within the set is associated with an antenna configuration and a transmission diversity scheme.

And United States Patent Application Publication 2007/0135161 entitled

SIGNALING SUPPORT FOR ANTENNA SELECTION USING SUBSET LISTS AND SUBSET MASKS associates antenna masks to the usage of virtual antennas/beams existing within a cell. The base station may select and signal to the mobile unit a subset of virtual antennas/beams out of a total available number of virtual antennas/beams. The base station will make use of the antennas/beams belonging to this subset for communicating downlink with the mobile unit and in turn the mobile unit transmits uplink channel quality reports for those antennas/beams only. An antenna subset mask is used for the associated signaling to the mobile unit indicting which antenna/beam is active or not.

The problem resolved by certain implementations of these teachings, namely avoiding or at least severely minimizing the opportunity for a UE to detect the E-PDCCH under an erroneous assumption on the antenna setup at eNB, is not directly addressed by any of the above references. Those documents deal with mis-detection of a common/broadcast channel (PBCH) under an erroneous assumption on the *total number of CRS ports* which are cell-specific, whereas the issue detailed above for Release 11 concerns UE-specific RSs and the mis-direction to be avoided arises from a potential erroneous assumption on a *UE-specific antenna port (index)* for E-PDCCH demodulation. The solutions detailed below introduce a linkage between a UE-specific antenna port information and the UE's resource assignment, whereas in the above solutions for the PBCH the linkage is between the total number of antenna ports at the eNB, and some also combine that with a transmit diversity scheme. The exemplary solutions detailed below apply to UE-specific dedicated antenna ports, whereas the above references deal with cell-specific (cell-wide) antenna ports. All of these differences arise from the fact that the above documents concern common (broadcast) channels used for communicating with all the mobile terminals associated to the base station, whereas the mis-direction problem solved by exemplary implementations of these teachings concern the E-PDCCH which is a dedicated (i.e. UE-specific) control channel.

Additionally, unlike the solutions in the above documents which are only proposed for SU-MIMO transmissions, exemplary embodiments of these teachings applied for the E-PDCCH are relevant for both SU-MIMO and MU-MIMO as well as for coordinated multi-point transmission (CoMP). Also, United States Patent Application Publication 2007/0135161 concerns the configuration of virtual antennas whereas these teachings concern the actual antenna port configuration which is used for demodulation.

Exemplary embodiments of these teachings introduce antenna port–specific encoding/detection schemes for the downlink control information (DCI) such that it is not possible to mis-detect the E-PDCCH using any antenna port other than the one to which it is associated. Below are detailed five distinct ways for this antenna port–specific encoding, and for convenience those five are summarized here. In a first embodiment an antenna port–dependent variable is added in the E-PDCCH scrambling sequence initialization value. In a second embodiment there is antenna port–specific masking of the E-PDCCH CRC in addition to UE-ID masking noted above. In a third embodiment there is antenna port–specific interleaving. For example, in one implementation of this third embodiment the encoded E-PDCCH bits are interleaved or rearranged in an antenna port–specific way. In another implementation of this third embodiment there is antenna port-specific symbol interleaving or resource mapping of the E-PDCCH (mapping of the E-PDCCH to resource elements). In a fourth embodiment the mapping of bits to the QPSK constellation is antenna port–specific. And in a fifth embodiment the eNB sends explicit signaling to inform the UE which antenna port configuration it used for the E-PDCCH, which is to say that the eNB adds an antenna port confirmation bit to the DCI format conveyed by the E-PDCCH.

Before detailing these five embodiments, consider first the process the eNB follows in constructing the E-PDCCH for transmission. The DCI to be transmitted by the eNB consists of a length-N bit sequence $b_0, \ldots b_{N-1}$ (this is the UE's payload in the E-PDCCH). First, the eNB attaches a CRC of length L ($L=16$ in current LTE) to the DCI payload. Typically the CRC is masked with the UE ID (C-RNTI) of the UE such that the UE can identify which DCI is intended for it. As a result of the CRC attachment, the bit sequence $b_0, \ldots b_{N-1+L}$ is the bit sequence that is input to channel coding. This sequence is channel coded (in LTE with a convolutional code) to get a length-M coded bit sequence $c_0, \ldots c_{M-1}$. This coded bit sequence is then scrambled with a scrambling sequence $s_0,....,s_{M-1}$ to result in the sequence $y_k = (c_k+s_k) \bmod 2$. Finally, the scrambled bit sequence is input into the eNB's modulator which maps the bits to modulation symbols (QPSK in LTE).

According to the various embodiments detailed herein, at least one of the above steps is done in an antenna port–specific manner.

According to the first embodiment, the scrambling sequence $s_0,...,s_{M-1}$ is generated using an initialization value that depends on the antenna port. For example, currently for PDCCH the scrambling sequence is initialized with $c_{\text{init}} = \lfloor n_s/2 \rfloor 2^9 + N_{\text{ID}}^{\text{cell}}$. One exemplary modification to make this antenna port–specific is to add an antenna port identifier in the initialization process, such as $c_{\text{init}} = \lfloor n_s/2 \rfloor 2^9 + N_{\text{ID}}^{\text{cell}} + N_{\text{ID}}^{\text{ap}}$. In the above equations, c_{init} is the initial element of the scrambling sequence, n_s is the slot number within a radio frame, $N_{\text{ID}}^{\text{cell}}$ is the physical layer cell identity, and $N_{\text{ID}}^{\text{ap}}$ is the identifier of a specific antenna port.

According to the second embodiment, the antenna port identifier is embedded in the CRC by masking (scrambling) the CRC further with an antenna port identifier. If we denote the CRC sequence masked only with the UE ID as x_k, $k=0,...,15$, then after antenna port-specific masking sequence a_k the CRC is $z_k=(x_k+a_k) \bmod 2$.

According to the third embodiment, the coded and scrambled bits y_k are interleaved or otherwise rearranged in a (different) antenna port–specific order. If we assume an original/conventional bit order for the coded bits y_k for the first antenna port is retained in this third embodiment, then the antenna-specific encoding can re-arrange the coded bits for the second antenna port so they are transmitted in a reverse order (or in any other antenna port–specific order where the bit order differs from that used for the first antenna port). Or alternatively the coded bits for the second antenna port can be interleaved such as by writing them one row at a time to a buffer memory having K columns then reading out the buffered bits one column at a time.

The interleaving/rearranging in this third embodiment may also be done to the coded bit sequence c_k before applying the scrambling code. The bit re-arrangement may also be done on the symbol level after the eNB's modulator (QPSK symbols in LTE). This is a bit re-arrangement because symbol-level re-arranging is a re-arrangement of the bits in batches of q bits, where q is the modulation order ($q=2$ for QPSK).

The fourth embodiment performs the bit-to-symbol mapping in an antenna port–specific way and one example of this is illustrated at Figure 2. The constellation at the left side shows the bit-to-QPSK mapping currently used in conventional LTE and in this example that mapping is used for the first antenna port. The constellation at the right side of Figure 2 shows bit-to-QPSK mapping used for the second antenna port according to this example of the fourth embodiment. As is evident from the right side constellation at Figure 2, it is also possible in this fourth embodiment to preserve the Gray coding–based bit mapping, in which each sequential bit value differs by only a single bit.

According to the fifth embodiment, the DCI payload $b_0,\ldots,b_{N-1}$ contains a field that explicitly indicates the used antenna port. For example, if there are only two possible antenna ports the indication may be as little as one bit, or if there is a total of four antenna ports the indication may be as few as two bits.

According to exemplary embodiment of the invention from the perspective of the UE, the UE searches for a downlink control information transmission by attempting blind detection from each possible search space location. The UE's search space location is defined by a combination of certain E-PDCCH resource mapping and antenna port. When detecting the E-PDCCH from a given search space location, the UE first estimates the channel from the corresponding antenna port, and equalizes the signal to obtain the received symbol stream. From the received symbols, the UE then demodulates and/or decodes the bit stream in an antenna port–specific way.

For the first embodiment the UE does this after symbol-to-bit mapping and before channel decoding. Namely the UE will descramble the received bits with the antenna-port specific scrambling sequence.

For the second embodiment the UE will do this after channel decoding when checking the CRC. Namely the UE will mask the CRC that is calculated based on the decoded DCI payload with the antenna port ID, in addition to the UE ID (C-RNTI). If the CRC matches with the received CRC, the UE determines that the DCI was intended for it, and then also verifies the antenna port used for transmission. It is considered extremely unlikely that the UE would find a matching CRC with an incorrect mask (a mis-detection arising from an incorrect assumption on the antenna port ID). Document R1-080944 referenced above provides simulation results that put such a probability of CRC false detection in the range of 10^{-7} to 10^{-5}.

For the third embodiment the UE will re-arrange the bits before channel decoding according to the antenna port–specific bit ordering.

For the fourth embodiment, before descrambling and decoding the UE will map the symbols to bits according to the antenna port–specific constellation mapping. For each of the first, third and fourth embodiments, the UE verifies the antenna port if the UE obtains a matching CRC since in these embodiments it is extremely unlikely to get a matching CRC from the wrong antenna port.

For the fifth embodiment, after finding the DCI the UE will verify the antenna port based on the explicit signaling bit which is in the DCI payload.

For both the eNB and for the UE, any suitable combinations of the above five embodiments can also be employed in practical implementations of these teachings. However it may not be necessary to do so since any individual embodiment should be sufficient to avoid any antenna port ambiguities and mis-detection of the E-PDCCH as a result.

Now are detailed with reference to Figures 3-4 further particular exemplary embodiments from the perspective of the network/eNB and of the UE, respectively. Figure 3 may be performed by the whole eNB, or by one or several components thereof such as a modem, a processor in combination with a program stored on a memory, etc. At block 302 a resource allocation is encoded for a specific UE using an encoding scheme that identifies a specific (logical) antenna port from among a plurality of antenna ports. Then at block 304 the encoded resource allocation is output to the specific antenna port for transmission to the specific user equipment.

Block 306 of Figure 3 summarizes the specific but non-limiting embodiments detailed above. If we represent the resource allocation as detailed above by a length-N bit sequence $b_0, \ldots b_{N-1}$, then the encoding comprises:

a) attaching a cyclic redundancy check CRC of length L to the bit sequence;

b) masking at least the CRC with an identifier of the specific user equipment;

c) channel coding the masked bit sequence with the attached CRC to achieve a length-M coded bit sequence $c_0,...c_{M-1}$;

d) scrambling the coded bit sequence with a scrambling sequence $s_0,....,s_{M-1}$ to achieve a scrambled and coded bit sequence $y_k = (c_k+s_k) \bmod 2$; and

e) mapping bits of the scrambled and coded bit sequence to modulation symbols

In the above encoding N, L and M are each integers greater than one.

For the first embodiment detailed above, the encoding scheme that identifies the specific antenna port comprises the scrambling, where the scrambling sequence is initiated with a value that depends on the specific antenna port. For the second embodiment the encoding scheme that identifies the specific antenna port is the masking, where the bit sequence is masked with the identifier of the specific UE and with an identifier of the UE-specific logical antenna port. For the third embodiment the encoding scheme that identifies the specific antenna port involves arranging the bits of the coded bit sequence $c_0,...c_{M-1}$ or of the scrambled and coded bit sequence $y_k = (c_k+s_k) \bmod 2$ in an order which identifies the specific antenna port. This arranging includes interleaving but is not limited only to interleaving. For the fourth embodiment the encoding scheme that identifies the specific antenna port is the mapping, where the bits of the scrambled and coded bit sequence are mapped to modulation symbols according to a mapping constellation associated only with the specific physical antenna port. And for the fifth embodiment the encoding scheme that identifies the specific antenna port comprises adding to the length-N bit sequence $b_0, ...b_{N-1}$ at least one further bit that identifies the specific antenna port. In this case the CRC is attached to the bit sequence with the at least one further bit; and the bit sequence with the further bit(s) is masked, rather than the attaching and masking being only on the length-N bit sequence $b_0, ...b_{N-1}$.

The eNB (or more generically a network access node), in particular a component thereof, transmits the encoded resource allocation as an E-PDCCH to the specific UE from an antenna associated with the specific antenna port.

Turning to Figure 4 which details an exemplary embodiment from the perspective of the UE, the method may be performed by the whole UE, or by one or several components thereof such as a modem, a processor in combination with a program stored on a memory, etc. At block 402 a control channel for a specific UE is blindly decoded, and at block 404 a resource allocation for the specific UE is determined by decoding the control channel using a decoding scheme that identifies a specific antenna port from among a plurality of transmit antenna ports.

Block 406 of Figure 4 summarizes the specific but non-limiting embodiments detailed above. If we again represent the resource allocation as a length-N bit sequence $b_0, \ldots b_{N-1}$; then the decoding comprises, for a received stream of symbols which comprise the detected the control channel:

a) mapping the stream of symbols to bits to achieve a scrambled and coded bit sequence $y_k = (c_k+s_k) \bmod 2$;

b) de-scrambling the scrambled and coded bit sequence with a scrambling sequence $s_0, \ldots, s_{M-1}$ to achieve a length-M coded bit sequence $c_0, \ldots c_{M-1}$;

c) channel decoding the coded bit sequence to achieve a masked bit sequence;

d) use an identifier of the specific UE to achieve, from the masked bit sequence, the bit sequence $b_0, \ldots b_{N-1}$ with an attached CRC of length L; and

e) checking the CRC.

As with Figure 3, for Figure 4 also N, L and M are each integers greater than one.

For the first embodiment detailed above, the decoding scheme that identifies the specific antenna port comprises the de-scrambling, where the scrambling sequence is initiated with a value that depends on the specific antenna port. For the second embodiment above the decoding scheme that identifies the specific antenna port comprises obtaining or achieving the bit sequence $b_0, \ldots b_{N-1}$ with an attached CRC of length L from the masked bit sequence. The masked bit sequence need not be entirely masked, and in some embodiments only the CRC which is attached to the N-length bit sequence is masked. In the above examples the CRC may be masked with the UE identifier, with or without also an identifier of the specific antenna port. In one embodiment the CRC is de-masked using one or both of those identifiers as the case may be. In another embodiment the UE takes the payload, computes the CRC, masks that computed CRC using one or both of those identifiers as the case may be, then compares the two masked CRCs to one another to perform step e) of block 406. For the third embodiment the decoding scheme that identifies the specific antenna port comprises de-arranging, prior to the channel decoding, the bits of the coded bit sequence $c_0, \ldots c_{M-1}$ or of the scrambled and coded bit sequence $y_k = (c_k + s_k) \bmod 2$ from an order which identifies the specific antenna port. For the fourth embodiment it is the de-mapping, where the stream of symbols are mapped to bits according to a mapping constellation associated only with the specific antenna port. And for the fifth embodiment the decoding scheme that identifies the specific antenna port comprises identifying the specific antenna port from at least one further bit that is added to the length-N bit sequence $b_0, \ldots b_{N-1}$.

The UE, in particular a component thereof, receives the control channel as an E-PDCCH from a network access node.

The logic flow diagrams of Figures 3-4 may each be considered to illustrate the operation of a method, and a result of execution of a computer program stored in a computer readable memory, and a specific manner in which components of an electronic device are configured to cause that electronic device to operate. The various blocks shown in either of Figures 3 or 4 may also be considered as a plurality of coupled logic circuit elements constructed to carry out the associated function(s), or specific result of strings of computer program code stored in a memory.

Such blocks and the functions they represent are non-limiting examples, and may be practiced in various components such as integrated circuit chips and modules, and that the exemplary embodiments of this invention may be realized in an apparatus that is embodied as an integrated circuit. The integrated circuit, or circuits, may comprise circuitry (as well as possibly firmware) for embodying at least one or more of a data processor or data processors, a digital signal processor or processors, baseband circuitry and radio frequency circuitry that are configurable so as to operate in accordance with the exemplary embodiments of this invention.

Reference is now made to Figure 5 for illustrating a simplified block diagram of various electronic devices and apparatus that are suitable for use in practicing the exemplary embodiments of this invention. In Figure 5 an eNB 22 is adapted for communication over a wireless link 21 with a mobile radio apparatus termed generically as a UE 20. The eNB 22 may be any access node (including frequency selective repeaters) of any type of radio access technology network such as LTE, LTE-A, WCDMA, and the like. The operator network of which the eNB 22 is a part may also include a network control element such as a mobility management entity MME and/or serving gateway SGW 24 which provides connectivity with further networks (e.g., a publicly switched telephone network and/or a data communications network/Internet).

The UE 20 includes processing means such as at least one data processor (DP) 20A, storing means such as at least one computer-readable memory (MEM) 20B which tangibly stores at least one computer program (PROG) 20C or other set of executable instructions, and communicating means such as a transmitter TX 20D and a receiver RX 20E for bidirectional wireless communications with the eNB 22 via one or more antennas 20F. Also stored in the MEM 20B at reference number 20G are the rules or algorithm for decoding the control channel (E-PDCCH) in a manner specific for an antenna port of the transmitting eNB 22 as detailed above in multiple but non-limiting embodiments.

The eNB 22 also includes processing means such as at least one data processor (DP) 22A, storing means such as at least one computer-readable memory (MEM) 22B that tangibly stores at least one computer program (PROG) 22C or other set of executable instructions, and communicating means such as a transmitter TX 22D and a receiver RX 22E for bidirectional wireless communications with the UE 20 via one or more antennas 22F. The eNB 22 stores at block 22G similar rules or algorithm for encoding the control channel (E-PDCCH) in a manner specific for an antenna port of the transmitting eNB 22 as detailed above in multiple but non-limiting embodiments.

For completeness, the MME 24 is also shown to have a processor DP 24A, a memory 24B storing a program 24C and a modem 24H for digitally modulating and demodulating information it communicates over the data and control link 25 with the eNB 22.

While not particularly illustrated for the UE 20 or eNB 22, those devices are also assumed to include as part of their wireless communicating means a modem and/or a chipset which may or may not be inbuilt onto an RF front end chip within those devices 20, 22 that may also carry the TX 20D/22D and the RX 20E/22E.

At least one of the PROGs 20C in the UE 20 is assumed to include a set of program instructions that, when executed by the associated DP 20A, enable the device to operate in accordance with the exemplary embodiments of this invention, as detailed above for Figure 4. The eNB 22 also has software stored in its MEM 22B to implement aspects of these teachings relevant to it as detailed above for Figure 3. In these regards the exemplary embodiments of this invention may be implemented at least in part by computer software stored on the MEM 20B, 22B which is executable by the DP 20A of the UE 20 and/or by the DP 22A of the eNB 22, or by hardware, or by a combination of tangibly stored software and hardware (and tangibly stored firmware). Electronic devices implementing these aspects of the invention need not be the entire devices as depicted at Figure 5 or may be one or more components of same such as the above described tangibly stored software, hardware, firmware and DP, or a system on a chip SOC or an application specific integrated circuit ASIC.

In general, the various embodiments of the UE 20 can include, but are not limited to personal portable digital devices having wireless communication capabilities, including but not limited to cellular telephones, navigation devices, laptop/palmtop/tablet computers, digital cameras and music devices, and Internet appliances, as well as the machine-to-machine type devices mentioned above.

Various embodiments of the computer readable MEMs 20B, 22B include any data storage technology type which is suitable to the local technical environment, including but not limited to semiconductor based memory devices, magnetic memory devices and systems, optical memory devices and systems, fixed memory, removable memory, disc memory, flash memory, DRAM, SRAM, EEPROM and the like. Various embodiments of the DPs 20A, 22A include but are not limited to general purpose computers, special purpose computers, microprocessors, digital signal processors (DSPs) and multi-core processors.

Various modifications and adaptations to the foregoing exemplary embodiments of this invention may become apparent to those skilled in the relevant arts in view of the foregoing description. While the exemplary embodiments have been described above in the context of the LTE and LTE-A system, as noted above the exemplary embodiments of this invention may be used with various other wireless communication systems which have non-static antenna ports for transmitting a control channel to specific UEs.

Further, some of the various features of the above non-limiting embodiments may be used to advantage without the corresponding use of other described features. The foregoing description should therefore be considered as merely illustrative of the principles, teachings and exemplary embodiments of this invention, and not in limitation thereof.

The following abbreviations used in the above description and/or in the drawing figures are defined as follows:

3GPP	third generation partnership project
CRC	cyclic redundancy check
C-RNTI	cell radio network temporary identifier
CRS	common reference signal
DCI	downlink control information
DL	downlink
eNB	node B/base station in an E-UTRAN system
E-PDCCH	enhanced PDCCH
E-UTRAN	evolved UTRAN (LTE)
LTE	long term evolution (also known as E-UTRAN)
MIMO	multiple-input multiple-output
MU-MIMO	multi user multiple-input multiple-output
OFDM	orthogonal frequency division multiplexing
PBCH	physical broadcast channel
PDCCH	physical downlink control channel
PDSCH	physical downlink shared channel
PUCCH	physical uplink control channel
PRB	physical resource block
QPSK	quadrature phase shift keying
RE	resource element
RS	reference signal
R-PDCCH	relay PDCCH

SU-MIMO	single user multiple-input multiple-output
UE	user equipment
UL	uplink
UTRAN	universal terrestrial radio access network

Claims

1. A method of configuring a resource allocation for a user equipment, the method comprising:

encoding a resource allocation for a specific user equipment using an encoding scheme that identifies a specific antenna port from among a plurality of antenna ports; and

outputting the encoded resource allocation to the specific antenna port for transmission to the specific user equipment.

2. The method according to claim 1, in which the resource allocation comprises a length-N bit sequence $b_0, \ldots b_{N-1},$ and the encoding comprises:

attaching a cyclic redundancy check CRC of length L to the bit sequence;

masking at least the CRC with an identifier of the specific user equipment;

channel coding the masked bit sequence with the attached CRC to achieve a length-M coded bit sequence $c_0, \ldots c_{M-1}$;

scrambling the coded bit sequence with a scrambling sequence $s_0, \ldots, s_{M-1}$ to achieve a scrambled and coded bit sequence $y_k = (c_k + s_k) \bmod 2$; and

mapping bits of the scrambled and coded bit sequence to modulation symbols, in which N, L and M are each integers greater than one.

3. The method according to claim 2, in which the encoding scheme that identifies the specific antenna port comprises the scrambling, in which the scrambling sequence is initiated with a value that depends on the specific antenna port.

4. The method according to claim 2, in which the encoding scheme that identifies the specific antenna port comprises the masking, in which at least the CRC is masked with the identifier of the specific user equipment and with an identifier of the specific antenna port.

5. The method according to claim 2, in which the encoding scheme that

identifies the specific antenna port comprises arranging the bits of the coded bit sequence $c_0, ...c_{M-1}$ or of the scrambled and coded bit sequence $y_k = (c_k+s_k) \bmod 2$ in an order which identifies the specific antenna port.

6. The method according to claim 2, in which the encoding scheme that identifies the specific antenna port comprises the mapping, in which the bits of the scrambled and coded bit sequence are mapped to modulation symbols according to a mapping constellation associated only with the specific antenna port.

7. The method according to claim 2, in which the encoding scheme that identifies the specific antenna port comprises adding to the length-N bit sequence $b_0, ...b_{N-1}$ at least one further bit that identifies the specific antenna port;

and in which the CRC is attached to the bit sequence with the added at least one further bit.

8. The method according to any one of claims 1 to 7, in which the method is executed by a network access node which transmits the encoded resource allocation as an enhanced physical downlink control channel E-PDCCH to the specific user equipment via the specific antenna port.

9. An apparatus for configuring a resource allocation for a user equipment, the apparatus comprising a processing system arranged to cause the apparatus to:

encode a resource allocation for a specific user equipment using an encoding scheme that identifies a specific antenna port from among a plurality of antenna ports; and

output the encoded resource allocation to the specific antenna port for transmission to the specific user equipment.

10. The apparatus according to claim 9, wherein the resource allocation comprises a length-N bit sequence $b_0, ...b_{N-1}$, and the processing system is arranged to

cause the apparatus to:

attach a cyclic redundancy check CRC of length L to the bit sequence;

mask at least the CRC with an identifier of the specific user equipment;

channel code the masked bit sequence with the attached CRC to achieve a length-M coded bit sequence $c_0, \ldots c_{M-1}$;

scramble the coded bit sequence with a scrambling sequence $s_0, \ldots., s_{M-1}$ to achieve a scrambled and coded bit sequence $y_k = (c_k+s_k) \bmod 2$; and

map bits of the scrambled and coded bit sequence to modulation symbols,

in which N, L and M are each integers greater than one,

whereby to encode the resource allocation.

11. The apparatus according to claim 10, wherein the encoding scheme that identifies the specific antenna port is such that the processing system is arranged to cause the apparatus to initiate the scrambling sequence with a value that depends on the specific antenna port, whereby to scramble the coded bit sequence.

12. The apparatus according to claim 10, wherein the encoding scheme that identifies the specific antenna port is such that the processing system is arranged to cause the apparatus to mask the CRC with the identifier of the specific user equipment and with an identifier of the specific antenna port, whereby to mask at least the CRC.

13. The apparatus according to claim 10, wherein the encoding scheme that identifies the specific antenna port is such that the processing system is arranged to cause the apparatus to arrange the bits of the coded bit sequence $c_0, \ldots c_{M-1}$ or of the scrambled and coded bit sequence $y_k = (c_k+s_k) \bmod 2$ in an order which identifies the specific antenna port.

14. The apparatus according to claim 10, wherein the encoding scheme that identifies the specific antenna port is such that the processing system is arranged to map the bits of the scrambled and coded bit sequence to modulation symbols

according to a mapping constellation associated only with the specific antenna port, whereby to map bits of the scrambled and coded bit sequence to modulation symbols.

15. The apparatus according to claim 10, wherein the encoding scheme that identifies the specific antenna port is such that the processing system is arranged to add to the length-N bit sequence $b_0, \ldots b_{N-1}$ at least one further bit that identifies the specific antenna port; and wherein the processing system is arranged to cause the apparatus to attach the CRC to the bit sequence with the added at least one further bit.

16. The apparatus according to any one of claims 9 to 15, wherein the apparatus comprises a network access node which is configured to transmit the encoded resource allocation as an enhanced physical downlink control channel E-PDCCH to the specific user equipment from an antenna associated with the specific antenna port.

17. A computer readable memory comprising a set of instructions, which, when executed by a computing device, causes the computing device to perform the steps of:

encoding a resource allocation for a specific user equipment using an encoding scheme that identifies a specific antenna port from among a plurality of antenna ports; and

outputting the encoded resource allocation to the specific antenna port for transmission to the specific user equipment.

18. The computer readable memory according to claim 17, in which the resource allocation comprises a length-N bit sequence $b_0, \ldots b_{N-1}$, and, when executed by the computing system, the set of instructions causes the computing device to perform the steps of:

attaching a cyclic redundancy check CRC of length L to the bit sequence;

masking at least the CRC with an identifier of the specific user equipment;

channel coding the masked bit sequence with the attached CRC to achieve a length-M coded bit sequence $c_0, \ldots c_{M-1}$;

scrambling the coded bit sequence with a scrambling sequence $s_0, \ldots, s_{M-1}$ to achieve a scrambled and coded bit sequence $y_k = (c_k + s_k) \bmod 2$; and

mapping bits of the scrambled and coded bit sequence to modulation symbols,

in which N, L and M are each integers greater than one.

19. A method of determining resource allocation for a user equipment, the method comprising:

blindly detecting a control channel for a specific user equipment; and

determining a resource allocation for the specific user equipment by decoding the control channel using a decoding scheme that identifies a specific antenna port from among a plurality of transmit antenna ports.

20. The method according to claim 19, in which the resource allocation comprises a length-N bit sequence $b_0, \ldots b_{N-1}$, and the decoding comprises, for a received stream of symbols which comprise the detected the control channel:

de-mapping the stream of symbols to bits to achieve a scrambled and coded bit sequence $y_k = (c_k + s_k) \bmod 2$;

de-scrambling the scrambled and coded bit sequence with a scrambling sequence $s_0, \ldots, s_{M-1}$ to achieve a length-M coded bit sequence $c_0, \ldots c_{M-1}$;

channel decoding the coded bit sequence to achieve a masked bit sequence;

using an identifier of the specific user equipment to achieve the bit sequence $b_0, \ldots b_{N-1}$ with an attached cyclic redundancy check CRC of length L from the masked bit sequence; and

checking the CRC,

in which N, L and M are each integers greater than one.

21. The method according to claim 20, in which the decoding scheme that identifies the specific antenna port comprises the de-scrambling, in which the scrambling sequence is initiated with a value that depends on the specific antenna port.

22. The method according to claim 20, in which the decoding scheme that identifies the specific antenna port comprises using the identifier of the specific user equipment and an identifier of the specific antenna port to:

de-mask the CRC from the masked bit sequence; or

mask a newly calculated CRC for checking against the CRC from the masked bit sequence.

23. The method according to claim 20, in which the decoding scheme that identifies the specific antenna port comprises, prior to the channel decoding, de-arranging the bits of the coded bit sequence $c_0, \ldots c_{M-1}$ or of the scrambled and coded bit sequence $y_k = (c_k + s_k) \bmod 2$ from an order which identifies the specific antenna port.

24. The method according to claim 20, in which the decoding scheme that identifies the specific antenna port comprises the de-mapping, in which the stream of symbols are mapped to bits according to a mapping constellation associated only with the specific antenna port.

25. The method according to claim 20, in which the decoding scheme that identifies the specific antenna port comprises identifying the specific antenna port from at least one further bit that is added to the length-N bit sequence $b_0, \ldots b_{N-1}$.

26. The method according to any one of claims 19 to 25, in which the method is executed by a user equipment which receives the control channel as an enhanced physical downlink control channel E-PDCCH from a network access node.

27. An apparatus for determining a resource allocation for a user equipment, the apparatus comprising a processing system arranged to cause the apparatus to:

blindly detect a control channel for a specific user equipment; and determine a resource allocation for the specific user equipment by decoding the control channel using a decoding scheme that identifies a specific antenna port from among a plurality of transmit antenna ports.

28. The apparatus according to claim 27, in which the resource allocation comprises a length-N bit sequence $b_0, \ldots b_{N-1}$, and the processing system is arranged, for a received stream of symbols which comprise the detected the control channel, to cause the apparatus to:

de-map the stream of symbols to bits to achieve a scrambled and coded bit sequence $y_k = (c_k+s_k) \bmod 2$;

de-scramble the scrambled and coded bit sequence with a scrambling sequence $s_0, \ldots, s_{M-1}$ to achieve a length-M coded bit sequence $c_0, \ldots c_{M-1}$;

channel decode the coded bit sequence to achieve a masked bit sequence;

use an identifier of the specific user equipment to achieve the bit sequence $b_0, \ldots b_{N-1}$ with an attached cyclic redundancy check CRC of length L from the masked bit sequence; and

check the CRC,

in which N, L and M are each integers greater than one, whereby to perform said decoding.

29. The apparatus according to claim 28, wherein the decoding scheme that identifies the specific antenna port is such that the processing system is arranged to cause the apparatus to initiate the scrambling sequence with a value that depends on the specific antenna port.

30. The apparatus according to claim 28, wherein the decoding scheme that identifies the specific antenna port is such that the processing system is arranged to cause the apparatus to use the identifier of the specific user equipment and an identifier of the specific antenna port to:

de-mask the CRC from the masked bit sequence; or

mask a newly calculated CRC for checking against the CRC from the masked bit sequence.

31. The apparatus according to claim 28, wherein the decoding scheme that identifies the specific antenna port is such that the processing system is arranged to cause the apparatus, prior to the channel decoding, to de-arrange the bits of the coded bit sequence $c_0,...c_{M-1}$ or of the scrambled and coded bit sequence $y_k = (c_k+s_k) \mod 2$ from an order which identifies the specific antenna port.

32. The apparatus according to claim 28, wherein the decoding scheme that identifies the specific antenna port is such that the processing system is arranged to cause the apparatus to map the stream of symbols to bits according to a mapping constellation associated only with the specific antenna port, whereby to perform said de-mapping.

33. The apparatus according to claim 28, wherein the decoding scheme that identifies the specific antenna port is such that the processing system is arranged to cause the apparatus to identify the specific antenna port from at least one further bit that is added to the length-N bit sequence $b_0, ...b_{N-1}$.

34. The apparatus according to any one of claims 27 to 33, wherein the apparatus comprises a user equipment which receives the control channel as an enhanced physical downlink control channel E-PDCCH from a network access node.

35. A computer readable memory comprising a set of instructions, which, when executed by a computer system, causes the computer system to perform the steps of:

blindly detecting a control channel for a specific user equipment; and

determining a resource allocation for the specific user equipment by decoding the control channel using a decoding scheme that identifies a specific antenna port from among a plurality of antenna ports.

36. The computer readable memory according to claim 35, in which the resource allocation comprises a length-N bit sequence $b_0, \ldots b_{N-1}$ and the detected control channel comprises a received stream of symbols, and, when executed by the computing system, the set of instructions causes the computing system to perform the steps of,:

for a received stream of symbols which comprise the detected the control channel:

mapping the stream of symbols to bits to achieve a scrambled and coded bit sequence $y_k = (c_k+s_k) \bmod 2$;

de-scrambling the scrambled and coded bit sequence with a scrambling sequence $s_0, \ldots, s_{M-1}$ to achieve a length-M coded bit sequence $c_0, \ldots c_{M-1}$;

channel decoding the coded bit sequence to achieve a masked bit sequence; and

using an identifier of the specific user equipment to achieve the bit sequence $b_0, \ldots b_{N-1}$ with an attached cyclic redundancy check CRC of length L from the masked bit sequence to check the CRC; and

checking the CRC,

in which N, L and M are each integers greater than one.

Application No:	GB1201379.3	**Examiner:**	Mrs Hannah Sylvester
Claims searched:	1-18	**Date of search:**	20 June 2012

Patents Act 1977: Search Report under Section 17

Documents considered to be relevant:

Category	Relevant to claims	Identity of document and passage or figure of particular relevance
A	-	US2009/060088 A1 (NORTEL NETWORKS LTD [CA])
X	1, 2, 9, 10, 17 and 18	WO2010/085909 A1 (HUAWEI TECH CO LTD [CN]) see page 2, line 24 to page 4, line 24.
A	-	US2011/194536 A1 (SAMSUNG ELECTRONICS CO LTD et al)
A,E	-	WO2012/053715 A1 (LG ELECTRONICS INC [KR])

Categories:

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.

Field of Search:

Search of GB, EP, WO & US patent documents classified in the following areas of the UKC^X :

Worldwide search of patent documents classified in the following areas of the IPC

H04B; H04L; H04W

The following online and other databases have been used in the preparation of this search report

WPI EPODOC TXTE INSPEC XP3GPP

International Classification:

Subclass	Subgroup	Valid From
None		