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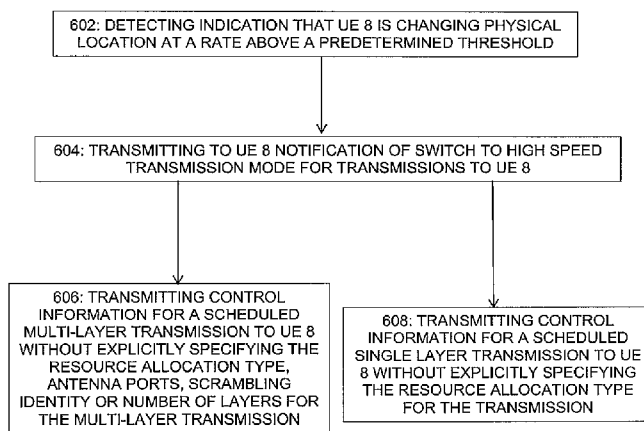


Figure 6

(57) Abstract: A technique, comprising: in response to an indication that a communication device is changing its physical location at a rate above a predetermined threshold, selecting for transmissions to said communication device a transmission mode according to which: data symbols are transmitted together with reference symbols according to the same pre-coding as said data symbols; data symbols and reference symbols share a common pre-coding matrix over a plurality of resource blocks; and multi-layer transmissions involve the transmission of reference symbols for a plurality of layers via shared pairs of resource elements using orthogonal cover codes according to which no despreading is required at the communication device.

TRANSMISSIONS TO HIGH-SPEED DEVICES

5 The multi-antenna transmission of reference symbols according to identical precoding as that used for data symbols in the same resource block, and the use of such reference signals at the receiver to demodulate the data signals, has been proposed as an enhanced technique for improving performance in a radio communication system.

10 The spread of high-speed train networks means that it is increasingly common for communication devices to be rapidly changing their physical location within a radio access network.

There has been identified the challenge of best exploiting the above-mentioned enhanced technique for communication devices in such situations.

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There is hereby provided a method, comprising: in response to an indication that a communication device is changing its physical location at a rate above a predetermined threshold, selecting for transmissions to said communication device a transmission mode according to which: data symbols are transmitted together with reference symbols according to the same precoding as said data symbols; data symbols and reference symbols share a common precoding matrix over a plurality of resource blocks; and multi-layer transmissions involve the transmission of reference symbols for a plurality of layers via shared pairs of resource elements using orthogonal cover codes according to which no despreading is required at the communication device.

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According to one embodiment, said transmission mode further comprises selecting a set of resource blocks for transmissions to said communication device without taking channel conditions into account.

According to one embodiment, the method further comprises informing said communication of the selection of said transmission mode for transmissions to said communication device.

- 5 According to one embodiment, the method further comprises informing said communication device of a scheduled transmission to said communication device without explicitly identifying the resource allocation type for said scheduled transmission.

- 10 According to one embodiment, the method further comprises informing said communication device of a scheduled multi-layer transmission to said communication device without explicitly identifying the antenna ports, scrambling identity and number of layers for said multi-layer transmission.

- 15 There is also hereby provided a method, comprising: receiving at a communication device from an access network an indication of the selection for transmissions from said access network to said communication device a transmission mode according to which: data symbols are transmitted together with reference symbols according to the same precoding as said data symbols; data symbols and reference symbols share a common precoding matrix over a plurality of resource blocks; and multi-layer transmissions involve the transmission of reference symbols for a plurality of layers via shared pairs of resource elements using orthogonal cover codes according to which no despreading is required at the communication device.

- 25 According to one embodiment, the method further comprises receiving information about a scheduled transmission to said communication device, and identifying the resources allocated to the scheduled transmission using the resource allocation type pre-specified for transmissions according to said transmission mode.

- 30 According to one embodiment, the method further comprises receiving information about a scheduled multi-layer transmission to said communication device, and processing the sig-

nals of said multi-layer transmission according to the antenna ports, scrambling identity and number of layers pre-specified for multi-layer transmissions according to said transmission mode.

There is also hereby provided an apparatus comprising: a processor and memory including computer program code, wherein the memory and computer program code are configured to, with the processor, cause the apparatus to: in response to an indication that a communication device is changing its physical location at a rate above a predetermined threshold, select for transmissions to said communication device a transmission mode according to which: data symbols are transmitted together with reference symbols according to the same precoding as said data symbols; data symbols and reference symbols share a common precoding matrix over a plurality of resource blocks; and multi-layer transmissions involve the transmission of reference symbols for a plurality of layers via shared pairs of resource elements using orthogonal cover codes according to which no despreading is required at the communication device.

According to one embodiment, said transmission mode further comprises selecting a set of resource blocks for transmissions to said communication device without taking channel conditions into account.

According to one embodiment, the memory and computer program code are further configured to, with the processor, cause the apparatus to: inform said communication of the selection of said transmission mode for transmissions to said communication device.

According to one embodiment, the memory and computer program code are further configured to, with the processor, cause the apparatus to: inform said communication device of a scheduled transmission to said communication device without explicitly identifying the resource allocation type for said scheduled transmission.

According to one embodiment, the memory and computer program code are further configured to, with the processor, cause the apparatus to: inform said communication device of a scheduled multi-layer transmission to said communication device without explicitly

identifying the antenna ports, scrambling identity and number of layers for said multi-layer transmission.

There is also hereby provided an apparatus comprising: a processor and memory including computer program code, wherein the memory and computer program code are configured to, with the processor, cause the apparatus to: receive at a communication device from an access network an indication of the selection for transmissions from said access network to said communication device a transmission mode according to which: data symbols are transmitted together with reference symbols according to the same precoding as said data symbols; data symbols and reference symbols share a common precoding matrix over a plurality of resource blocks; and multi-layer transmissions involve the transmission of reference symbols for a plurality of layers via shared pairs of resource elements using orthogonal cover codes according to which no despreading is required at the communication device.

According to one embodiment, the memory and computer program code are further configured to, with the processor, cause the apparatus to: receive information about a scheduled transmission to said communication device, and identifying the resources allocated to the scheduled transmission using the resource allocation type pre-specified for transmissions according to said transmission mode.

According to one embodiment, the memory and computer program code are further configured to, with the processor, cause the apparatus to: receive information about a scheduled multi-layer transmission to said communication device, and processing the signals of said multi-layer transmission according to the antenna ports, scrambling identity and number of layers pre-specified for multi-layer transmissions according to said transmission mode.

There is also hereby provided a computer program product comprising program code means which when loaded into a computer controls the computer to: in response to an indication that a communication device is changing its physical location at a rate above a predetermined threshold, select for transmissions to said communication device a trans-

mission mode according to which: data symbols are transmitted together with reference symbols according to the same precoding as said data symbols; data symbols and reference symbols share a common precoding matrix over a plurality of resource blocks; and multi-layer transmissions involve the transmission of reference symbols for a plurality of layers via shared pairs of resource elements using orthogonal cover codes according to which no despreading is required at the communication device.

There is also hereby provided a computer program product comprising program code means which when loaded into a computer controls the computer to: receive at a communication device from an access network an indication of the selection for transmissions from said access network to said communication device a transmission mode according to which: data symbols are transmitted together with reference symbols according to the same precoding as said data symbols; data symbols and reference symbols share a common precoding matrix over a plurality of resource blocks; and multi-layer transmissions involve the transmission of reference symbols for a plurality of layers via shared pairs of resource elements using orthogonal cover codes according to which no despreading is required at the communication device.

Embodiments of the present invention are described in detail hereunder, by way of example only, with reference to the accompanying drawings, in which:

Figure 1 illustrates an example of a cellular network in which embodiments of the present invention are implemented;

Figure 2 illustrates an example of apparatus for use at user equipment in Figure 1;

Figure 3 illustrates an example of apparatus for use at eNodeB in Figure 1;

Figure 4 illustrates an example of an enhanced transmission technique for transmitting data symbols;

Figure 5 illustrates an example of transmitting reference symbols in a multi-layer transmission technique according to an embodiment of the present invention;

Figure 6 illustrates an example of operations at a network access node in accordance with an embodiment of the present invention;

Figure 7 illustrates an example of operations at a user equipment of Figure 1 in accordance with an embodiment of the present invention; and

Figures 8 and 9 illustrate the achievement in performance improvement through the use of a transmission mode that does not require dispreading of reference signals at the receiver.

Embodiments of the invention are described in detail below, by way of example only, in the context of a cellular network operating in accordance with an E-UTRAN standard.

Figure 1 illustrates an example of a cellular network in which embodiments of the present invention can be implemented. The cellular network includes cells 4 with transceivers at respective eNodeBs (eNBs). Only nine cells are shown in Figure 1, but a mobile telecommunication network will typically comprise tens of thousands of cells. Each eNB 2 is connected by a wired link to a core network (not shown).

Figure 2 shows a schematic view of an example of user equipment 8 that may be used for communicating with the eNBs 2 of Figure 1 via a wireless interface. The user equipment (UE) 8 may be used for various tasks such as making and receiving phone calls, for receiving and sending data from and to a data network and for experiencing, for example, multimedia or other content.

The UE 8 may be any device capable of at least sending or receiving radio signals to or from the eNBs 2 of Figure 1. Non-limiting examples include a mobile station (MS), a portable computer provided with a wireless interface card or other wireless interface facility, personal data assistant (PDA) provided with wireless communication capabilities, or any combinations of these or the like. The UE 8 may communicate via an appropriate radio interface arrangement of the UE 8. The interface arrangement may be provided for example by means of a radio part and associated antenna arrangement. The antenna arrangement may be arranged internally or externally to the UE 8, and may include a plurality of antennas capable of operating in the kind of multi-layer transmission scheme described below.

The UE 8 may be provided with at least one data processing entity 203 and at least one memory or data storage entity 217 for use in tasks it is designed to perform. The data processor 213 and memory 217 may be provided on an appropriate circuit board 219 and/or in chipsets.

The user may control the operation of the UE 8 by means of a suitable user interface such as key pad 201, voice commands, touch sensitive screen or pad, combinations thereof or the like. A display 215, a speaker and a microphone may also be provided. Furthermore, the UE 8 may comprise appropriate connectors (either wired or wireless) to other devices and/or for connecting external accessories, for example hands-free equipment, thereto.

UE 8 may also be a relay node configured to relay transmissions from eNB 2 to one or more communication devices.

Figure 3 shows an example of apparatus for use at the eNBs 2 of Figure 1 and for serving the cell 4 in which UE 8 is located. The apparatus comprises a radio frequency antenna array 301 configured to receive and transmit radio frequency signals; radio frequency interface circuitry 303 configured to interface the radio frequency signals received and transmitted by the 8-antenna array 301 and the data processor 306. The radio frequency interface circuitry 303 may also be known as a transceiver. The apparatus also comprises an interface 309 via which it can send and receive information to and from one or more other network nodes. The data processor 306 is configured to process signals from the radio frequency interface circuitry 303, control the radio frequency interface circuitry 303 to generate suitable RF signals to communicate information to the UE 6 via the wireless communications link, and also to exchange information with other network nodes via the interface 309. The memory 307 is used for storing data, parameters and instructions for use by the data processor 306.

It would be appreciated that the apparatus shown in each of figures 2 and 3 described above may comprise further elements which are not directly involved with the embodiments of the invention described hereafter.

5 The downlink transmission of data to a communication device on a physical downlink shared channel (PDSCH) involves a MAC (medium access control) scheduler at eNB 2 allocating radio resources in the time-frequency domain to said downlink transmission of data to said communication device. The bandwidth available to eNB 2 is divided up into physical resource blocks (PRBs), wherein each physical resource block consists of a grid
10 of 84 resource elements comprising 7 consecutive OFDM time symbols for each of 12 contiguous OFDM sub-carriers). The MAC scheduler assigns PRBs in pairs of 2 consecutive PRBs in the time domain.

The downlink (DL) physical processing chain involves generating complex-valued modulation symbols (data and reference symbols). The process of generating these complex
15 valued modulation symbols includes: scrambling of coded bits, and modulation of the scrambled bits.

For a transmission according to a beamforming transmission scheme, the complex-valued modulation symbols are next mapped onto one or more transmission layers (antenna
20 ports), according to whether the transmission is to be a single layer transmission or a multi-layer transmission.

The physical processing next involves deciding on a precoding matrix for the complex-valued modulation symbols (both data symbols and reference symbols) of each
25 transmission layer (antenna port). For each transmission layer (antenna port), the precoding matrix maps the stream of complex-valued modulation symbols for the antenna port onto the 8 antennas. In the case of a multi-layer transmission, different precoding matrices are used for each antenna ports.

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As illustrated in Figure 4, reference symbols for UE-specific reference signals (DM-RS) (as described at Section 6.10.3 of 3GPP TS36.211) of antenna port N are subjected to the same precoding as the complex-valued modulation data symbols for antenna port N. This non-codebook-based transmission technique does not use predefined precoding matrices for the precoding at eNB 2 and deprecoding at UE 8. Based on channel state information received from UE 8, eNB 2 freely selects downlink transmission weights for each antenna of the antenna array, without being restricted to one of a limited predefined number of combinations. UE 8 demodulates the signals detected on time-frequency resources allocated to data symbols according to information derived by UE 8 from the DM-RS that UE 8 knows have been transmitted with the same precoding as the data signals.

The physical processing next involves mapping the modulation symbols for each antenna port to the resource elements of the resource blocks assigned to the transmission by the MAC scheduler, and finally involves generating complex-valued time-domain OFDM signals for each of the eight antennas in accordance with the one or more precoding matrices decided for the transmission.

eNB 2 generally selects Transmission Mode 8 or Transmission Mode 9 defined at 3GPP TS 36.213 V10.1.0, Section 7.1 for transmissions to UEs. Both the dual layer transmission scheme of said Transmission Mode 8 and the spatial multiplexing transmission scheme of said Transmission Mode 9 are characterised by: (a) using respective sets of DM-RS reference symbols for each layer (antenna port), and using code division multiplexing (CDM) to differentiate the respective sets of DM-RS reference symbols transmitted on common time-frequency resources; and (b) deciding respective precoding matrices for each PRB bandwidth.

However, in response to an indication that UE 8 is changing its physical location at a rate above a predetermined threshold (STEP 602 of Figure 6), eNB 2 selects a new "high-speed" transmission mode for transmissions to UE 8, as described below. Such an indication may, for example, be the result of eNB 2 continuously estimating the UE's

moving speed from information available to eNB 2, or may be a message from UE 8 reporting the detection of high-speed movement at UE 8.

eNB 2 notifies UE 8 of a switch to this new "high-speed" transmission mode (STEP 604 of Figure 6 and STEP 702 of Figure 7). UE 8 is aware of the characteristics (as discussed below) of this new "high-speed" transmission mode; and as mentioned below, informing UE 8 of the switch to the new "high-speed" transmission mode reduces the amount of information that eNB 2 needs to explicitly specify in downlink control information (DCI) for each scheduled PDSCH transmission according to the new "high-speed" transmission mode.

The new "high-speed" transmission mode exclusively involves either a single layer transmission (Rank 1 transmission) or a dual layer transmission (Rank 2 transmission). The single layer transmission uses antenna port 7 mentioned at 3GPP TS 36.213 V10.1.0, Section 7.1. The dual layer transmission involves using two new antenna ports X and Y that reuse the resource elements of ports 7 and 8 mentioned at 3GPP TS 36.213 V10.1.0, Section 7.1. The common location in a pair 42 of PRBs 44 of the resource elements 46 commonly used for both reference symbols for antenna port 7 and reference symbols for antenna port 8 is illustrated in Figure 5. According to this new "high-speed" transmission mode, special orthogonal cover codes (OCC) are used for the reference symbols for ports X and Y that do not require a despreading procedure at UE 8. One example of such special OCCs is [0 1] for port X and [1 0] for port Y.

The reference symbols y_1 and y_2 transmitted on a pair of resource elements of antenna ports 7 and 8 can generally be represented by the following respective equations:

$$y_1 = w_{71} * s_7 + w_{81} * s_8$$

$$y_2 = w_{72} * s_7 + w_{82} * s_8$$

wherein $[w_{71} \ w_{72}]$ and $[w_{81} \ w_{82}]$ are the OCCs for antenna ports 7 and 8, respectively; and s_7 and s_8 are predetermined reference symbols for antenna ports 7 and 8, respectively.

tively. When $[w_{71} \ w_{72}] = [1 \ 0]$ and $[w_{81} \ w_{82}] = [0 \ 1]$ (i.e. the example of special OCCs mentioned above), then $y_1 = s_7$ and $y_2 = s_8$, and no despreading of the signals received at the pair of resource elements is required at UE 8. The effect of these special OCCs is that for each pair of PRBs only 6 reference symbols are available to UE 8 for estimating the effective channel for each antenna port (instead of the 12 reference symbols that would be available to UE 8 if OCCs were used that require despreading at UE 8). However, it is found that the use of such special OCCs can improve performance in the case of transmissions to UEs 8 moving at high speed.

- 10 The remaining resource elements 46 of the pair 42 of PRBs 44 are used for data symbols etc..

The new "high-speed" transmission mode also involves using the same precoding matrix (beamforming vector) across all PRBs allocated to the transmission to UE 8. UE 8 recognises the above-mentioned notification of a switch to the new "high-speed" transmission mode as an instruction to start reporting an average of the detected channel conditions across the whole of the bandwidth on which it receives transmissions from eNB 2, instead of making respective reports for each PRB bandwidth on which UE 8 receives transmissions from eNB 2. eNB 2 decides on a common precoding matrix (or matrices for a dual-layer transmission) for all allocated PRBs based on these reports of average channel conditions from UE 8.

The new "high-speed" transmission mode also involves eNB 2 calculating the precoding matrix (beamforming vector) according to long-term channel state information received from UE 8. This involves eNB 2 measuring the channel(s) for UE 8 based on either measurements of transmissions by UE 8 on the physical uplink shared channel (PUSH) or measurements of uplink sounding reference signals (UL SRS) transmitted by UE 8, and then averaging the measurements over time to derive long term channel state information for UE 8. In high-speed scenarios, short term channel state information is found to soon become out-of-date, and the use of long term averages is found to be more effective for deciding the precoding. It is found that the lower the azimuth spread (e.g. a low azimuth spread can be typical in the case of transmissions to high speed trains), the higher the

probability of clearly deriving direction-of-arrival from the UE's long term channel co-variance matrix, i.e. $E[H^H H]$.

5 The new "high-speed" transmission mode also involves: scheduling time-frequency resources (PRBs) i.e. performing frequency domain packet scheduling (FDPS), without taking channel conditions into account; and exclusively using resource allocation type 1 for the assignment of PRBs, which involves selecting a contiguous set of PRB pairs, and for which the minimum size of the allocated resource is 2 or more PRB pairs. As mentioned above, it is found that the higher the speed at which UE 8 is changing its physical location:
10 the less useful is the feedback from UE 8 about the state or quality of the channel(s) between eNB 2 and UE 8 (CSI or CQI feedback), and the less effective it is to perform FDPS taking into account such feedback.

15 For each scheduled single-layer or dual-layer transmission to UE 8, eNB 2 transmits downlink control information (DCI) to UE 8 (STEPS 606 and 608 of Figure 6; and STEPS 704 and 706 of Figure 7). For a single-layer transmission according to the new high-speed transmission mode, eNB 2 uses DCI Format 1A as defined at Section 5.3.3.1.3 of GPP TS 36.212 V10.5.0; and for a dual-layer transmission according to the new "high-speed" transmission scheme, eNB 2 uses a simplified version (as described
20 below) of DCI Format 2C as defined at Section 5.3.3.1.5C of GPP TS 36.212 V10.5.0. Because UE 8 has been notified of the switch to the new "high-speed" transmission mode, there is no need to explicitly specify in the downlink control information for a scheduled transmission which antenna ports are used for the transmission. The use of DCI Format 1A indicates to UE 8 that the transmission is a single layer transmission using antenna
25 port 7 (and that port 8 is unused and that no de-spreading of the DM-RS is required before channel estimation). On the other hand, the use of DCI Format 2C indicates to UE 8 that the transmission is a dual-layer transmission using two antenna ports X and Y that use the resource elements of antenna ports 7 and 8, and that special OCCs are used according to which no despreading of the DM-RS is required, as described above.

30 The modifications to DCI Format 2C as defined at Section 5.3.3.1.3 of GPP TS 36.212 V10.5.0 include the following: (a) removing the 1-bit resource allocation header (which is redundant for the new "high-speed transmission mode, because only resource allocation

type 1 is used); and (b) removing the 3-bit information element that explicitly indicates the antenna ports, the scrambling identity and the number of layers. In relation to (a), it is noted again that performing distributed PRB allocation (allocation type 2), i.e. allocating PRBs at selected frequencies based on CQI or CSI feedback, is found to be less effective
5 in high speed scenarios. In relation to (b): it is noted that fast rank adaptation is found to be less effective in high speed scenarios, and that it is found to be more effective to configure the rank by RRC (radio resource control) signalling, instead of specifying the rank individually for each transmission time interval (TTI).

10 For a scheduled single-layer transmission, UE 8 identifies the resources allocated to the scheduled transmission using the resource allocation type pre-specified for the new "high-speed" transmission mode (STEP 710); and for a scheduled multi-layer transmission, UE 8 both identifies the resources allocated to the scheduled transmission using the resource allocation type pre-specified for the new "high-speed" transmission mode, and
15 processes the signals of the multi-layer transmission according to the antenna ports, scrambling identity and number of layers pre-specified for multi-layer transmissions according to the new high-speed transmission mode (STEP 708).

In one embodiment, UE 8 is a relay node located on a high speed train, and the train relay
20 node 8 functions to relay data from eNB 2 to individual communication devices on the high-speed train. According to a technique developed by the inventors: for any TTI (sub-frame) including a transmission to the train relay node, eNB is configured to allocate all PRBs in said TTI (i.e. all 50PRBs in the case of a 10MHz system) to transmissions to said train relay node 8. This technique has the advantage that the downlink control
25 information to the train relay node 8 for that TTI does not need to include a resource allocation bit mask, whereby the overhead for downlink control information can be significantly reduced. For the relatively short period that the train is moving at high speed through the cell of eNB 2, eNB 2 could allocate all of the TTIs for that short period to transmissions to the train relay node 8. In the event that there happens to be two high speed trains
30 (each having its own relay node 8) moving at high speed through the same cell of eNB 2 at the same time, then again for the relatively short period that both high speed trains are moving at high speed through the cell of eNB 2, eNB 2 could allocate all TTIs for that short period to transmissions to the train relay nodes 8 of the two high speed trains, and schedule the two train relay nodes 8 alternatively in the time domain, e.g. using

even-numbered subframes (TTIs) for one train relay node 8, and using odd-numbered subframes (TTIs) for the other train relay node 8. The impact of this technique on performance is found to be insignificant for the high-speed transmission mode described above, in which FDPS is performed without taking channel state or quality into account.

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As mentioned above, the new "high-speed" transmission mode does not require despreading of DM-RS at UE 8. Figures 8 and 9 together illustrate how this can achieve an improvement in performance. Figure 8 shows error rates for transmissions involving the despreading of DM-RS at the receiver, and Figure 9 shows error rates for transmissions without despreading of DM-RS at the receiver.

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The above-described operations may require data processing in the various entities. The data processing may be provided by means of one or more data processors. Similarly various entities described in the above embodiments may be implemented within a single or a plurality of data processing entities and/or data processors. Appropriately adapted computer program code product may be used for implementing the embodiments, when loaded to a computer. The program code product for providing the operation may be stored on and provided by means of a carrier medium such as a carrier disc, card or tape. A possibility is to download the program code product via a data network. Implementation may be provided with appropriate software in a server.

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For example the embodiments of the invention may be implemented as a chipset, in other words a series of integrated circuits communicating among each other. The chipset may comprise microprocessors arranged to run code, application specific integrated circuits (ASICs), or programmable digital signal processors for performing the operations described above.

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Embodiments of the invention may be practiced in various components such as integrated circuit modules. The design of integrated circuits is by and large a highly automated process. Complex and powerful software tools are available for converting a logic level design into a semiconductor circuit design ready to be etched and formed on a semiconductor substrate.

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Programs, such as those provided by Synopsys, Inc. of Mountain View, California and Cadence Design, of San Jose, California automatically route conductors and locate components on a semiconductor chip using well established rules of design as well as libraries of pre stored design modules. Once the design for a semiconductor circuit has been completed, the resultant design, in a standardized electronic format (e.g., Opus, GDSII, or the like) may be transmitted to a semiconductor fabrication facility or "fab" for fabrication.

In addition to the modifications explicitly mentioned above, it will be evident to a person skilled in the art that various other modifications of the described embodiment may be made within the scope of the invention.

WHAT IS CLAIMED IS:

1. A method, comprising: in response to an indication that a communication device is changing its physical location at a rate above a predetermined threshold, selecting for
5 transmissions to said communication device a transmission mode according to which: data symbols are transmitted together with reference symbols according to the same pre-coding as said data symbols; data symbols and reference symbols share a common pre-coding matrix over a plurality of resource blocks; and multi-layer transmissions involve the transmission of reference symbols for a plurality of layers via shared pairs of resource
10 elements using orthogonal cover codes according to which no despreading is required at the communication device.
2. A method according to claim 1, wherein said transmission mode further comprises selecting a set of resource blocks for transmissions to said communication device without
15 taking channel conditions into account.
3. A method according to claim 1, comprising informing said communication of the selection of said transmission mode for transmissions to said communication device.
- 20 4. A method according to claim 3, comprising informing said communication device of a scheduled transmission to said communication device without explicitly identifying the resource allocation type for said scheduled transmission.
- 25 5. A method according to claim 3, further comprising informing said communication device of a scheduled multi-layer transmission to said communication device without explicitly identifying the antenna ports, scrambling identity and number of layers for said multi-layer transmission.

6. A method, comprising: receiving at a communication device from an access network an indication of the selection for transmissions from said access network to said communication device a transmission mode according to which: data symbols are transmitted together with reference symbols according to the same precoding as said data symbols; data symbols and reference symbols share a common precoding matrix over a plurality of resource blocks; and multi-layer transmissions involve the transmission of reference symbols for a plurality of layers via shared pairs of resource elements using orthogonal cover codes according to which no despreading is required at the communication device.

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7. A method according to claim 6, comprising receiving information about a scheduled transmission to said communication device, and identifying the resources allocated to the scheduled transmission using the resource allocation type pre-specified for transmissions according to said transmission mode.

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8. A method according to claim 6, further comprising receiving information about a scheduled multi-layer transmission to said communication device, and processing the signals of said multi-layer transmission according to the antenna ports, scrambling identity and number of layers pre-specified for multi-layer transmissions according to said transmission mode.

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9. An apparatus comprising: a processor and memory including computer program code, wherein the memory and computer program code are configured to, with the processor, cause the apparatus to: in response to an indication that a communication device is changing its physical location at a rate above a predetermined threshold, select for transmissions to said communication device a transmission mode according to which: data symbols are transmitted together with reference symbols according to the same precoding as said data symbols; data symbols and reference symbols share a common precoding matrix over a plurality of resource blocks; and multi-layer transmissions involve the transmission of reference symbols for a plurality of layers via shared pairs of resource elements using orthogonal cover codes according to which no despreading is required at the communication device.

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10. An apparatus according to claim 9, wherein said transmission mode further comprises selecting a set of resource blocks for transmissions to said communication device without taking channel conditions into account.

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11. An apparatus according to claim 9, wherein the memory and computer program code are further configured to, with the processor, cause the apparatus to: inform said communication of the selection of said transmission mode for transmissions to said communication device.

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12. An apparatus according to claim 11, wherein the memory and computer program code are further configured to, with the processor, cause the apparatus to: inform said communication device of a scheduled transmission to said communication device without explicitly identifying the resource allocation type for said scheduled transmission.

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13. An apparatus according to claim 11, wherein the memory and computer program code are further configured to, with the processor, cause the apparatus to: inform said communication device of a scheduled multi-layer transmission to said communication device without explicitly identifying the antenna ports, scrambling identity and number of layers for said multi-layer transmission.

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14. An apparatus comprising: a processor and memory including computer program code, wherein the memory and computer program code are configured to, with the processor, cause the apparatus to: receive at a communication device from an access network an indication of the selection for transmissions from said access network to said communication device a transmission mode according to which: data symbols are transmitted together with reference symbols according to the same precoding as said data symbols; data symbols and reference symbols share a common precoding matrix over a plurality of resource blocks; and multi-layer transmissions involve the transmission of reference symbols for a plurality of layers via shared pairs of resource elements using or-

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thogonal cover codes according to which no despreading is required at the communication device.

15. An apparatus according to claim 14, wherein the memory and computer program
5 code are further configured to, with the processor, cause the apparatus to: receive information about a scheduled transmission to said communication device, and identifying the resources allocated to the scheduled transmission using the resource allocation type pre-specified for transmissions according to said transmission mode.

10 16. An apparatus according to claim 14, wherein the memory and computer program code are further configured to, with the processor, cause the apparatus to: receive information about a scheduled multi-layer transmission to said communication device, and processing the signals of said multi-layer transmission according to the antenna ports, scrambling identity and number of layers pre-specified for multi-layer transmissions
15 according to said transmission mode.

17. A computer program product comprising program code means which when loaded into a computer controls the computer to: in response to an indication that a communication device is changing its physical location at a rate above a predetermined threshold,
20 select for transmissions to said communication device a transmission mode according to which: data symbols are transmitted together with reference symbols according to the same precoding as said data symbols; data symbols and reference symbols share a common precoding matrix over a plurality of resource blocks; and multi-layer transmissions involve the transmission of reference symbols for a plurality of layers via shared
25 pairs of resource elements using orthogonal cover codes according to which no despreading is required at the communication device.

18. A computer program product comprising program code means which when loaded into a computer controls the computer to: receive at a communication device from an access network an indication of the selection for transmissions from said access network to
30 said communication device a transmission mode according to which: data symbols are transmitted together with reference symbols according to the same precoding as said data

symbols; data symbols and reference symbols share a common precoding matrix over a plurality of resource blocks; and multi-layer transmissions involve the transmission of reference symbols for a plurality of layers via shared pairs of resource elements using orthogonal cover codes according to which no despreading is required at the communication device.

5

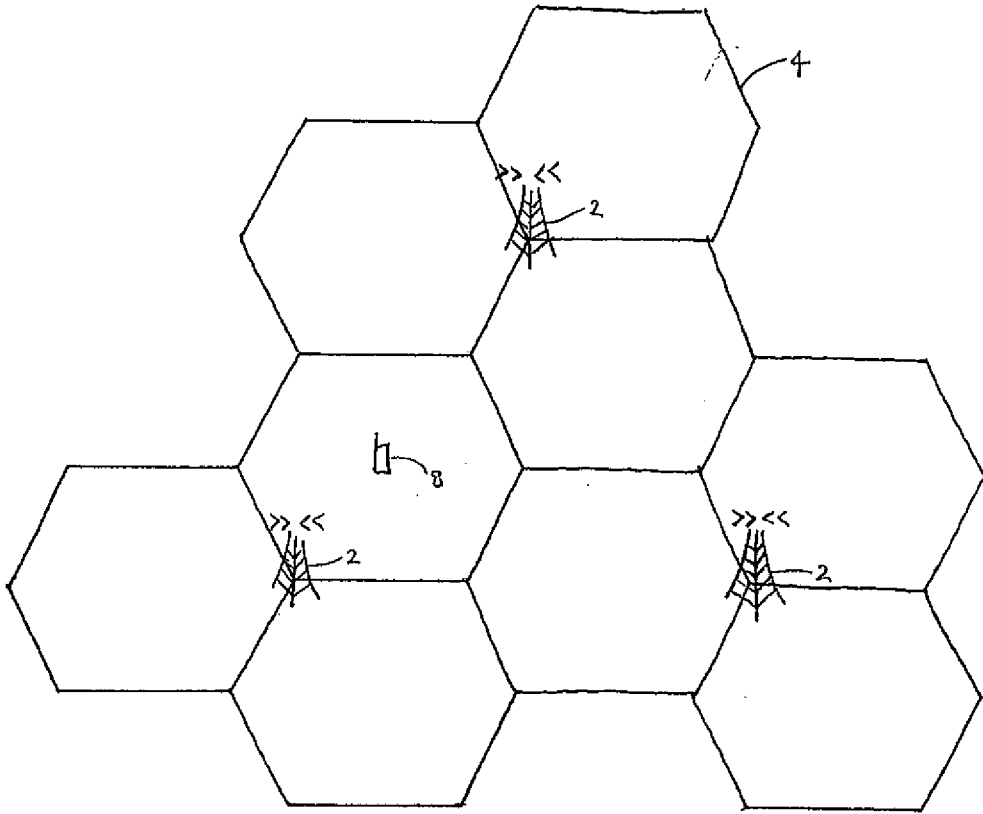


Figure 1

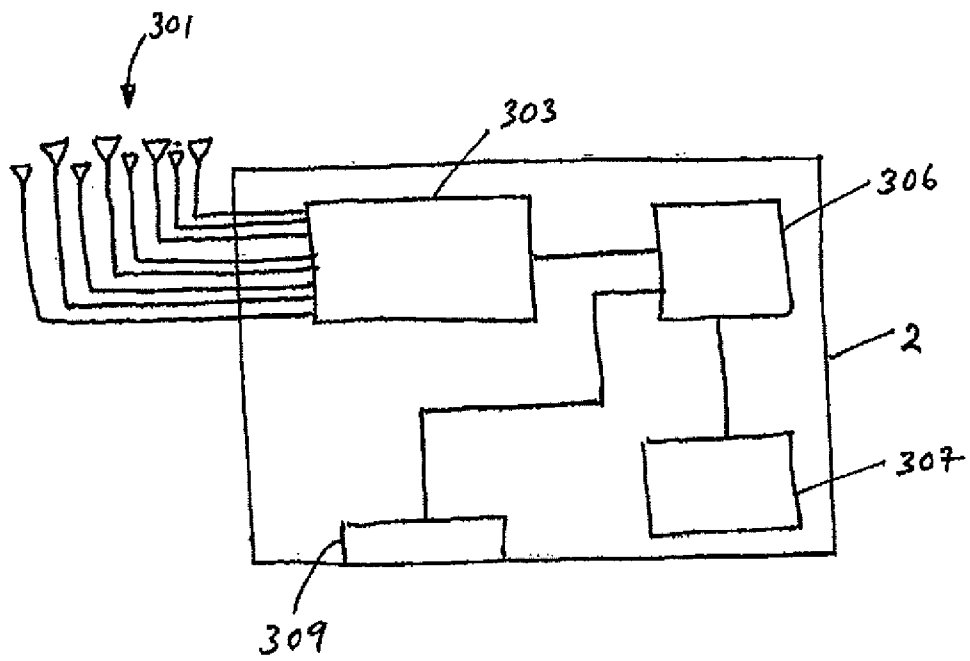


Figure 2

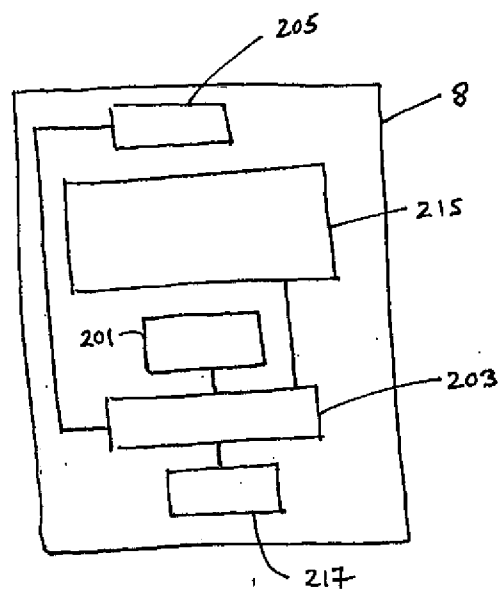


Figure 3

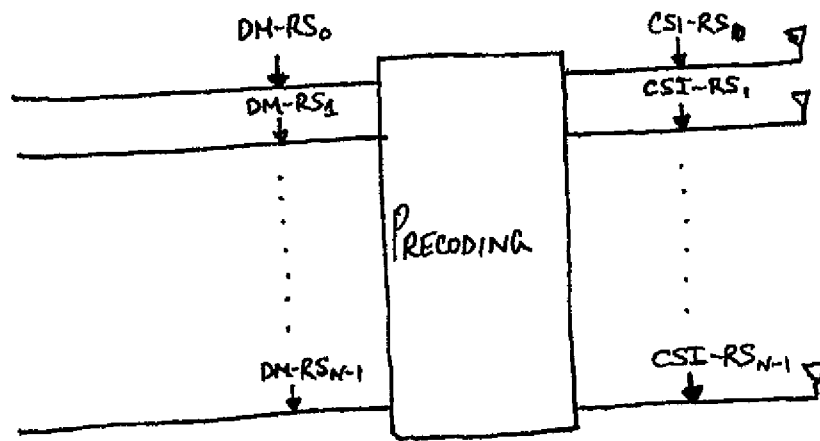


Figure 4

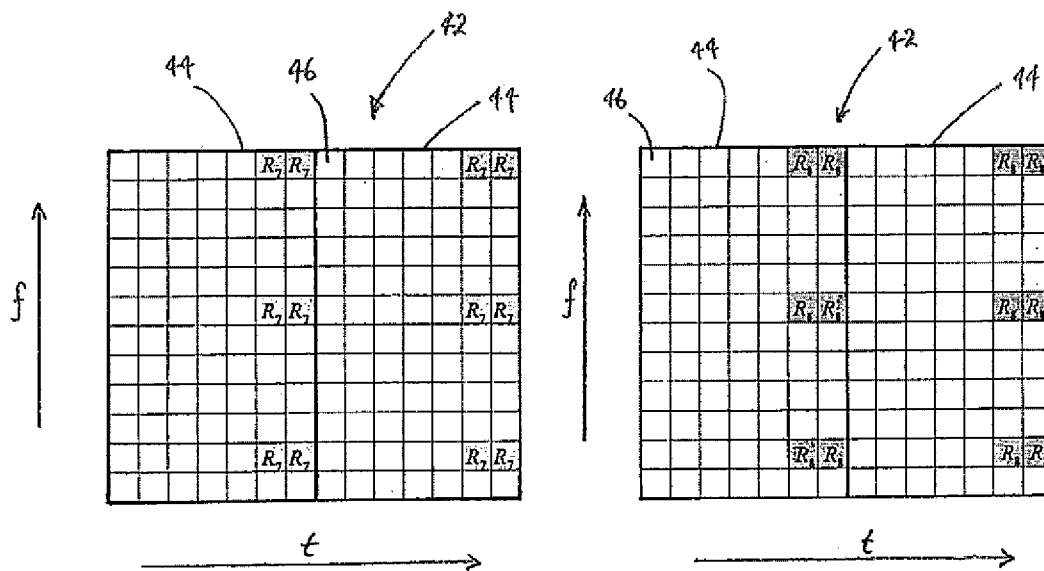


Figure 5

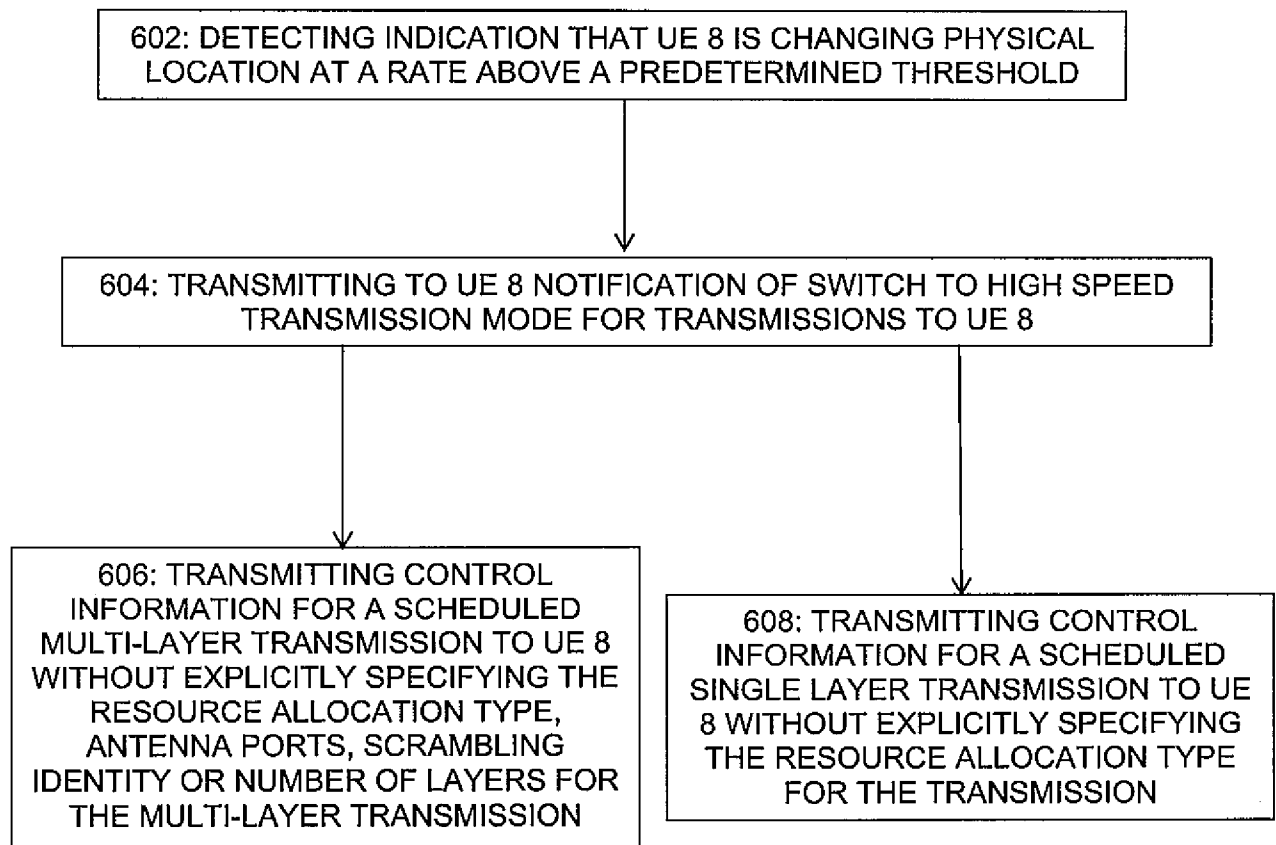


Figure 6

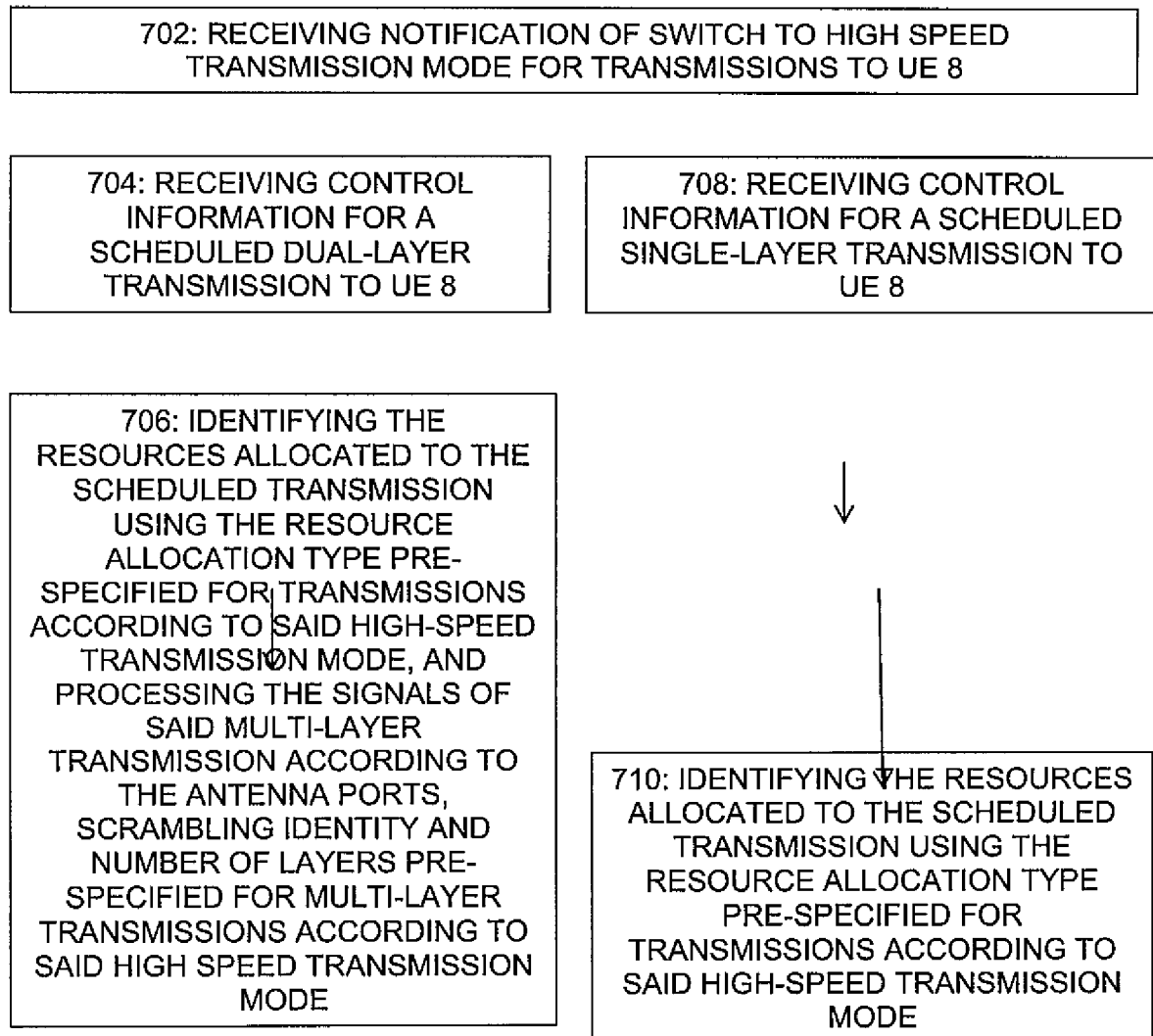


Figure 7

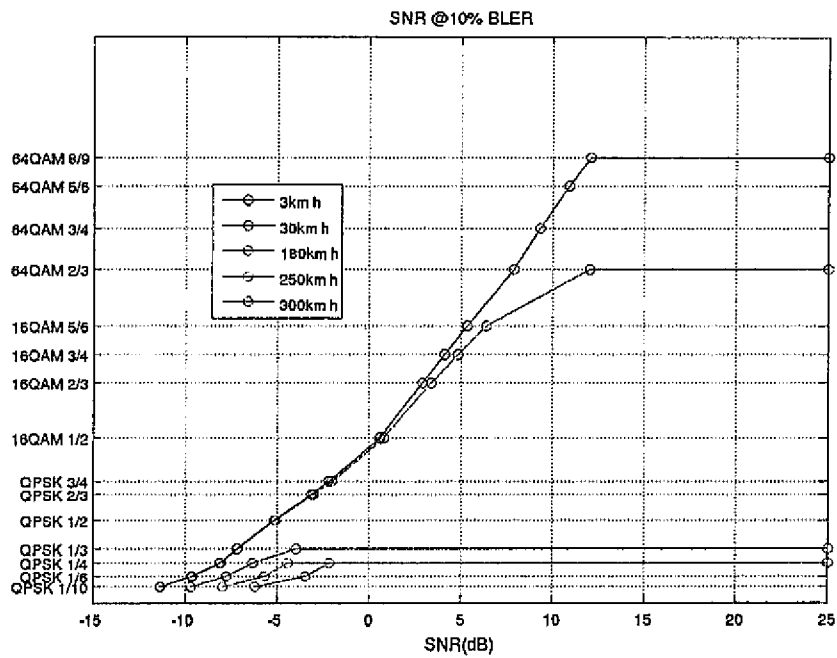


Figure 8

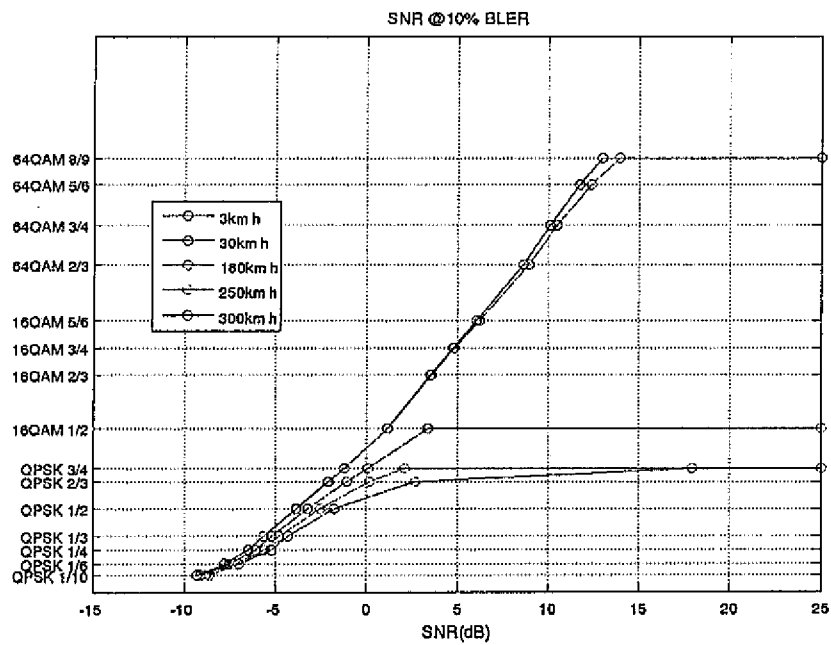


Figure 9

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2012/076611

A. CLASSIFICATION OF SUBJECT MATTER

H04W 88/08 (2009.01) i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC:H04W, H04L, H04B

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

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

CNPAT,WPI,EPODOC,IEEE,3GPP,GOOGLE SCHOLAR: high speed, rate, train, communication, transmission, hand-off, handover, reference symbol, data symbol, matrix, precoding, shar+

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	Null Sub-Carrier Aided Reference Symbol Mapping for Improved Channel Estimation in 3GPP LTE Downlink, MURUGANATHAN, Siva D. et al., Vehicular Technology Conference (VTC 2010-Spring), 19 May 2010 (19.05.2010), see page 1, right column, line 7- page 3, left column, line 20	1-18
A	A High-speed Railway Mobile Communication System Based on LTE, GAO Tingting, 2010 International Conference on Electronics and Information Engineering (ICEIE 2010), Vol. 1, Pages 414-417	1-18
A	CN101389064A(RUIFENGXING CO., LTD.),18 Mar. 2009 (18.03.2009), the whole document	1-18
A	Seamless Dual-Link Handover Scheme in Broadband Wireless Communication Systems for High-Speed Rail, TIAN, Lin et al., IEEE JOURNAL ON SELECTED AREAS IN COMMUNICATIONS, VOL. 30, NO. 4, May 2012, the whole document	1-18

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

* Special categories of cited documents:	“T” later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
“A” document defining the general state of the art which is not considered to be of particular relevance	“X” document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
“E” earlier application or patent but published on or after the international filing date	“Y” document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
“L” document which may throw doubts on priority claim (S) or which is cited to establish the publication date of another citation or other special reason (as specified)	“&” document member of the same patent family
“O” document referring to an oral disclosure, use, exhibition or other means	
“P” document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search 27 Feb. 2013 (27.02.2013)	Date of mailing of the international search report 14 Mar. 2013 (14.03.2013)
Name and mailing address of the ISA/CN The State Intellectual Property Office, the P.R.China 6 Xitucheng Rd., Jimen Bridge, Haidian District, Beijing, China 100088 Facsimile No. 86-10-62019451	Authorized officer YU,Liwen Telephone No. (86-10)62414025

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CN2012/076611

Patent Documents referred in the Report	Publication Date	Patent Family	Publication Date
CN101389064A	18.03.2009	NONE	