

(51) International Patent Classification:
H04W 24/10 (2009.01)(21) International Application Number:
PCT/CN2012/087155(22) International Filing Date:
21 December 2012 (21.12.2012)

(25) Filing Language: English

(26) Publication Language: English

(71) Applicant (for all designated States except US): **BROAD-COM CORPORATION** [US/US]; 5300 California Avenue, Irvine, California 92617 (US).

(72) Inventors; and

(71) Applicants (for US only): **CHARBIT, Gilles** [GB/GB]; 18 Carlyon Close, Farnborough GU14 7BX (GB). **ZENG, Erlin** [CN/CN]; Room 1605, Building A-12, Xi San Qi Jian Cai Cheng, Fu Li Tao Yuan, Haidian District, Beijing 100096 (CN).(74) Agent: **KING & WOOD MALLESONS**; 20th Floor, East Tower, World Financial Center, No. 1 Dongsanhuan Zhonglu, Chaoyang District, Beijing 100020 (CN).

(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

[Continued on next page]

(54) Title: METHOD FOR DETERMINING CHANNEL QUALITY INFORMATION (CQI) FOR PHYSICAL RESOURCE BLOCKS HAVING REDUCED OVERHEAD

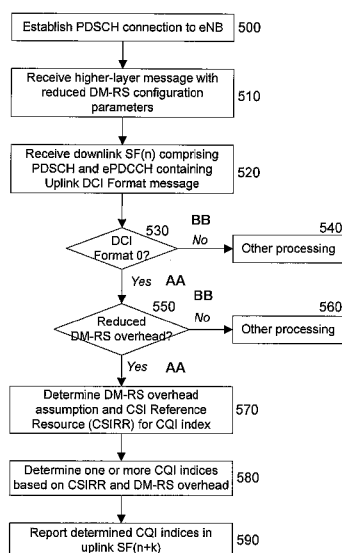


Fig. 5A

(57) Abstract: Embodiments include methods for a network equipment (e.g., eNB) requesting channel quality information (CQI) from a communication device (e.g., UE) to provide the device with information that identifies a resource for measuring CQI and the type, amount, and/or location of overhead information (e.g., demodulation reference signals) within the resource. Embodiments also include methods for a communication device to receive, in conjunction with a CQI request, information identifying a resource used for measuring CQI and the type, amount, and/or location of overhead information within the resource. The device utilizes the information to determine one or more values (e.g., CQI indices) and reports these to the network equipment. Embodiments include communication devices or apparatus, network equipment or apparatus, and computer-readable media embodying one or more of the methods.



Declarations under Rule 4.17:

— *of inventorship (Rule 4.17(iv))*

Published:

— *with international search report (Art. 21(3))*

METHOD FOR DETERMINING CHANNEL QUALITY INFORMATION (CQI)
FOR PHYSICAL RESOURCE BLOCKS HAVING REDUCED OVERHEAD

TECHNICAL FIELD

5 [0001] The disclosure herein relates to the field of wireless or cellular communications, and more particularly to methods, devices, and network equipment for determining channel quality information (CQI) for a radio signal comprised of physical resource blocks having a reduced amount of overhead information, such as demodulation reference signals.

BACKGROUND

10 [0002] The Third Generation Partnership Project (3GPP) unites six telecommunications standards bodies, known as “Organizational Partners,” and provides their members with a stable environment to produce the highly successful Reports and Specifications that define 3GPP technologies. These technologies are constantly evolving through what have become known as “generations” of commercial cellular/mobile systems. 3GPP also uses a system of
15 parallel “releases” to provide developers with a stable platform for implementation and to allow for the addition of new features required by the market. Each release includes specific functionality and features that are specified in detail by the version of the 3GPP standards associated with that release.

[0003] Universal Mobile Telecommunication System (UMTS) is an umbrella term for the
20 third generation (3G) radio technologies developed within 3GPP and initially standardized in Release 4 and Release 99, which preceded Release 4. UMTS includes specifications for both the UMTS Terrestrial Radio Access Network (UTRAN) as well as the Core Network. UTRAN includes the original Wideband CDMA (W-CDMA) radio access technology that uses paired or unpaired 5-MHz channels, initially within frequency bands near 2 GHz but
25 subsequently expanded into other licensed frequency bands. The UTRAN generally includes node-Bs (NBs) and radio network controllers (RNCs). Similarly, GSM/EDGE is an umbrella term for the second-generation (2G) radio technologies initially developed within the European Telecommunication Standards Institute (ETSI) but now further developed and maintained by 3GPP. The GSM/EDGE Radio Access Network (GERAN) generally
30 comprises base stations (BTSS) and base station controllers (BSCs).

[0004] Long Term Evolution (LTE) is another umbrella term for so-called fourth-generation (4G) radio access technologies developed within 3GPP and initially standardized in Releases 8 and 9, also known as Evolved UTRAN (E-UTRAN). As with UMTS, LTE is targeted at various licensed frequency bands, including the 700-MHz band in the United States. LTE is accompanied by improvements to non-radio aspects commonly referred to as System Architecture Evolution (SAE), which includes Evolved Packet Core (EPC) network. LTE continues to evolve through subsequent releases. One of the features of Release 11 is an enhanced Physical Downlink Control Channel (ePDCCH), which has the goals of increasing capacity and improving spatial reuse of control channel resources, improving inter-cell interference coordination (ICIC), and supporting antenna beamforming and/or transmit diversity for control channel.

[0005] Another feature of Release 11 is carrier aggregation (CA), which by which individual carriers are combined or aggregated to increase the bandwidth available for transmission and, consequently, the data transmission rates. Each aggregated carrier is referred to as a component carrier (CC). Each CC can have a bandwidth of 1.4, 3, 5, 10, 15 or 20 MHz and a maximum of five CCs can be aggregated. In FDD the number of aggregated carriers can be different in downlink (network-to-device) and uplink (device-to-network). For compatibility with Release-8 and Release-9 devices already deployed, only CC types defined in Releases 8 and 9 are allowed to be aggregated in Release 11 CA.

SUMMARY

[0007] Embodiments of the present disclosure include methods for determining channel quality information (CQI) for a received physical-layer (PHY) channel comprising a plurality of subframes, comprising receiving a first set of one or more subframes comprising a data message, wherein at least a portion of the first set of one or more subframes comprise overhead information related to demodulation of the data message; receiving a subframe comprising a first control message, wherein the first control message comprises a request to determine CQI and configuration information related to the request; determining, based on the configuration information, a resource within the first set of subframes to be used for CQI determination and one or more overhead information patterns within the resource; determining one or more CQI values for each of the overhead information patterns; and

transmitting a subframe comprising a second control message, wherein the second control message comprises the determined CQI values.

[0008] Embodiments of the present disclosure also include methods for determining CQI for a transmitted PHY channel comprising a plurality of subframes, comprising transmitting
5 a first set of one or more subframes comprising a data message to a receiving apparatus, wherein at least a portion of the first set of subframes comprise overhead information related to demodulation of the data message; determining a set of parameters for CQI determination, wherein the parameters include a resource within the first set of subframes to be used for CQI determination and one or more overhead information patterns within the resource; encoding
10 the set of parameters into configuration information comprising one of a plurality of assumptions to be used by the receiving apparatus; transmitting a subframe comprising a first control message, wherein the first control message comprises the configuration information and a request to determine CQI; and receiving a subframe comprising a second control message, wherein the second control message comprises one or more CQI values.

15 [0009] Embodiments also include wireless network equipment or apparatus (e.g., eNB or component of an eNB), wireless communication device or apparatus (e.g., a UE or component of a UE), and computer-readable media embodying one or more of these methods.

DESCRIPTION OF THE DRAWINGS

[0010] The detailed description will refer to the following drawings, wherein like numerals
20 refer to like elements, and wherein:

Fig. 1 is a high-level block diagram of the architecture of the Long Term Evolution (LTE) Evolved UTRAN (E-UTRAN) and Evolved Packet Core (EPC) network, as standardized by 3GPP;

25 Fig. 2A is a high-level block diagram of the E-UTRAN architecture in terms of its constituent components, protocols, and interfaces;

Fig. 2B is a block diagram of the protocol layers of the control-plane portion of the radio (Uu) interface between a user equipment (UE) and the E-UTRAN;

Fig. 2C is a block diagram of the LTE radio interface protocol architecture from the perspective of the PHY layer;

30 Fig. 3 is block diagram of the type-1 LTE radio frame structure used for both full-duplex and half-duplex FDD operation;

Fig. 4A is a block diagram illustrating one manner in which control channel elements (CCEs) and resource element groups (REGs) for a PDCCH can be mapped with a PDSCH into LTE physical resource blocks (PRBs);

Fig. 4B is a block diagram illustrating one manner in which a PDCCH and a PDSCH can be mapped into PRBs along with various amounts of demodulation reference signal (DM-RS) overhead;

Fig. 4C is a block diagram showing multiple PDSCH subframes comprising different amounts of DM-RS overhead;

Fig. 5A is a flowchart of an exemplary method for measuring and reporting channel quality information (CQI) by a wireless communication device, according to embodiments of the present disclosure;

Figs. 5B, 5C, and 5D are flowcharts illustrating variations of operations performed in particular blocks of the method shown in Fig. 5A, according to embodiments of the present disclosure;

Fig. 6 is a flowchart of an exemplary method in a network equipment for providing information characterizing channel resources to be used for a CQI report by a wireless communication device, according to one or more embodiments of the present disclosure;

Figs. 7A, 7B, and 7C are exemplary tables associating values of bit fields in a message with actions related to CQI measurements, according to various embodiments of the present disclosure;

Figs. 8A, 8B, 8C, 8D, and 8E are high-level timing diagrams showing relationships between PRBs used for CQI measurements and DM-RS overhead information, according to various embodiments of the present disclosure;

Fig. 9 is a block diagram an exemplary apparatus, such as a wireless communication device, according to one or more embodiments of the present disclosure; and

Fig. 10 is a block diagram an exemplary apparatus, such as a network equipment, according to one or more embodiments of the present disclosure.

DETAILED DESCRIPTION

[0011] The overall architecture of a network comprising LTE and SAE is shown in Fig.1. E-UTRAN 100 comprises one or more evolved Node B's (eNB), such as eNBs 105, 110, and 115, and one or more user equipment (UE), such as UE 120. As used within the 3GPP

standards, “user equipment” or “UE” means any wireless communication device (e.g., smartphone or computing device) that is capable of communicating with 3GPP-standard-compliant network equipment, such as UTRAN, E-UTRAN, and/or GERAN, as the second-generation (“2G”) 3GPP radio access network is commonly known.

5 [0012] As specified by 3GPP, E-UTRAN 100 is responsible for all radio-related functions in the network, including radio bearer control, radio admission control, radio mobility control, scheduling, and dynamic allocation of resources to UEs in uplink and downlink, as well as security of the communications with the UE. These functions reside in the eNBs, such as eNBs 105, 110, and 115. The eNBs in the E-UTRAN communicate with each other via the
10 X1 interface, as shown in Fig. 1A. The eNBs also are responsible for the E-UTRAN interface to the EPC, specifically the S1 interface to the Mobility Management Entity (MME) and the Serving Gateway (SGW), shown collectively as MME/S-GWs 134 and 138 in Fig. 1A. Generally speaking, the MME/S-GW handles both the overall control of the UE and data flow between the UE and the rest of the EPC. More specifically, the MME processes
15 the signaling protocols between the UE and the EPC, which are known as the Non Access Stratum (NAS) protocols. The S-GW handles all Internet Protocol (IP) data packets between the UE and the EPC, and serves as the local mobility anchor for the data bearers when the UE moves between eNBs, such as eNBs 105, 110, and 115.

[0013] Fig. 2A is a high-level block diagram of LTE architecture in terms of its constituent
20 entities – UE, E-UTRAN, and EPC – and high-level functional division into the Access Stratum (AS) and the Non-Access Stratum (NAS). Fig. 1 also illustrates two particular interface points, namely Uu (UE/E-UTRAN Radio Interface) and S1 (E-UTRAN/EPC interface), each using a specific set of protocols, i.e., Radio Protocols and S1 Protocols. Each of the two protocols can be further segmented into user plane (or “U-plane”) and control
25 plane (or “C-plane”) protocol functionality. On the Uu interface, the U-plane carries user information (e.g., data packets) while the C-plane carries control information between UE and E-UTRAN.

[0014] Fig. 2B is a block diagram of the C-plane protocol stack on the Uu interface comprising Physical (PHY), Medium Access Control (MAC), Radio Link Control (RLC),
30 Packet Data Convergence Protocol (PDCP), and Radio Resource Control (RRC) layers. The PHY layer is concerned with how and what characteristics are used to transfer data over

transport channels on the LTE radio interface. The MAC layer provides data transfer services on logical channels, maps logical channels to PHY transport channels, and reallocates PHY resources to support these services. The RLC layer provides error detection and/or correction, concatenation, segmentation, and reassembly, reordering of data transferred to or from the upper layers. The PHY, MAC, and RLC layers perform identical functions for both the U-plane and the C-plane. The PDCP layer provides ciphering/deciphering and integrity protection for both U-plane and C-plane, as well as other functions for the U-plane such as header compression.

[0015] Fig. 2C is a block diagram of the LTE radio interface protocol architecture from the perspective of the PHY. The interfaces between the various layers are provided by Service Access Points (SAPs), indicated by the ovals in Fig. 2C. The PHY layer interfaces with the MAC and RRC protocol layers described above. The MAC provides different logical channels to the RLC protocol layer (also described above), characterized by the type of information transferred, whereas the PHY provides a transport channel to the MAC, characterized by how the information is transferred over the radio interface. In providing this transport service, the PHY performs various functions including error detection and correction; rate-matching and mapping of the coded transport channel onto physical channels; power weighting, modulation; and demodulation of physical channels; transmit diversity, beamforming multiple input multiple output (MIMO) antenna processing; and providing radio measurements to higher layers, such as RRC. Downlink (i.e., eNB to UE) physical channels provided by the LTE PHY include Physical Downlink Shared Channel (PDSCH), Physical Multicast Channel (PMCH), Physical Downlink Control Channel (PDCCH), Relay Physical Downlink Control Channel (R-PDCCH), Physical Broadcast Channel (PBCH), Physical Control Format Indicator Channel (PCFICH), and Physical Hybrid ARQ Indicator Channel (PHICH).

[0016] The multiple access scheme for the LTE PHY is based on Orthogonal Frequency Division Multiplexing (OFDM) with a cyclic prefix (CP) in the downlink, and on Single-Carrier Frequency Division Multiple Access (SC-FDMA) with a cyclic prefix in the uplink. To support transmission in paired and unpaired spectrum, the LTE PHY supports both: Frequency Division Duplexing (FDD) (including both full- and half-duplex operation) and Time Division Duplexing (TDD). Fig. 3 shows the radio frame structure ("type 1") used for

both full-duplex and half-duplex FDD operation. The radio frame has a duration of 10 ms and consists of 20 slots, labeled 0 through 19, each with a duration of 0.5 ms. A 1-ms subframe comprises two consecutive slots where subframe i consists of slots $2i$ and $2i+1$. Each slot consists of $N_{\text{symb}}^{\text{DL}}$ OFDM symbols, each of which is comprised of N_{sc} OFDM subcarriers. The value of $N_{\text{symb}}^{\text{DL}}$ is typically 7 (with a normal CP) or 6 (with an extended-length CP) for subcarrier bandwidth of 15 kHz. The value of N_{sc} is configurable based upon the available channel bandwidth. Since persons of ordinary skill in the art will be familiar with the principles of OFDM, further details are omitted in this description.

[0017] As shown in Fig. 3, the combination of a particular subcarrier in a particular symbol is known as a resource element (RE). Each RE is used to transmit a particular number of bits, depending on the type of modulation and/or bit-mapping constellation used for that RE. For example, some REs may carry two bits using QPSK modulation, while other REs may carry four or six bits using 16- or 64-QAM, respectively. The radio resources of the LTE PHY are also defined in terms of physical resource blocks (PRBs). A PRB spans $N_{\text{sc}}^{\text{RB}}$ sub-carriers over the duration of a slot (i.e., $N_{\text{symb}}^{\text{DL}}$ symbols), where $N_{\text{sc}}^{\text{RB}}$ is typically either 12, (with a sub-carrier bandwidth of 15kHz) or 24 (with a sub-carrier bandwidth of 7.5kHz). A PRB spanning the same $N_{\text{sc}}^{\text{RB}}$ subcarriers during an entire subframe (i.e., $2N_{\text{symb}}^{\text{DL}}$ symbols) is known as a PRB pair. Accordingly, the resources available in a subframe of the LTE PHY downlink comprise $N_{\text{RB}}^{\text{DL}}$ PRB pairs, each of which comprises $2N_{\text{symb}}^{\text{DL}} \cdot N_{\text{sc}}^{\text{RB}}$ REs. For a normal CP and 15-KHz sub-carrier bandwidth, a PRB pair comprises 168 REs.

[0018] One characteristic of PRBs is that consecutively numbered PRBs (e.g., PRB_i and PRB_{i+1}) comprise consecutive blocks of subcarriers. For example, with a normal CP and 15-KHz sub-carrier bandwidth, PRB_0 comprises sub-carrier 0 through 11 while PRB_1 comprises sub-carriers 12 through 23. The LTE PHY resource also can be defined in terms of virtual resource blocks (VRBs), which are the same size as PRBs but may be of either a localized or a distributed type. Localized VRBs are mapped directly to PRBs such that VRB n_{VRB} corresponds to $\text{PRB}_{n_{\text{PRB}} = n_{\text{VRB}}}$. On the other hand, distributed VRBs may be mapped to non-consecutive PRBs according to various rules, as described in 3GPP Technical Specification (TS) 36.213 or otherwise known to persons of ordinary skill in the art. However, the term “PRB” will be used in this disclosure to refer to both physical and virtual

resource blocks. Moreover, the term “PRB” will be used henceforth to refer to a resource block for the duration of a subframe, i.e., a PRB pair, unless otherwise specified.

[0019] As mentioned above, the LTE PHY maps the various downlink physical channels to the resources shown in Fig. 3. For example, the PDCCH carries scheduling assignments and other control information. A physical control channel is transmitted on an aggregation of one or several consecutive control channel elements (CCEs), and a CCE is mapped to the physical resource shown in Fig. 3 based on resource element groups (REGs), each of which is comprised of a plurality of REs. For example, a CCE may be comprised of nine (9) REGs, each of which is comprised of four (4) REs. Fig. 4A illustrates one manner in which the CCEs and REGs can be mapped to the physical resource, i.e., PRBs. As shown in Fig. 4A, the REGs comprising the CCEs of the PDCCH may be mapped into the first three symbols of a subframe, whereas the remaining symbols are available for other physical channels, such as the PDSCH which carries user data. Each of the REGs comprises four REs, which are represented by the small, dashed-line rectangles. Since QPSK modulation is used for the PDCCH, in the exemplary configuration of Fig. 4A, each REG comprises eight (8) bits and each CCE comprises 72 bits. Although two CCEs are shown in Fig. 4A, the number of CCEs may vary depending on the required PDCCH capacity, determined by number of users, amount of measurements and/or control signaling, etc. Moreover, other ways of mapping REGs to CCEs will be apparent to those of ordinary skill in the art.

[0020] Beginning with Release 11, the 3GPP specifications include an enhanced PDCCH (ePDCCH) in addition to the legacy PDCCH described above. The ePDCCH is intended to increase capacity and improve spatial reuse of control channel resources, improve inter-cell interference coordination (ICIC), and add antenna beamforming and/or transmit diversity support for control channel. Much like the Release 8 PDCCH, the ePDCCH is constructed by aggregating one or more enhanced control channel elements (eCCEs). An eCCE is comprised of one or more enhanced resource element groups (eREGs), each of which is comprised of one or more REs. For example, an eCCE comprised of nine eREGs, each having four REs, may be configured with the same capacity as a CCE. Unlike CCEs, however, eCCEs may be flexibly configured with various numbers and sizes of eREGs.

[0021] Moreover, the ePDCCH (i.e., eCCEs) may be mapped to PRBs for transmission either in a localized or distributed manner. The localized mapping provides frequency

selective scheduling gain and beamforming gain while the distributed transmission provides robust ePDCCH transmission via frequency diversity in case valid channel state information is not available to the receiver. In order to achieve sufficient frequency diversity, however, each eCCE must be mapped to a minimum number PRBs distributed sufficiently throughout the range of sub-carriers in the physical resource.

[0022] As mentioned above, another feature of Release 11 is carrier aggregation (CA), which by which individual carriers are combined or aggregated to increase the bandwidth available for transmission and, consequently, the data transmission rates. Each aggregated carrier is referred to as a component carrier (CC). Each CC can have a channel bandwidth of 1.4, 3, 5, 10, 15 or 20 MHz and a maximum of five CCs can be aggregated. For compatibility with Release-8 and Release-9 devices already deployed, only CC types defined in Releases 8 and 9 are allowed to be aggregated in Release 11 CA.

[0023] A UE with CA reception and/or transmission capability can simultaneously receive and/or transmit on multiple CCs corresponding to multiple serving cells. Nevertheless, a UE has only one RRC connection with the network, which occurs through a serving cell referred to as the Primary Cell (PCell). The UE also conducts NAS procedures (e.g., mobility and connection management) via the PCell. Depending on UE capabilities, Secondary Cells (SCells) can be configured to form together with the PCell a set of serving cells for the UE. A PCell and one or more SCells may be aggregated for a UE within coverage areas of the PCell and the SCells.

[0024] One of the features under consideration for Release 12 is new carrier types (NCTs), including NCTs that are not backward compatible with Release 8/9 types. These proposed NCTs would also be used as CCs for CA. The ultimate goals for NCTs include higher data transmission rates to the end user and improved usage efficiency of the limited spectrum resources. One approach for achieving these goals via CA using NCTs is to reduce the interference level at low-to-medium system usage levels by minimizing overhead information in the uplink and downlink transmissions, such as legacy control signaling and reference signals. For example, in a set of serving cells comprising a PCell and one or more NCT SCells, the PCell may control the configuration of the NCT SCells including reduced overhead information.

[0025] Various downlink reference signals are defined in Release 11, and each comprises a particular set of predetermined information that is known by the UE and used by UE for a particular purpose. Cell-specific reference signals (CRS) are transmitted to all UEs in a particular cell, and enable a receiving UE to determine the phase reference for demodulating the downlink control channels (e.g., PDCCH) and downlink data channels (e.g., PDSCH). As defined in Release 11, CRS are included in every downlink PRB of every subframe. In addition, various UE-specific reference signals may be transmitted along with downlink control- or data-channel information directed to a particular UE. These UE-specific reference signals are used by the UE to derive channel estimates used for demodulating the associated data or control channel, and as such are referred to as demodulation reference signals (DM-RS). These include DM-RS associated with a PDSCH and DM-RS associated with an ePDCCH. As defined in Release 11, these DM-RS are included in every PRB comprising PDSCH and ePDCCH information, respectively, directed to a particular UE.

[0026] Another type of downlink reference signal defined in Release 11 is channel-state information reference signals (CSI-RS). These CSI-RS are used by the UE for to compute a channel estimate that is further used to compute certain channel-state information (CSI) for feedback to the transmitting eNB, such as the channel quality indicator (CQI). CSI-RS are more sparsely distributed in frequency than UE-specific DM-RS but are transmitted regularly by the eNB, while UE-specific DM-RS are only transmitted in association with UE-specific data or control information. Separating the reference-signal structures supporting CSI feedback and demodulation reduces reference-signal overhead and allows for implementation of various beam-forming schemes.

[0027] At least two ways of reducing the reference signal overhead in Release-12 NCTs have been proposed. First, CRS will be eliminated. Consequently, the UE will no longer be able measure certain CSI (e.g., Rank Indicator (RI) and Precoding Matrix Indicator (PMI)) using the CRS as in Release 11 but instead will be required to measure these CSI values using the CSI-RS. Second, DM-RS will no longer be provided in every PRB comprising PDSCH or ePDCCH, but instead will be transmitted in only a subset of such PRBs. This is illustrated in Fig. 4B that shows two PRBs in a subframe, one PRB that comprises DM-RS and one that does not. PRB_m includes 36 REs comprising PDCCH 480, similar to the illustration of Fig. 4A. The remainder of PRB_m comprises PDSCH 460 and DM-RS 470,

which is associated with PDSCH 460 and comprises the 12 shaded REs, whose positions in PRB_{*m*} are merely exemplary. The DM-RS size of 12 REs corresponds to a rank of two or less (i.e., 1 or 2 different data streams transmitted simultaneously on the same time/frequency resources); DM-RS 470 comprises 24 REs for ranks of three or more. Note that DM-RS 470
 5 does not carry user data comprising PDSCH 460, and vice versa. In contrast, PRB_{*m+1*} also comprises PDCCH 480 (32 REs) but does not include DM-RS 470, with a result that PDSCH 465 comprises 132 REs compared to the 120 REs comprising PDSCH 460 of PRB_{*m*}.

[0028] Although Fig. 4B shows one PRB with DM-RS and one without, the proportion of PDSCH PRBs within a subframe that contain DM-RS may be varied. For example, one out
 10 of every three PDSCH PRBs in a subframe may contain DM-RS. This is illustrated in Fig. 4C, where PRBs *m* and *m+3* of subframe *n* include DM-RS information (as indicated by the shading and annotation) while PRBs *m+1*, *m+2*, *m+4*, and *m+5* do not. In addition, the proportion of PDSCH PRBs containing DM-RS may be varied across subframes. For example, DM-RS may be included with PDSCH PRBs transmitted every third subframe.
 15 This is illustrated in Fig. 4C, where subframe *n* includes two PRBs with DM-RS while subframes *n+1* and *n+2* do not include any PRBs with DM-RS. However, the person of ordinary skill will recognize that these proportions are merely exemplary and other inter- or intra-subframe DM-RS proportions may be used within the scope of the present disclosure.

[0029] In Release 11, specification 3GPP TS 36.213 requires that, for a CQI value reported
 20 in uplink subframe *n*, the UE shall determine the highest CQI index between 1 and 15 in Table 7.2.3-1 that satisfies the condition that a single PDSCH transport block using a combination of modulation and coding scheme (MCS) and transport block size (TBS) corresponding to the CQI index in the Table, and occupying a group of downlink physical resource blocks termed the CSI Reference Resource (CSIRR), could be received with a
 25 transport block error probability not exceeding 0.1. If CQI index 1 (i.e., lowest modulation scheme plus smallest TBS) does not satisfy the condition, then the UE shall report CQI index 0. More simply put, the UE determines which of the 15 allowed combinations of MCS and TBS gives the highest data throughput without exceeding a maximum error rate. The UE may report CQI index periodically or aperiodically (e.g., upon demand). An aperiodic CQI
 30 report in subframe *n+k* is triggered by the UE's receipt in subframe *n* of an uplink DCI format message containing an appropriate value in the "CSI Request" field.

[0030] As mentioned above, the CSI-RS information is used by the UE to compute a channel estimate that is further used to compute the CQI index for the PDSCH transport block comprising the CSI Reference Resource (CSIRR). The CSIRR is defined in the frequency domain by the group of downlink PRBs corresponding to the band for which the determined CQI index relates, and in the time domain by a single downlink subframe $n - n_{CQI_ref}$ (i.e., n_{CQI_ref} subframes prior to the current uplink subframe n). Moreover, when determining the CQI index, the UE assumes that the first three symbols of subframe $n - n_{CQI_ref}$ are occupied by control-channel signaling (e.g., PDCCH) and that no REs in the CSI reference resource comprise broadcast or synchronization signals.

[0031] In addition, if the UE is also configured to report other CSI including PMI and RI, the UE is required to assume when determining CQI index that the UE-specific reference signal overhead (i.e., DM-RS) is consistent with the RI that it most recently reported to the eNB. For example, if the UE most recently reported $RI \leq 2$, then it should assume when determining CQI index that each of the PRBs in subframe $n - n_{CQI_ref}$ that comprise the CSIRR include a 12-RE DM-RS (e.g., similar to PRB_m in Fig. 4B); otherwise the UE should assume that each of these PRBs include a 24-RE DM-RS.

[0032] Such assumptions provide the necessary accuracy in CQI index determination for pre-Release 12 implementations because the CSI reference resource comprises one or more PRBs of a PDSCH, and DM-RS information is included in every PDSCH PRB. For the proposed reduced-overhead NCT feature of Release 12, however, the DM-RS information may be included in only a portion of PDSCH PRBs in some subframes and in no PDSCH PRBs in other subframes, as illustrated in Fig. 4C. This may result in a mismatch or ambiguity between the actual DM-RS scheduling and the UE's DM-RS assumption for the purposes of CQI index determination. For example, the UE may determine the CQI index by assuming 24 DM-RS REs per PDSCH PRB (i.e., most recent $RI > 2$) in subframe $n - n_{CQI_ref}$, but PDSCH PRBs in that subframe actually contained zero DM-RS REs.

[0033] Without knowledge of actual DM-RS scheduling, the UE must assume that each PRB used for CQI index determination comprises DM-RS REs, which leaves fewer REs available for PDSCH. Using the $RI \leq 2$ example shown in Fig. 4B, PRB_m comprises 120 REs available for PDSCH 460 while PRB_{m+1} comprises 132 REs available for PDSCH 465 – a 10% difference. For $RI > 2$, a PRB with DM-RS comprises 108 REs available for PDSCH

while a PRB without DM-RS comprises 132 REs – a 22% difference. As a result of this overly pessimistic assumption for non-DM-RS PRBs, the UE will underestimate the number of REs – and thus the transport block size (TBS) – available for PDSCH when determining CQI index. This will cause the UE to report a CQI index corresponding to a lower-order MCS and/or smaller TBS than is warranted by actual channel conditions, resulting in lower downlink user data rates and less-efficient spectral usage.

[0034] Embodiments of the present disclosure solve these and other problems by providing methods for determining channel quality information (CQI) for a received physical-layer (PHY) channel comprising a plurality of subframes, comprising receiving a first set of one or more subframes comprising a data message, wherein at least a portion of the first set of one or more subframes comprise overhead information related to demodulation of the data message; receiving a subframe comprising a first control message, wherein the first control message comprises a request to determine CQI and configuration information related to the request; determining, based on the configuration information, a resource within the first set of subframes to be used for CQI determination and one or more overhead information patterns within the resource; determining one or more CQI values for each of the overhead information patterns; and transmitting a subframe comprising a second control message, wherein the second control message comprises the determined CQI values.

[0035] Embodiments of the present disclosure also include methods for determining CQI for a transmitted PHY channel comprising a plurality of subframes, comprising transmitting a first set of one or more subframes comprising a data message to a receiving apparatus, wherein at least a portion of the first set of subframes comprise overhead information related to demodulation of the data message; determining a set of parameters for CQI determination, wherein the parameters include a resource within the first set of subframes to be used for CQI determination and one or more overhead information patterns within the resource; encoding the set of parameters into configuration information comprising one of a plurality of assumptions to be used by the receiving apparatus; transmitting a subframe comprising a first control message, wherein the first control message comprises the configuration information and a request to determine CQI; and receiving a subframe comprising a second control message, wherein the second control message comprises one or more CQI values.

[0036] In some embodiments, the first set of one or more subframes comprises one of a Physical Downlink Shared Channel (PDSCH) and an Enhanced Physical Downlink Control Channel (ePDCCH); the first control message is received in subframe n and comprises an Uplink DCI Format message; the one or more CQI values comprise one or more CQI indices; the resource comprises physical resource blocks (PRBs); and the overhead information comprises demodulation reference signal (DM-RS) overhead information. Embodiments also include wireless network equipment or apparatus (e.g., eNB or component of an eNB), wireless communication device or apparatus (e.g., a UE or component of a UE), and computer-readable media embodying one or more of these methods.

[0037] Embodiments of the present disclosure also include methods for a network equipment or apparatus (e.g., eNB or component of an eNB) requesting channel state information (CSI) from a wireless communication device or apparatus (e.g., a UE or component of a UE) to provide the device with additional information that identifies a CSI Reference Resource (CSIRR) used for measuring CSI and resolves the uncertainty or ambiguity of which PRBs within the CSIRR have full DM-RS and which have reduced DM-RS (e.g., no DM-RS). The network equipment receives CSI reports comprising one or more measurements (e.g., CQI indices) based on the additional information from the device, and utilizes the measurements to determine a configuration for a downlink transmission channel (e.g., a PDSCH) received by the device. Other embodiments include network equipment or apparatus and computer-readable media embodying one or more of the methods.

[0038] Embodiments of the present disclosure also include methods for a wireless communication device or apparatus (e.g., a UE or component of a UE) to receive, in conjunction with a CSI request from a network equipment or apparatus (e.g., eNB or component of an eNB), additional information identifying a CSIRR used for measuring CSI and resolving the uncertainty or ambiguity of which PRBs within the CSIRR have full DM-RS and which have reduced DM-RS (e.g., no DM-RS). The device further utilizes the additional information to make one or more measurements (e.g., CQI indices) and reports these measurements to the network equipment. Other embodiments include wireless communication devices or apparatus and computer-readable media embodying one or more of the methods.

[0039] Fig. 5A is a flowchart of a communication method according to one or more embodiments of the present disclosure. While the communication method of Fig. 5A is described in terms of being performed by a wireless communication device (e.g., a UE or a component of a UE, such as a modem) in relation to downlink communication from a network equipment (e.g., an eNB) to the device, in some embodiments it may be performed by a network equipment in relation to uplink communication from the device to the network equipment. Although the method is illustrated by blocks in the particular order of Fig. 5A, this order is merely exemplary and the steps of the method may be performed in a different order than shown by Fig. 5A, and may be combined and/or divided into blocks having different functionality.

[0040] In block 500, the device establishes a PDSCH connection with the network equipment. This may be done, for example, using various signaling messages (e.g., RRC messages) known to persons of ordinary skill in the art. In some embodiments, the establishment of the PDSCH connection may be initiated by the device, while in other embodiments it may be initiated by the network equipment. In other embodiments, the connection may be an ePDCCH connection. In block 510, the device receives one or more higher-layer signaling messages comprising reduced DM-RS overhead configuration parameters. These parameters may comprise identifiers for one or more DM-RS overhead patterns, repetition period (e.g., in subframes) of one or more DM-RS overhead patterns, pointers to one or more subframes within a repetition period, or other parameters described in more detail below. In some embodiments, the operation of block 510 also may comprise the device storing the received configuration parameters in memory.

[0041] In block 520, the device receives downlink subframe n comprising ePDCCH PRBs bearing an Uplink DCI Format message. In some embodiments, the device also receives PRBs comprising a PDSCH in downlink subframe n . In block 530, the device determines whether the Uplink DCI Format message received in block 520 is a Format-0 message that includes a CSI Request field. If the device determines that it is not a Format-0 message, then it proceeds to block 540 where it performs other processing appropriate to the particular format type. If the device determines that the Uplink DCI Format message received in block 520 is a Format-0 message, then it proceeds to block 550.

[0042] In block 550, the device determines whether the Uplink DCI Format message indicates that channel measurements (e.g., CQI index) should be made on PRBs having reduced DM-RS overhead. For example, the device may determine this by comparing the value of the CSI Request field in the Uplink DCI Format message to a table stored in the device's memory that associates a plurality of CSI Request values with DM-RS overhead assumptions, commands, instructions, or other information. An exemplary table corresponding to a two-bit CSI Request field is shown in Fig. 7A. In this table, values "10" and "11" correspond to CSI Requests for which two different DM-RS overhead assumptions are indicated. If the received CSI Request equals "10" or "11", then the device proceeds to block 570; otherwise, the device proceeds to block 560 where it performs other processing corresponding to other CSI Request values.

[0043] Fig. 7B shows another exemplary table of values for the CSI Request field that can be used for the operation of block 550. In this table, values "10" and "11" correspond to CSI Requests for which an aperiodic CSI report is configured by higher layers. If the received CSI Request equals "10" or "11", then the device proceeds to block 570; otherwise, the device proceeds to block 560 where it performs other processing corresponding to other CSI Request values.

[0044] In block 570, the device determines the DM-RS overhead assumption and CSIRR to be used for determining the CQI index. The DM-RS overhead assumption may be determined, for example, from the contents of the Uplink DCI Format message received by device in block 510. For example, the device may determine this by comparing the value of the CSI Request field in the Uplink DCI Format message to a table stored in the device's memory that associates a plurality of CSI Request values with DM-RS overhead assumptions, commands, instructions, or other information. Fig. 7A shows an exemplary table corresponding to a two-bit CSI Request field that can be used for the operation of block 570. In this table, value "10" corresponds to a CSI Request for which DM-RS overhead assumption #1 is to be used by the device for CQI index determination, while value "11" corresponds to a CSI Request for which DM-RS overhead assumptions #2 is to be used. As shown in Fig. 7A, these two values may be used to indicate not merely a single serving cell but also a set of serving cells, such as a PCell and one or more NCT SCells aggregated for communication between the device and the network. Although the table of Fig. 7A includes

values corresponding to two overhead assumptions, the person of ordinary skill will understand that if the length of CSI Request field is increased (e.g., to three bits), the table can be expanded to include more values indicating additional DM-RS overhead assumptions.

[0045] Alternately, the device may determine the DM-RS overhead assumption to be used for CQI index determination from a different field in the Uplink DCI Format message. In some embodiments, the Uplink DCI Format message may comprise a dedicated field for indicating which DM-RS overhead assumption that the device should use. For example, a single-bit field (“ b_0 ”) can be used to indicate two different overhead assumptions. Fig. 7C shows an exemplary table that can be stored in the device’s memory and used to interpret single-bit values of b_0 received by the device.

[0046] Fig. 5B is a flowchart describing a particular embodiment of blocks 570 and 580 that are shown in and were described above with reference to Fig. 5A. In block 570a of Fig. 5B, the device determines that the DM-RS overhead assumption to be used for CQI index determination is “assumption #1.” This can be determined in any manner described above with reference to Figs. 5A, 7A, and 7C. In this embodiment, assumption #1 corresponds to full DM-RS overhead, such as shown in subframe n of Fig. 4C. In block 570b, the device determines the CSIRR to be used together with DM-RS overhead assumption #1 for CQI index determination. In this embodiment, the device determines that the CSIRR is the PDSCH PRBs of downlink subframe $n - n_{CQI_ref}$.

[0047] The operations of blocks 570a and 570b of Fig. 5B are further illustrated by Fig. 8A, which shows a sequence of subframes received and transmitted by the device according to this embodiment. Using the same conventions as Fig. 4C, Fig. 8A shows a series of four subframes $n - n_{CQI_ref} - 3$, $n - n_{CQI_ref} - 2$, $n - n_{CQI_ref} - 1$, and $n - n_{CQI_ref}$, containing PDSCH PRBs received by the device. In subframe n , the device receives an Uplink DCI Format message comprising a CSI Request and information indicating DM-RS overhead assumption #1, as described above with respect to block 510 of Fig. 5A. Based on this information, the device also determines that the CSIRR is the PDSCH PRBs of downlink subframe $n - n_{CQI_ref}$, indicated by CSIRR 800 in Fig. 5B. In block 580, the device determines the CQI index based on CSIR 800 with the assumption of full DM-RS overhead. Subsequently, the device then returns to block 590 of Fig. 5A where it sends a CSI Report in subframe $n+k$ comprising the determined CQI index, as also shown in Fig. 8A.

[0048] Fig. 5C is a flowchart describing another particular embodiment of blocks 570 and 580 that are shown in and were described above with reference to Fig. 5A. In block 570c of Fig. 5C, the device determines that the DM-RS overhead assumption to be used for CQI index determination is “assumption #2.” This can be determined in any manner described above with reference to Figs. 5A, 7A, and 7C. In this embodiment, assumption #2 corresponds to full DM-RS overhead, such as shown in subframe n of Fig. 4C. In block 570d, the device determines the CSIRR to be used together with DM-RS overhead assumption #2 for CQI index determination. In this embodiment, the device determines that the CSIRR is the PDSCH PRBs of downlink subframe $n - n_{CQI_ref} - n_{pattern1}$, where $n_{pattern1}$ is a value from the set $[0, 1, \dots, T_{RDMRS}-1]$. The parameter T_{RDMRS} represents the repetition period of the reduced DM-RS overhead pattern.

[0049] The operations of blocks 570c and 570d of Fig. 5C are further illustrated by Fig. 8B, which shows a sequence of subframes received and transmitted by the device according to this embodiment. Using the same conventions as Fig. 4C, Fig. 8B shows a series of four subframes $n - n_{CQI_ref} - 3$, $n - n_{CQI_ref} - 2$, $n - n_{CQI_ref} - 1$, and $n - n_{CQI_ref}$ containing PDSCH PRBs received by the device. In the example of Fig. 8B, the DM-RS overhead pattern has a periodicity of $T_{RDMRS} = 4$ subframes.

[0050] In subframe n , the device receives an Uplink DCI Format message comprising a CSI Request and information indicating DM-RS overhead assumption #2, as described above with respect to block 510 of Fig. 5A. Based on this information, the device determines that the CSIRR is the PDSCH PRBs of downlink subframe $n - n_{CQI_ref} - 2$ based on the value of $n_{pattern1} = 2$. This is illustrated by CSIRR 810 in Fig. 8B. Also based on this information, the device determines that the DM-RS overhead pattern in CSIRR 810 is full DM-RS overhead, illustrated by pattern 811 in Fig. 8B. In some embodiments, one or more of the values of T_{RDMRS} and $n_{pattern1}$ may be received by the device as fields in the Uplink DCI Format message. In some embodiments, one or more of the values of T_{RDMRS} and $n_{pattern1}$ may be received by the device in an upper-layer signaling message (e.g. an RRC message) from the eNB. In block 580 of Fig. 5C, the device determines the CQI index based on CSIR 810 with the assumption of full DM-RS overhead. Subsequently, the device then returns to block 590 of Fig. 5A where it sends a CSI Report in subframe $n+k$ comprising the determined CQI index, as also shown in Fig. 8B.

[0051] Fig. 5D is a flowchart describing another particular embodiment of blocks 570 and 580 that are shown in and were described above with reference to Fig. 5A. In block 570e of Fig. 5D, the device determines that the DM-RS overhead assumption to be used for CQI index determination is “assumption #2.” This can be determined in any manner described above with reference to Figs. 5A, 7A, and 7C. In this embodiment, assumption #2 corresponds to a group of T_{RDMRS} subframes with p different DM-RS overhead patterns, where $p \geq 2$. In block 570f, the device determines that the CSIRR is the PDSCH PRBs of downlink subframes $n - n_{\text{CQI_ref}} - i$, where $i = 0, 1, \dots, T_{\text{RDMRS}} - 1$.

[0052] The operations of blocks 570e and 570f of Fig. 5D are further illustrated by Fig. 8C, which shows a sequence of subframes received and transmitted by the device according to this embodiment. Using the same conventions as Fig. 4C, Fig. 8C shows a series of four subframes $n - n_{\text{CQI_ref}} - 3$, $n - n_{\text{CQI_ref}} - 2$, $n - n_{\text{CQI_ref}} - 1$, and $n - n_{\text{CQI_ref}}$ containing PDSCH PRBs received by the device, where $T_{\text{RDMRS}} = 4$ subframes. In subframe n , the device receives an Uplink DCI Format message comprising a CSI Request and information indicating DM-RS overhead assumption #2, as described above with respect to block 510 of Fig. 5A. Based on this information, the device determines that the CSIRR is the PDSCH PRBs of downlink subframes $n - n_{\text{CQI_ref}} - 3$, $n - n_{\text{CQI_ref}} - 2$, $n - n_{\text{CQI_ref}} - 1$, and $n - n_{\text{CQI_ref}}$ based on the value of $T_{\text{RDMRS}} = 4$. This is illustrated by CSIRR 820 in Fig. 8C. The device also determines two different DM-RS overhead pattern assumptions for CSIRR 820. Pattern 1 (identified as pattern 821) corresponds to full DM-RS overhead while pattern 2 (identified as pattern 822) corresponds to zero-DM-RS overhead. In some embodiments, the value of T_{RDMRS} may be received by the device as a field in the Uplink DCI Format message or in an upper-layer signaling message (e.g. an RRC message) from the network equipment. In some embodiments, DM-RS overhead patterns 1 and 2 may be implicitly understood by the device, while in other embodiments, information about patterns 1 and/or 2 may be received by the device as a field in the Uplink DCI Format message or in an upper-layer signaling message (e.g. an RRC message).

[0053] In block 580a of Fig. 5D, the device initializes the pattern index $p = 1$ to point at the first DM-RS overhead pattern. The device proceeds to block 580b, where it determines the CQI index based on the assumption of DM-RS overhead pattern 1 throughout CSIRR 820. Subsequently, the device proceeds to block 580c where it determines whether more overhead

patterns exist. If pattern p is the last overhead pattern, then the device returns to block 590 shown in Fig. 5A. Otherwise, the device proceeds to block 580d where it increments pattern index p , then returns to block 580b to determine CQI index based on the assumption of DM-RS overhead pattern p throughout CSIRR 820. In the illustration shown in Fig. 8C, the device would determine two different CQI indices corresponding to patterns 1 and 2.

[0054] The various DM-RS overhead assumptions used by the device for determining CQI indices according to the embodiment of Fig. 5D are not limited to full and zero DM-RS overhead patterns, but can be any combination of full, partial, and zero DM-RS overhead patterns. For example, Fig. 8D illustrates a possible arrangement in which CSIRR 830 comprises subframes having two different partial DM-RS overhead patterns, 831 and 832, and when combined they comprise full DM-RS overhead. Fig. 8E illustrates another exemplary variation in which CSIRR 840 comprises subframes having two different partial DM-RS overhead patterns 841 and 842 and a zero-overhead DM-RS pattern 843. Persons of ordinary skill will recognize that many different numbers and types of patterns may be used within the scope of this embodiment.

[0055] Fig. 6 is a flowchart of another communication method according to one or more other embodiments of the present disclosure. While the communication method of Fig. 6 is described in terms of being performed by a network equipment (e.g., an eNB or component of an eNB) in relation to downlink communication from the network equipment to a wireless communication device (e.g., a UE or component of a UE, such as a modem), in some embodiments it may be performed by a device in relation to uplink communication from the device to the network equipment. Although the method is illustrated by blocks in the particular order of Fig. 6, this order is merely exemplary and the steps of the method may be performed in a different order than shown by Fig. 6, and may be combined and/or divided into blocks having different functionality.

[0056] In block 600, the network equipment establishes a PDSCH connection with the device. This may be done, for example, using various signaling messages (e.g., RRC messages) known to persons of ordinary skill in the art. In some embodiments, the establishment of the PDSCH connection may be initiated by the device, while in other embodiments it may be initiated by the network equipment. In other embodiments, the connection may be an ePDCCH connection. In block 610, the network equipment transmits

one or more higher-layer signaling messages comprising reduced DM-RS overhead configuration parameters. These parameters may comprise identifiers for one or more DM-RS overhead patterns, repetition period (e.g., in subframes) of one or more DM-RS overhead patterns, pointers to one or more subframes within a repetition period, or other parameters described in more detail below.

[0057] In block 620, the network equipment transmits one or more subframes comprising one or more patterns of full and/or reduced DM-RS overhead information to the device. The subframes may comprise PRBs corresponding to a PDSCH and/or an ePDCCH. In block 630, the network equipment determines that a CSI report, including a CQI index, is needed for the device. In block 640, the network equipment determines the CSI Reference Resource (CSIRR), DM-RS overhead assumption, and related information that the device should use for determining the CQI index. For example, the network equipment may determine that the CSIRR comprises the PDSCH PRBs of a single downlink subframe and that the device should measure CQI index on that CSIRR using an assumption of full DM-RS overhead. The network equipment may further determine the position of the subframe comprising the CSIRR relative to the subframe when the CSI Request will be scheduled for transmission (described below). For example, the network equipment may determine in block 640 that the CSIRR subframe is n_{CQI_ref} subframes before the CSI Request subframe. In such case, the network equipment determines that the device should use DM-RS overhead assumption #1, as described above and illustrated in Fig. 8A.

[0058] Alternately, the network equipment may determine that it cannot schedule a subframe with full DM-RS overhead n_{CQI_ref} subframes before the CSI Request subframe. In that case, the network equipment may identify the CSIRR as PRBs comprising a subframe having full DM-RS overhead within the $T_{RDMRS} - 1$ subframes immediately preceding the $n_{CQI_ref}^{th}$ subframe before the subframe in which the CSI Request will be sent. If the CSIRR is in subframe $n - n_{CQI_ref} - i$, then the network equipment identifies this subframe by the setting $n_{pattern1} = i$. In such case, the network equipment determines that the device should use DM-RS overhead assumption #2, as described above and illustrated in Fig. 8B.

[0059] In other embodiments, if the network equipment determines that it cannot reliably schedule a downlink subframe with full DM-RS overhead in the $n_{CQI_ref}^{th}$ subframe before the CSI Request subframe, it may identify the CSIRR as PRBs in a group of T_{RDMRS}

contiguous subframes ending with subframe $n - n_{CQI_ref}$. In such case, the network equipment determines that the device should use DM-RS overhead assumption #2, which corresponds to a plurality of different DM-RS overhead patterns over the duration of the CSIRR. This is illustrated by the various configurations shown in Figs. 8C, 8D, and 8E.

5 [0060] In block 650, the network equipment encodes an Uplink DCI Format message comprising a CSI Request field with the device as the intended recipient. In some embodiments, the operation of block 650 comprises encoding the Uplink DCI Format message in "Format 0" as defined in relevant 3GPP standards specifications. In some
10 embodiments, the CSI Request field may comprise information indicating a DM-RS overhead assumption for the device, such as shown in Fig. 7A. In other embodiments, the operation of block 650 may comprise encoding a CSI Request field and a separate field comprising information indicating a DM-RS overhead assumption for the device, such as shown in Figs. 7B and 7C. In some embodiments, the operation of block 650 may comprise encoding one or more fields with information indicating DM-RS overhead patterns such as,
15 for example, the exemplary patterns shown in Figs. 8A through 8E.

[0061] In block 660, the network equipment transmits downlink subframe n comprising the Uplink DCI Format message encoded in block 650. In some embodiments, the Uplink DCI Format message may be transmitted as part of a PDCCH or an ePDCCH. In some
20 embodiments, the network equipment also may transmit a PDSCH to the device in subframe n . In block 670, the network equipment receives a CSI Report message from the device in subframe $n+k$ in response to the CSI Request comprising the Uplink DCI Format message transmitted in block 650. The value of k may be predetermined between the network equipment and the device. The CSI Report message comprises one or more CQI index measurements made by the device according to the particular DM-RS overhead assumption
25 indicated in the Uplink DCI Format message. In block 680, the network equipment determines a modulation and coding scheme (MCS) and/or a transmit block size (TBS) for subsequent PDSCH transmissions to the device.

[0062] Fig. 9 is a block diagram of exemplary apparatus 900 utilizing certain embodiments of the present disclosure, including one or more of the methods described above with
30 reference to Figs. 5 through 8. In some embodiments, apparatus 900 comprises a wireless communication device, such as a UE or component of a UE. Apparatus 900 comprises

processor 910 which is operably connected to program memory 920 and data memory 930 via bus 970, which may comprise parallel address and data buses, serial ports, or other methods and/or structures known to those of ordinary skill in the art. Program memory 920 comprises software code executed by processor 910 that enables apparatus 900 to communicate with one or more other devices using protocols according to various embodiments of the present disclosure, including the LTE PHY protocol layer and improvements thereto, including those described above with reference to Figs. 6 through 9.

[0063] Program memory 920 also comprises software code executed by processor 910 that enables apparatus 900 to communicate with one or more other devices using other protocols or protocol layers, such as LTE MAC, RLC, PDCP, and RRC layer protocols standardized by 3GPP, or any improvements thereto; UMTS, HSPA, GSM, GPRS, EDGE, and/or CDMA2000 protocols; Internet protocols such as IP, TCP, UDP, or others known to persons of ordinary skill in the art; or any other protocols utilized in conjunction with radio transceiver 940, user interface 950, and/or host interface 960. Program memory 920 further comprises software code executed by processor 910 to control the functions of apparatus 900, including configuring and controlling various components such as radio transceiver 940, user interface 950, and/or host interface 960. Such software code may be specified or written using any known or future developed programming language, such as e.g. Java, C++, C, and Assembler, as long as the desired functionality, e.g., as defined by the implemented method steps, is preserved. Program memory 920 may comprise non-volatile memory (e.g., flash memory), volatile memory (e.g., static or dynamic RAM), or a combination thereof.

[0064] Data memory 930 may comprise memory area for processor 910 to store variables used in protocols, configuration, control, and other functions of apparatus 900. For example, information associated with one or more of the tables shown in Figs. 7A, 7B, and 7C may be stored in data memory 930. Data memory 930 may comprise non-volatile memory, volatile memory, or a combination thereof.

[0065] Persons of ordinary skill in the art will recognize that processor 910 may comprise multiple individual processors (not shown), each of which implements a portion of the functionality described above. In such case, multiple individual processors may be commonly connected to program memory 920 and data memory 930 or individually connected to multiple individual program memories and or data memories. More generally,

persons of ordinary skill in the art will recognize that various protocols and other functions of apparatus 900 may be implemented in many different combinations of hardware and software including, but not limited to, application processors, signal processors, general-purpose processors, multi-core processors, ASICs, fixed digital circuitry, programmable digital
5 circuitry, analog baseband circuitry, radio-frequency circuitry, software, firmware, and middleware.

[0066] Radio transceiver 940 may comprise radio-frequency transmitter and/or receiver functionality that enables apparatus 900 to communicate with other equipment supporting like wireless communication standards. In an exemplary embodiment, radio transceiver 940
10 includes an LTE transmitter and receiver that enable apparatus 900 to communicate with various E-UTRANs according to standards promulgated by 3GPP. In some embodiments, radio transceiver 940 includes circuitry, firmware, etc. necessary for apparatus 900 to communicate with network equipment using the LTE PHY protocol layer methods and improvements thereto such as those described above with reference to Figs. 5 through 8. In
15 some embodiments, radio transceiver 940 includes circuitry, firmware, etc. necessary for apparatus 900 to communicate with various UTRANs and GERANs according to 3GPP standards known to persons of ordinary skill in the art. In some embodiments, radio transceiver 940 includes circuitry, firmware, etc. necessary for apparatus 900 to communicate with various CDMA2000 networks according to 3GPP2 and/or 3GPP standards known to
20 persons of ordinary skill in the art.

[0067] In some embodiments, radio transceiver 940 is capable of communicating on a plurality of LTE frequency-division-duplex (FDD) frequency bands 1 through 25, as specified in 3GPP standards. In some embodiments, radio transceiver 940 is capable of communicating on a plurality of LTE time-division-duplex (TDD) frequency bands 33
25 through 43, as specified in 3GPP standards. In some embodiments, radio transceiver 940 is capable of communicating on a combination of these LTE FDD and TDD bands, as well as other bands specified in the 3GPP standards. In some embodiments, radio transceiver 940 is capable of communicating on one or more unlicensed frequency bands, such as the ISM band in the region of 2.4 GHz. The radio functionality particular to each of these embodiments
30 may be coupled with or controlled by other circuitry in apparatus 900, such as processor 910 executing protocol program code stored in program memory 920.

[0068] User interface 950 may take various forms depending on the particular embodiment of apparatus 900. In some embodiments, apparatus 900 is a mobile phone, in which case user interface 950 may comprise a microphone, a loudspeaker, slidable buttons, depressable buttons, a keypad, a keyboard, a display, a touchscreen display, and/or any other user-interface features commonly found on mobile phones. In some embodiments, apparatus 900 may comprise a tablet device, in which case user interface 950 may be primarily – but not strictly limited to – a touchscreen display. In other embodiments, apparatus 900 may be a data modem capable of being utilized with a host device, e.g., a tablet, laptop computer, etc. In such case, apparatus 900 may be fixedly integrated with or may be removably connectable to the host device, such as via a USB port. In these embodiments, user interface 950 may be very simple or may utilize features of the host computing device, such as the host device's display and/or keyboard.

[0069] Host interface 960 of apparatus 900 also may take various forms depending on the particular embodiment of apparatus 900. In embodiments where apparatus 900 is a mobile phone or tablet, host interface 960 may comprise a USB interface, an HDMI interface, or the like. In the embodiments where apparatus 900 is a data modem capable of being utilized with a host device, host interface may be a USB or PCMCIA interface.

[0070] In some embodiments, apparatus 900 may comprise more functionality than is shown in Fig. 9. In some embodiments, apparatus 900 may also comprise functionality such as a video and/or still-image camera, media player, etc., and radio transceiver 940 may include circuitry necessary to communicate using additional radio-frequency communication standards including GSM, GPRS, EDGE, UMTS, HSPA, CDMA2000, LTE, WiFi, Bluetooth, GPS, and/or others. Persons of ordinary skill in the art will recognize the above list of features and radio-frequency communication standards is merely exemplary and not intended to limit the scope of the present disclosure. Accordingly, processor 910 may execute software code stored in program memory 920 to control such additional functionality.

[0071] Fig. 10 is a block diagram of an exemplary apparatus 1000 utilizing certain embodiments of the present disclosure, including those described above with reference to Figs. 5 through 8. In some embodiments, apparatus 1000 comprises a network equipment such as an eNB or component of an eNB. Apparatus 1000 comprises processor 1010 which is operably connected to program memory 1020 and data memory 1030 via bus 1070, which

may comprise parallel address and data buses, serial ports, or other methods and/or structures known to those of ordinary skill in the art. Program memory 1020 comprises software code executed by processor 1010 that enables apparatus 1000 to communicate with one or more other devices using protocols according to various embodiments of the present disclosure, including the Radio Resource Control (RRC) protocol and improvements thereto. Program memory 1020 also comprises software code executed by processor 1010 that enables apparatus 1000 to communicate with one or more other devices using other protocols or protocol layers, such as one or more of the PHY, MAC, RLC, PDCP, and RRC layer protocols standardized by 3GPP, or any other higher-layer protocols utilized in conjunction with radio network interface 1040 and core network interface 1050. By way of example and without limitation, core network interface 1050 may comprise the S1 interface and radio network interface 1050 may comprise the Uu interface, as standardized by 3GPP. Program memory 1020 further comprises software code executed by processor 1010 to control the functions of apparatus 1000, including configuring and controlling various components such as radio network interface 1040 and core network interface 1050.

[0072] Data memory 1030 may comprise memory area for processor 1010 to store variables used in protocols, configuration, control, and other functions of apparatus 1000. As such, program memory 1020 and data memory 1030 may comprise non-volatile memory (e.g., flash memory, hard disk, etc.), volatile memory (e.g., static or dynamic RAM), network-based (e.g., “cloud”) storage, or a combination thereof. Persons of ordinary skill in the art will recognize that processor 1010 may comprise multiple individual processors (not shown), each of which implements a portion of the functionality described above. In such case, multiple individual processors may be commonly connected to program memory 1020 and data memory 1030 or individually connected to multiple individual program memories and/or data memories. More generally, persons of ordinary skill in the art will recognize that various protocols and other functions of apparatus 1000 may be implemented in many different combinations of hardware and software including, but not limited to, application processors, signal processors, general-purpose processors, multi-core processors, ASICs, fixed digital circuitry, programmable digital circuitry, analog baseband circuitry, radio-frequency circuitry, software, firmware, and middleware.

[0073] Radio network interface 1040 may comprise transmitters, receivers, signal processors, ASICs, antennas, beamforming units, and other circuitry that enables apparatus 1000 to communicate with other equipment such as, in some embodiments, a plurality of compatible user equipments (UEs). In some embodiments, radio network interface may
5 comprise various protocols or protocol layers, such as the LTE PHY, MAC, RLC, PDCP, and RRC layer protocols standardized by 3GPP, improvements thereto such as described herein with reference to one of more Figs. 6 through 10, or any other higher-layer protocols utilized in conjunction with radio network interface 1040. In some embodiments, the radio network interface 1040 may comprise a PHY layer based on orthogonal frequency division
10 multiplexing (OFDM) or orthogonal frequency division multiple access (OFDMA) technologies.

[0074] Core network interface 1050 may comprise transmitters, receivers, and other circuitry that enables apparatus 1000 to communicate with other equipment in a core network such as, in some embodiments, circuit-switched (CS) and/or packet-switched Core (PS)
15 networks. In some embodiments, core network interface 1050 may comprise the S1 interface standardized by 3GPP. In some embodiments, core network interface 1050 may comprise one or more interfaces to one or more SGWs, MMEs, SGSNs, GGSNs, and other physical devices that comprise functionality found in GERAN, UTRAN, E-UTRAN, and CDMA2000 core networks that are known to persons of ordinary skill in the art. In some embodiments,
20 these one or more interfaces may be multiplexed together on a single physical interface. In some embodiments, lower layers of core network interface 1050 may comprise one or more of asynchronous transfer mode (ATM), Internet Protocol (IP)-over-Ethernet, SDH over optical fiber, T1/E1/PDH over a copper wire, microwave radio, or other wired or wireless transmission technologies known to those of ordinary skill in the art.

[0075] OA&M interface 1060 may comprise transmitters, receivers, and other circuitry that enables apparatus 1000 to communicate with external networks, computers, databases, and the like for purposes of operations, administration, and maintenance of apparatus 1000 or other network equipment operably connected thereto. Lower layers of OA&M interface 1060 may comprise one or more of asynchronous transfer mode (ATM), Internet Protocol
25 (IP)-over-Ethernet, SDH over optical fiber, T1/E1/PDH over a copper wire, microwave radio,
30 or other wired or wireless transmission technologies known to those of ordinary skill in the

art. Moreover, in some embodiments, one or more of radio network interface 1040, core network interface 1050, and OA&M interface 1060 may be multiplexed together on a single physical interface, such as the examples listed above.

[0076] As described herein, a device or apparatus may be represented by a semiconductor chip, a chipset, or a (hardware) module comprising such chip or chipset; this, however, does not exclude the possibility that a functionality of a device or apparatus, instead of being hardware implemented, be implemented as a software module such as a computer program or a computer program product comprising executable software code portions for execution or being run on a processor. A device or apparatus may be regarded as a device or apparatus, or as an assembly of multiple devices and/or apparatuses, whether functionally in cooperation with or independently of each other. Moreover, devices and apparatuses may be implemented in a distributed fashion throughout a system, so long as the functionality of the device or apparatus is preserved. Such and similar principles are considered as known to a skilled person.

[0077] More generally, even though the present disclosure and exemplary embodiments are described above with reference to the examples according to the accompanying drawings, it is to be understood that they are not restricted thereto. Rather, it is apparent to those skilled in the art that the disclosed embodiments can be modified in many ways without departing from the scope of the disclosure herein. Moreover, the terms and descriptions used herein are set forth by way of illustration only and are not meant as limitations. Those skilled in the art will recognize that many variations are possible within the spirit and scope of the disclosure as defined in the following claims, and their equivalents, in which all terms are to be understood in their broadest possible sense unless otherwise indicated.

WHAT IS CLAIMED IS:

1. A method for determining channel quality information (CQI) for a received physical-layer (PHY) channel comprising a plurality of subframes, comprising:

5 receiving a first set of one or more subframes comprising a data message, wherein at least a portion of the first set of one or more subframes comprise overhead information related to demodulation of the data message;

receiving a subframe comprising a first control message, wherein the first control message comprises a request to determine CQI and configuration information related to the
10 request;

determining, based on the configuration information, a resource within the first set of subframes to be used for CQI determination and one or more overhead information patterns within the resource;

determining one or more CQI values for each of the overhead information patterns;
15 and

transmitting a subframe comprising a second control message, wherein the second control message comprises the determined CQI values.

2. The method of claim 1, wherein:

the first set of one or more subframes comprises one of a Physical Downlink Shared
20 Channel (PDSCH) and an Enhanced Physical Downlink Control Channel (ePDCCH);

the first control message is received in subframe n and comprises an Uplink DCI Format message;

the one or more CQI values comprise one or more CQI indices;

the resource comprises physical resource blocks (PRBs); and

25 the overhead information comprises demodulation reference signal (DM-RS) overhead information.

3. The method of claim 1, wherein the portion comprises a first subset of subframes comprising a full pattern of overhead information, and wherein the first set comprises a second subset of subframes comprising zero overhead information.

30 4. The method of claim 1, wherein:

the portion comprises a first subset of subframes comprising a first pattern of partial overhead information and a second subset of subframes comprising a second pattern of partial overhead information; and

the first set comprises a third subset of subframes comprising zero overhead
5 information.

5. The method of claim 2, wherein at least a portion of the configuration information comprises the Channel State Information (CSI) Request field of the Uplink DCI Format message.

6. The method of claim 2, wherein the configuration information comprises an
10 index value identifying one of a plurality of assumptions, where each of the plurality is associated with a particular resource for CQI determination and one or more overhead information patterns within the resource.

7. The method of claim 6, wherein one of the plurality of assumptions is associated with the resource of PRBs received in subframe $n - n_{CQI_ref}$ of the first set of
15 subframes, and with the overhead information pattern of full DM-RS overhead.

8. The method of claim 6, wherein one of the plurality of assumptions is associated with the resource of PRBs received in subframe $n - n_{CQI_ref} - n_{pattern1}$ of the first set of subframes, and with the overhead information pattern of full DM-RS overhead.

9. The method of claim 8, wherein the configuration information comprises the
20 value of $n_{pattern1}$.

10. The method of claim 8, further comprising receiving an upper-layer signaling message comprising the value of $n_{pattern1}$.

11. The method of claim 6, wherein one of the plurality of assumptions is associated with the resource of PRBs received in a contiguous group of T_{RDRMS} subframes
25 comprising the first set and ending with subframe $n - n_{CQI_ref}$, and with a plurality of DM-RS overhead information patterns.

12. The method of claim 11, wherein the plurality of DM-RS overhead information patterns comprises a pattern of full DM-RS overhead and a pattern of zero DM-RS overhead.

30 13. The method of claim 11, wherein the plurality of DM-RS overhead information patterns comprises at least one pattern of partial DM-RS overhead information.

14. The method of claim 11, wherein the configuration information comprises the value of T_{RDRMS} .

15. The method of claim 11, further comprising receiving an upper-layer signaling message comprising the value of T_{RDRMS} .

5 16. The method of claim 2, wherein the DM-RS overhead information is associated with component carriers from a set of serving cells comprising a primary cell (PCell) and one or more secondary cells (SCells).

17. A method for determining channel quality information (CQI) for a transmitted physical-layer (PHY) channel comprising a plurality of subframes, comprising:

10 transmitting a first set of one or more subframes comprising a data message to a receiving apparatus, wherein at least a portion of the first set of subframes comprise overhead information related to demodulation of the data message;

determining a set of parameters for CQI determination, wherein the parameters include a resource within the first set of subframes to be used for CQI determination and one
15 or more overhead information patterns within the resource;

encoding the set of parameters into configuration information comprising one of a plurality of assumptions to be used by the receiving apparatus;

transmitting a subframe comprising a first control message, wherein the first control message comprises the configuration information and a request to determine CQI; and

20 receiving a subframe comprising a second control message, wherein the second control message comprises one or more CQI values.

18. The method of claim 17, wherein:

the first set of one or more subframes comprises one of a Physical Downlink Shared Channel (PDSCH) and an Enhanced Physical Downlink Control Channel (ePDCCH);

25 the first control message is transmitted in subframe n and comprises an Uplink DCI Format message;

the one or more CQI values comprise one or more CQI indices;

the resource comprises physical resource blocks (PRBs); and

the overhead information comprises demodulation reference signal (DM-RS)
30 overhead information.

19. The method of claim 17, wherein the portion comprises a first subset of subframes comprising a pattern of full overhead information, and wherein the first set comprises a second subset of subframes comprising zero overhead information.

20. The method of claim 17, wherein:

5 the portion comprises a first subset of subframes comprising a first pattern of partial overhead information and a second subset of subframes comprising a second pattern of partial overhead information; and

the first set comprises a third subset of subframes comprising zero overhead information.

10 21. The method of claim 18, wherein at least a portion of the configuration information comprises the Channel State Information (CSI) Request field of the Uplink DCI Format message.

22. The method of claim 18, wherein the configuration information comprises an index value identifying one of the plurality of assumptions, where each of the plurality is
15 associated with a particular resource for CQI determination and one or more overhead information patterns within the resource.

23. The method of claim 22, wherein one of the plurality of assumptions is associated with the resource of PRBs transmitted in subframe $n-n_{CQI_ref}$ of the first set of subframes, and with the overhead information pattern of full DM-RS overhead.

20 24. The method of claim 22, wherein one of the plurality of assumptions is associated with the resource of PRBs transmitted in subframe $n-n_{CQI_ref}-n_{pattern1}$ of the first set of subframes, and with the overhead information pattern of full DM-RS overhead.

25. The method of claim 24, wherein the configuration information comprises the value of $n_{pattern1}$.

25 26. The method of claim 24, further comprising transmitting an upper-layer signaling message comprising the value of $n_{pattern1}$.

27. The method of claim 22, wherein one of the plurality of assumptions is associated with the resource of PRBs transmitted in a contiguous group of T_{RDRMS} subframes comprising the first set and ending with subframe $n-n_{CQI_ref}$, and with a plurality of DM-RS
30 overhead information patterns.

28. The method of claim 27, wherein the plurality of DM-RS overhead information patterns comprises a pattern of full DM-RS overhead and a pattern of zero DM-RS overhead.

29. The method of claim 27, wherein the plurality of DM-RS overhead
5 information patterns comprises at least one pattern of partial DM-RS overhead information.

30. The method of claim 27, wherein the configuration information comprises the value of T_{RDRMS} .

31. The method of claim 27, further comprising transmitting an upper-layer signaling message comprising the value of T_{RDRMS} .

10 32. The method of claim 18, wherein the DM-RS overhead information is associated with component carriers from a set of serving cells comprising a primary cell (PCell) and one or more secondary cells (SCells).

33. The method of claim 17, further comprising determining at least one of a modulation and coding scheme (MCS) and a transport block size (TBS) based on the
15 received one or more CQI values.

34. An apparatus capable of communicating on a physical-layer (PHY) channel comprising a plurality of subframes, comprising:

a transmitter;

a receiver;

20 a processor; and

at least one memory including program code that, when executed by the processor, causes the apparatus to:

25 receive a first set of one or more subframes comprising a data message, wherein at least a portion of the first set of one or more subframes comprise overhead information related to demodulation of the data message;

receive a subframe comprising a first control message, wherein the first control message comprises a request to determine channel quality information (CQI) and configuration information related to the request;

30 determine, based on the configuration information, a resource within the first set of subframes to be used for CQI determination and one or more overhead information patterns within the resource;

determine one or more CQI values for each of the overhead information patterns; and

transmit a subframe comprising a second control message, wherein the second control message comprises the determined CQI values.

5 35. The apparatus of claim 34, wherein:

the apparatus is one of a user equipment (UE) and a component of a UE;

the first set of one or more subframes comprises one of a Physical Downlink Shared Channel (PDSCH) and an Enhanced Physical Downlink Control Channel (ePDCCH);

10 the first control message is received in subframe n and comprises an Uplink DCI Format message;

the one or more CQI values comprise one or more CQI indices;

the resource comprises physical resource blocks (PRBs); and

the overhead information comprises demodulation reference signal (DM-RS) overhead information.

15 36. The apparatus of claim 34, wherein the portion comprises a first subset of subframes comprising a full pattern of overhead information, and wherein the first set comprises a second subset of subframes comprising zero overhead information.

37. The apparatus of claim 34, wherein:

20 the portion comprises a first subset of subframes comprising a first pattern of partial overhead information and a second subset of subframes comprising a second pattern of partial overhead information; and

the first set comprises a third subset of subframes comprising zero overhead information.

25 38. The apparatus of claim 35, wherein at least a portion of the configuration information comprises the Channel State Information (CSI) Request field of the Uplink DCI Format message.

30 39. The apparatus of claim 35, wherein the configuration information comprises an index value identifying one of a plurality of assumptions, where each of the plurality is associated with a particular resource for CQI determination and one or more overhead information patterns within the resource.

40. The apparatus of claim 39, wherein one of the plurality of assumptions is associated with the resource of PRBs received in subframe $n-n_{CQI_ref}$ of the first set of subframes, and with the overhead information pattern of full DM-RS overhead.

41. The apparatus of claim 39, wherein one of the plurality of assumptions is
5 associated with the resource of PRBs received in subframe $n-n_{CQI_ref}-n_{pattern1}$ of the first set of subframes, and with the overhead information pattern of full DM-RS overhead.

42. The apparatus of claim 41, wherein the configuration information comprises the value of $n_{pattern1}$.

43. The apparatus of claim 41, wherein the at least one memory further comprises
10 program code that, when executed by the processor, causes the apparatus to receive an upper-layer signaling message comprising the value of $n_{pattern1}$.

44. The apparatus of claim 39, wherein one of the plurality of assumptions is associated with the resource of PRBs received in a contiguous group of T_{RDRMS} subframes comprising the first set and ending with subframe $n-n_{CQI_ref}$, and with a plurality of DM-RS
15 overhead information patterns.

45. The apparatus of claim 44, wherein the plurality of DM-RS overhead information patterns comprises a pattern of full DM-RS overhead and a pattern of zero DM-RS overhead.

46. The apparatus of claim 44, wherein the plurality of DM-RS overhead
20 information patterns comprises at least one pattern of partial DM-RS overhead information.

47. The apparatus of claim 44, wherein the configuration information comprises the value of T_{RDRMS} .

48. The apparatus of claim 44, wherein the at least one memory further comprises
25 program code that, when executed by the processor, causes the apparatus to receive an upper-layer signaling message comprising the value of T_{RDRMS} .

49. The apparatus of claim 35, wherein the DM-RS overhead information is associated with component carriers from a set of serving cells comprising a primary cell (PCell) and one or more secondary cells (SCells).

50. An apparatus capable of communicating on a physical-layer (PHY) channel
30 comprising a plurality of subframes comprising:

a transmitter;

a receiver;

a processor; and

at least one memory including program code that, when executed by the processor, causes the apparatus to:

5 transmit a first set of one or more subframes comprising a data message to a receiving apparatus, wherein at least a portion of the first set of subframes comprise overhead information related to demodulation of the data message;

 determine a set of parameters for channel quality information (CQI) determination, wherein the parameters include a resource within the first set of
10 subframes to be used for CQI determination and one or more overhead information patterns within the resource;

 encode the set of parameters into configuration information comprising one of a plurality of assumptions to be used by the receiving apparatus;

 transmit a subframe comprising a first control message, wherein the first
15 control message comprises the configuration information and a request to determine CQI; and

 receive a subframe comprising a second control message, wherein the second control message comprises one or more CQI values.

51. The apparatus of claim 50, wherein:

20 the apparatus is an evolved Node B (eNB);

 the first set of one or more subframes comprises one of a Physical Downlink Shared Channel (PDSCH) and an Enhanced Physical Downlink Control Channel (ePDCCH);

 the first control message is transmitted in subframe n and comprises an Uplink DCI Format message;

25 the one or more CQI values comprise one or more CQI indices;

 the resource comprises physical resource blocks (PRBs); and

 the overhead information comprises demodulation reference signal (DM-RS) overhead information.

52. The apparatus of claim 50, wherein the portion comprises a first subset of
30 subframes comprising a pattern of full overhead information, and wherein the first set comprises a second subset of subframes comprising zero overhead information.

53. The apparatus of claim 50, wherein:

the portion comprises a first subset of subframes comprising a first pattern of partial overhead information and a second subset of subframes comprising a second pattern of partial overhead information; and

5 the first set comprises a third subset of subframes comprising zero overhead information.

54. The apparatus of claim 51, wherein at least a portion of the configuration information comprises the Channel State Information (CSI) Request field of the Uplink DCI Format message.

10 55. The apparatus of claim 51, wherein the configuration information comprises an index value identifying one of the plurality of assumptions, where each of the plurality is associated with a particular resource for CQI determination and one or more overhead information patterns within the resource.

56. The apparatus of claim 55, wherein one of the plurality of assumptions is
15 associated with the resource of PRBs transmitted in subframe $n - n_{CQI_ref}$ of the first set of subframes, and with the overhead information pattern of full DM-RS overhead.

57. The apparatus of claim 55, wherein one of the plurality of assumptions is associated with the resource of PRBs transmitted in subframe $n - n_{CQI_ref} - n_{pattern1}$ of the first set of subframes, and with the overhead information pattern of full DM-RS overhead.

20 58. The apparatus of claim 57, wherein the configuration information comprises the value of $n_{pattern1}$.

59. The apparatus of claim 57, wherein the at least one memory further comprises program code that, when executed by the processor, causes the apparatus to transmit an upper-layer signaling message comprising the value of $n_{pattern1}$.

25 60. The apparatus of claim 55, wherein one of the plurality of assumptions is associated with the resource of PRBs transmitted in a contiguous group of T_{RDRMS} subframes comprising the first set and ending with subframe $n - n_{CQI_ref}$, and with a plurality of DM-RS overhead information patterns.

30 61. The apparatus of claim 60, wherein the plurality of DM-RS overhead information patterns comprises a pattern of full DM-RS overhead and a pattern of zero DM-RS overhead.

62. The apparatus of claim 60, wherein the plurality of DM-RS overhead information patterns comprises at least one pattern of partial DM-RS overhead information.

63. The apparatus of claim 60, wherein the configuration information comprises the value of T_{RDRMS} .

5 64. The apparatus of claim 60, wherein the at least one memory further comprises program code that, when executed by the processor, causes the apparatus to transmit an upper-layer signaling message comprising the value of T_{RDRMS} .

65. The apparatus of claim 51, wherein the DM-RS overhead information is associated with component carriers from a set of serving cells comprising a primary cell
10 (PCell) and one or more secondary cells (SCells).

66. The apparatus of claim 50, wherein the at least one memory further comprises program code that, when executed by the processor, causes the apparatus to determine at least one of a modulation and coding scheme (MCS) and a transport block size (TBS) based on the received one or more CQI values.

15 67. A computer-readable medium comprising a set of instructions that, when executed by an apparatus comprising at least one processor and capable of communicating on a physical-layer (PHY) channel comprising a plurality of subframes, causes the apparatus to:

20 receive a first set of one or more subframes, wherein the first set comprises a data message and at least a portion of the subframes comprising the first set include overhead information related to demodulation of the data message;

 receive a subframe comprising a first control message, wherein the first control message comprises a request to determine channel quality information (CQI) and configuration information related to the request;

25 determine, based on the configuration information, a resource within the first set of subframes to be used for CQI determination and one or more overhead information patterns within the resource;

 determine one or more CQI values for each of the overhead information patterns; and
 transmit a subframe comprising a second control message, wherein the second control message comprises the determined CQI values.

30 68. The computer-readable medium of claim 67, wherein:
 the apparatus is one of a user equipment (UE) and a component of a UE;

the first set of one or more subframes comprises one of a Physical Downlink Shared Channel (PDSCH) and an Enhanced Physical Downlink Control Channel (ePDCCH);

the first control message is received in subframe n and comprises an Uplink DCI Format message;

5 the one or more CQI values comprise one or more CQI indices;

the resource comprises physical resource blocks (PRBs); and

the overhead information comprises demodulation reference signal (DM-RS) overhead information.

69. The computer-readable medium of claim 67, wherein the portion comprises a
10 first subset of subframes comprising a full pattern of overhead information, and wherein the first set comprises a second subset of subframes comprising zero overhead information.

70. The computer-readable medium of claim 67, wherein:

the portion comprises a first subset of subframes comprising a first pattern of partial overhead information and a second subset of subframes comprising a second pattern of
15 partial overhead information; and

the first set comprises a third subset of subframes comprising zero overhead information.

71. The computer-readable medium of claim 68, wherein at least a portion of the configuration information comprises the Channel State Information (CSI) Request field of
20 the Uplink DCI Format message.

72. The computer-readable medium of claim 68, wherein the configuration information comprises an index value identifying one of a plurality of assumptions, where each of the plurality is associated with a particular resource for CQI determination and one or more overhead information patterns within the resource.

25 73. The computer-readable medium of claim 72, wherein one of the plurality of assumptions is associated with the resource of PRBs received in subframe $n - n_{CQI_ref}$ of the first set of subframes, and with the overhead information pattern of full DM-RS overhead.

74. The computer-readable medium of claim 72, wherein one of the plurality of assumptions is associated with the resource of PRBs received in subframe $n - n_{CQI_ref} - n_{pattern1}$
30 of the first set of subframes, and with the overhead information pattern of full DM-RS overhead.

75. The computer-readable medium of claim 74, wherein the configuration information comprises the value of $n_{pattern1}$.

76. The computer-readable medium of claim 74, further comprising program code that, when executed by the apparatus, causes the apparatus to receive an upper-layer
5 signaling message comprising the value of $n_{pattern1}$.

77. The computer-readable medium of claim 72, wherein one of the plurality of assumptions is associated with the resource of PRBs received in a contiguous group of T_{RDRMS} subframes comprising the first set and ending with subframe $n-n_{CQI_ref}$, and with a plurality of DM-RS overhead information patterns.

10 78. The computer-readable medium of claim 77, wherein the plurality of DM-RS overhead information patterns comprises a pattern of full DM-RS overhead and a pattern of zero DM-RS overhead.

79. The computer-readable medium of claim 77, wherein the plurality of DM-RS overhead information patterns comprises at least one pattern of partial DM-RS overhead
15 information.

80. The computer-readable medium of claim 77, wherein the configuration information comprises the value of T_{RDRMS} .

81. The computer-readable medium of claim 77, further comprising program code that, when executed by the apparatus, causes the apparatus to receive an upper-layer
20 signaling message comprising the value of T_{RDRMS} .

82. The computer-readable medium of claim 78, wherein the DM-RS overhead information is associated with component carriers from a set of serving cells comprising a primary cell (PCell) and one or more secondary cells (SCells).

83. A computer-readable medium comprising a set of instructions that, when
25 executed by an apparatus comprising at least one processor and capable of communicating on a physical-layer (PHY) channel comprising a plurality of subframes, causes the apparatus to:

transmit a first set of one or more subframes comprising a data message to a receiving apparatus, wherein at least a portion of the first set of subframes comprise overhead information related to demodulation of the data message;

determine a set of parameters for channel quality information (CQI) determination, wherein the parameters include a resource within the first set of subframes to be used for CQI determination and one or more overhead information patterns within the resource;

5 encode the set of parameters into configuration information comprising one of a plurality of assumptions to be used by the receiving apparatus;

transmit a subframe comprising a first control message, wherein the first control message comprises the configuration information and a request to determine CQI; and

receive a subframe comprising a second control message, wherein the second control message comprises one or more CQI values.

10 84. The computer readable medium of claim 83, wherein:

the apparatus is an evolved Node B (eNB);

the first set of one or more subframes comprises one of a Physical Downlink Shared Channel (PDSCH) and an Enhanced Physical Downlink Control Channel (ePDCCH);

15 the first control message is transmitted in subframe n and comprises an Uplink DCI Format message;

the one or more CQI values comprise one or more CQI indices;

the resource comprises physical resource blocks (PRBs); and

the overhead information comprises demodulation reference signal (DM-RS) overhead information.

20 85. The computer readable medium of claim 83, wherein the portion comprises a first subset of subframes comprising a pattern of full overhead information, and wherein the first set comprises a second subset of subframes comprising zero overhead information.

86. The computer readable medium of claim 83, wherein:

25 the portion comprises a first subset of subframes comprising a first pattern of partial overhead information and a second subset of subframes comprising a second pattern of partial overhead information; and

the first set comprises a third subset of subframes comprising zero overhead information.

30 87. The computer readable medium of claim 84, wherein at least a portion of the configuration information comprises the Channel State Information (CSI) Request field of the Uplink DCI Format message.

88. The computer readable medium of claim 84, wherein the configuration information comprises an index value identifying one of the plurality of assumptions, where each of the plurality is associated with a particular resource for CQI determination and one or more overhead information patterns within the resource.

5 89. The computer readable medium of claim 88, wherein one of the plurality of assumptions is associated with the resource of PRBs transmitted in subframe $n - n_{CQI_ref}$ of the first set of subframes, and with the overhead information pattern of full DM-RS overhead.

90. The computer readable medium of claim 88, wherein one of the plurality of assumptions is associated with the resource of PRBs transmitted in subframe $n - n_{CQI_ref} -$
 10 $n_{pattern1}$ of the first set of subframes, and with the overhead information pattern of full DM-RS overhead.

91. The computer readable medium of claim 90, wherein the configuration information comprises the value of $n_{pattern1}$.

92. The computer readable medium of claim 90, further comprising program code
 15 that, when executed by the processor, causes the apparatus to transmit an upper-layer signaling message comprising the value of $n_{pattern1}$.

93. The computer readable medium of claim 88, wherein one of the plurality of assumptions is associated with the resource of PRBs transmitted in a contiguous group of T_{RDRMS} subframes comprising the first set and ending with subframe $n - n_{CQI_ref}$, and with a
 20 plurality of DM-RS overhead information patterns.

94. The computer readable medium of claim 93, wherein the plurality of DM-RS overhead information patterns comprises a pattern of full DM-RS overhead and a pattern of zero DM-RS overhead.

95. The computer readable medium of claim 93, wherein the plurality of DM-RS
 25 overhead information patterns comprises at least one pattern of partial DM-RS overhead information.

96. The computer readable medium of claim 93, wherein the configuration information comprises the value of T_{RDRMS} .

97. The computer readable medium of claim 93, further comprising program code
 30 that, when executed by the apparatus, causes the apparatus to transmit an upper-layer signaling message comprising the value of T_{RDRMS} .

98. The computer readable medium of claim 84, wherein the DM-RS overhead information is associated with component carriers from a set of serving cells comprising a primary cell (PCell) and one or more secondary cells (SCells).

5 99. The computer readable medium of claim 83, further comprising program code that, when executed by the apparatus, causes the apparatus to determine at least one of a modulation and coding scheme (MCS) and a transport block size (TBS) based on the received one or more CQI values.

100. An apparatus capable of communicating on a physical-layer (PHY) channel comprising a plurality of subframes, comprising:

10 transmitter means;

receiver means;

processor means; and

at least one memory means including program code that, when executed by the processor means, causes the apparatus to:

15 receive a first set of one or more subframes comprising a data message, wherein at least a portion of the first set of one or more subframes comprise overhead information related to demodulation of the data message;

receive a subframe comprising a first control message, wherein the first control message comprises a request to determine channel quality information (CQI) and configuration information related to the request;

20 determine, based on the configuration information, a resource within the first set of subframes to be used for CQI determination and one or more overhead information patterns within the resource;

25 determine one or more CQI values for each of the overhead information patterns; and

transmit a subframe comprising a second control message, wherein the second control message comprises the determined CQI values.

101. The apparatus of claim 100, wherein:

the apparatus is one of a user equipment (UE) and a component of a UE;

30 the first set of one or more subframes comprises one of a Physical Downlink Shared Channel (PDSCH) and an Enhanced Physical Downlink Control Channel (ePDCCH);

the first control message is received in subframe n and comprises an Uplink DCI Format message;

the one or more CQI values comprise one or more CQI indices;

the resource comprises physical resource blocks (PRBs); and

5 the overhead information comprises demodulation reference signal (DM-RS) overhead information.

102. The apparatus of claim 100, wherein the portion comprises a first subset of subframes comprising a full pattern of overhead information, and wherein the first set comprises a second subset of subframes comprising zero overhead information.

10 103. The apparatus of claim 100, wherein:

the portion comprises a first subset of subframes comprising a first pattern of partial overhead information and a second subset of subframes comprising a second pattern of partial overhead information; and

15 the first set comprises a third subset of subframes comprising zero overhead information.

104. The apparatus of claim 101, wherein at least a portion of the configuration information comprises the Channel State Information (CSI) Request field of the Uplink DCI Format message.

20 105. The apparatus of claim 101, wherein the configuration information comprises an index value identifying one of a plurality of assumptions, where each of the plurality is associated with a particular resource for CQI determination and one or more overhead information patterns within the resource.

25 106. The apparatus of claim 105, wherein one of the plurality of assumptions is associated with the resource of PRBs received in subframe $n - n_{CQI_ref}$ of the first set of subframes, and with the overhead information pattern of full DM-RS overhead.

107. The apparatus of claim 105, wherein one of the plurality of assumptions is associated with the resource of PRBs received in subframe $n - n_{CQI_ref} - n_{pattern1}$ of the first set of subframes, and with the overhead information pattern of full DM-RS overhead.

30 108. The apparatus of claim 107, wherein the configuration information comprises the value of $n_{pattern1}$.

109. The apparatus of claim 107, wherein the at least one memory means further comprises program code that, when executed by the processor, causes the apparatus to receive an upper-layer signaling message comprising the value of $n_{pattern1}$.

110. The apparatus of claim 105, wherein one of the plurality of assumptions is
5 associated with the resource of PRBs received in a contiguous group of T_{RDRMS} subframes comprising the first set and ending with subframe $n - n_{CQL_ref}$, and with a plurality of DM-RS overhead information patterns.

111. The apparatus of claim 110, wherein the plurality of DM-RS overhead
10 information patterns comprises a pattern of full DM-RS overhead and a pattern of zero DM-RS overhead.

112. The apparatus of claim 110, wherein the plurality of DM-RS overhead information patterns comprises at least one pattern of partial DM-RS overhead information.

113. The apparatus of claim 110, wherein the configuration information comprises the value of T_{RDRMS} .

114. The apparatus of claim 110, wherein the at least one memory means further
15 comprises program code that, when executed by the processor, causes the apparatus to receive an upper-layer signaling message comprising the value of T_{RDRMS} .

115. The apparatus of claim 101, wherein the DM-RS overhead information is
20 associated with component carriers from a set of serving cells comprising a primary cell (PCell) and one or more secondary cells (SCells).

116. An apparatus capable of communicating on a physical-layer (PHY) channel comprising a plurality of subframes comprising:

transmitter means;

receiver means;

25 processor means; and

at least one memory means including program code that, when executed by the processor means, causes the apparatus to:

transmit a first set of one or more subframes comprising a data message to a receiving apparatus, wherein at least a portion of the first set of subframes comprise
30 overhead information related to demodulation of the data message;

determine a set of parameters for channel quality information (CQI) determination, wherein the parameters include a resource within the first set of subframes to be used for CQI determination and one or more overhead information patterns within the resource;

5 encode the set of parameters into configuration information comprising one of a plurality of assumptions to be used by the receiving apparatus;

 transmit a subframe comprising a first control message, wherein the first control message comprises the configuration information and a request to determine CQI; and

10 receive a subframe comprising a second control message, wherein the second control message comprises one or more CQI values.

117. The apparatus of claim 116, wherein:

 the apparatus is an evolved Node B (eNB);

 the first set of one or more subframes comprises one of a Physical Downlink Shared
15 Channel (PDSCH) and an Enhanced Physical Downlink Control Channel (ePDCCH);

 the first control message is transmitted in subframe n and comprises an Uplink DCI Format message;

 the one or more CQI values comprise one or more CQI indices;

 the resource comprises physical resource blocks (PRBs); and

20 the overhead information comprises demodulation reference signal (DM-RS) overhead information.

118. The apparatus of claim 116, wherein the portion comprises a first subset of subframes comprising a pattern of full overhead information, and wherein the first set comprises a second subset of subframes comprising zero overhead information.

25 119. The apparatus of claim 116, wherein:

 the portion comprises a first subset of subframes comprising a first pattern of partial overhead information and a second subset of subframes comprising a second pattern of partial overhead information; and

 the first set comprises a third subset of subframes comprising zero overhead
30 information.

120. The apparatus of claim 117, wherein at least a portion of the configuration information comprises the Channel State Information (CSI) Request field of the Uplink DCI Format message.

121. The apparatus of claim 117, wherein the configuration information comprises
5 an index value identifying one of the plurality of assumptions, where each of the plurality is associated with a particular resource for CQI determination and one or more overhead information patterns within the resource.

122. The apparatus of claim 121, wherein one of the plurality of assumptions is associated with the resource of PRBs transmitted in subframe $n - n_{CQI_ref}$ of the first set of
10 subframes, and with the overhead information pattern of full DM-RS overhead.

123. The apparatus of claim 121, wherein one of the plurality of assumptions is associated with the resource of PRBs transmitted in subframe $n - n_{CQI_ref} - n_{pattern1}$ of the first set of subframes, and with the overhead information pattern of full DM-RS overhead.

124. The apparatus of claim 123, wherein the configuration information comprises
15 the value of $n_{pattern1}$.

125. The apparatus of claim 123, wherein the at least one memory means further comprises program code that, when executed by the processor, causes the apparatus to transmit an upper-layer signaling message comprising the value of $n_{pattern1}$.

126. The apparatus of claim 121, wherein one of the plurality of assumptions is
20 associated with the resource of PRBs transmitted in a contiguous group of T_{RDRMS} subframes comprising the first set and ending with subframe $n - n_{CQI_ref}$, and with a plurality of DM-RS overhead information patterns.

127. The apparatus of claim 126, wherein the plurality of DM-RS overhead information patterns comprises a pattern of full DM-RS overhead and a pattern of zero DM-
25 RS overhead.

128. The apparatus of claim 126, wherein the plurality of DM-RS overhead information patterns comprises at least one pattern of partial DM-RS overhead information.

129. The apparatus of claim 126, wherein the configuration information comprises the value of T_{RDRMS} .

130. The apparatus of claim 126, wherein the at least one memory means further comprises program code that, when executed by the processor, causes the apparatus to transmit an upper-layer signaling message comprising the value of T_{RDRMS} .

5 131. The apparatus of claim 117, wherein the DM-RS overhead information is associated with component carriers from a set of serving cells comprising a primary cell (PCell) and one or more secondary cells (SCells).

132. The apparatus of claim 116, wherein the at least one memory means further comprises program code that, when executed by the processor, causes the apparatus to determine at least one of a modulation and coding scheme (MCS) and a transport block size
10 (TBS) based on the received one or more CQI values.

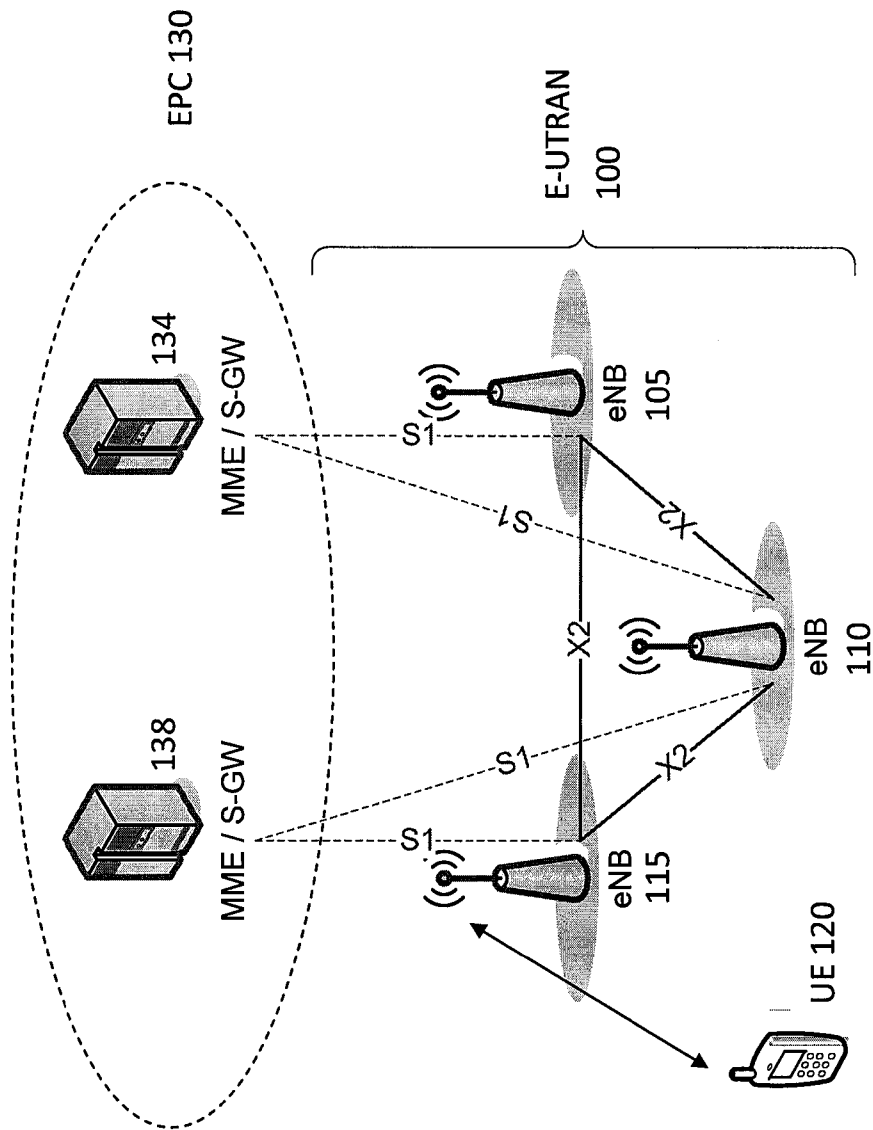


Fig. 1

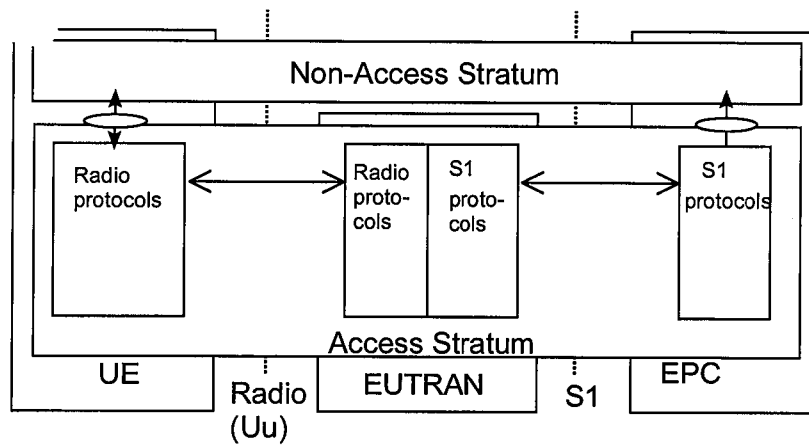


Fig. 2A

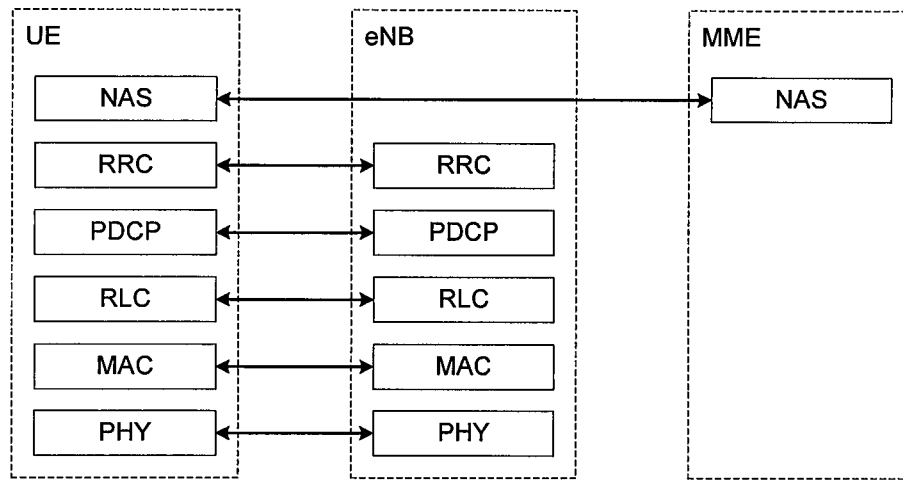


Fig. 2B

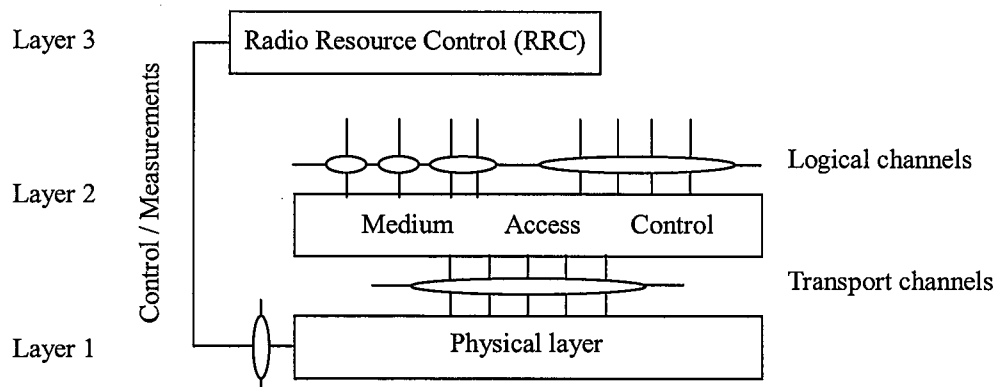
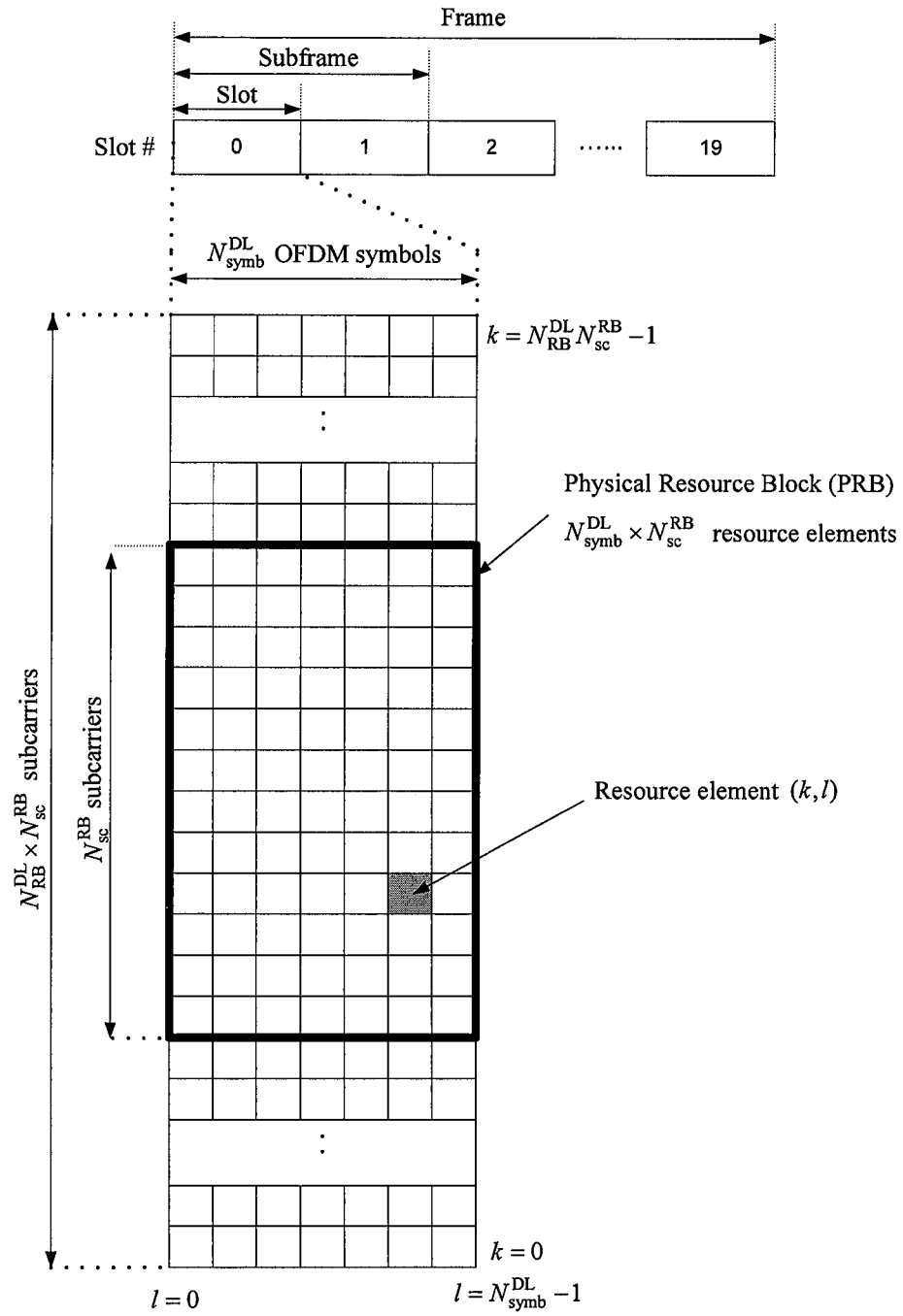
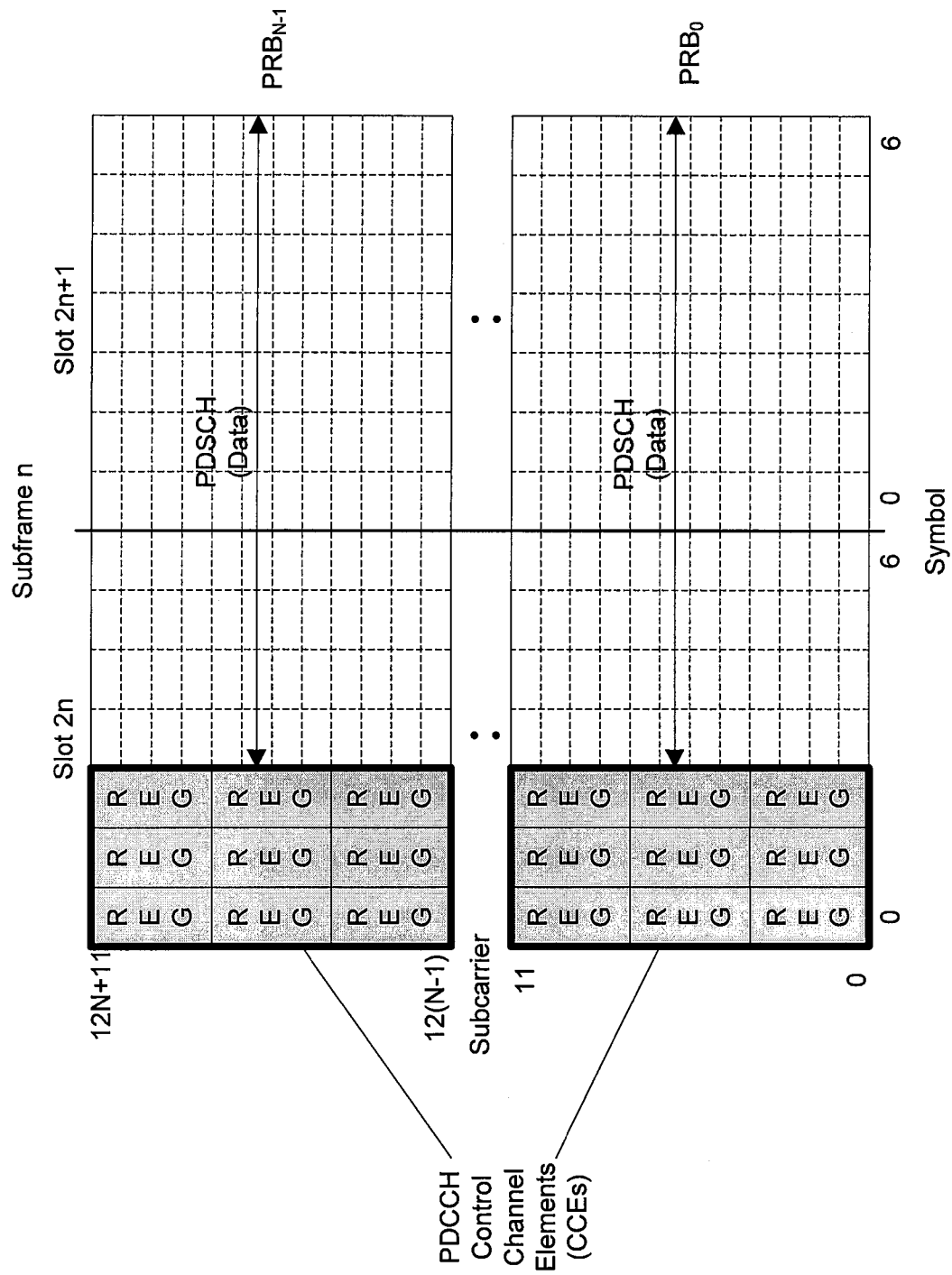


Fig. 2C

**Fig. 3**

**Fig. 4A**

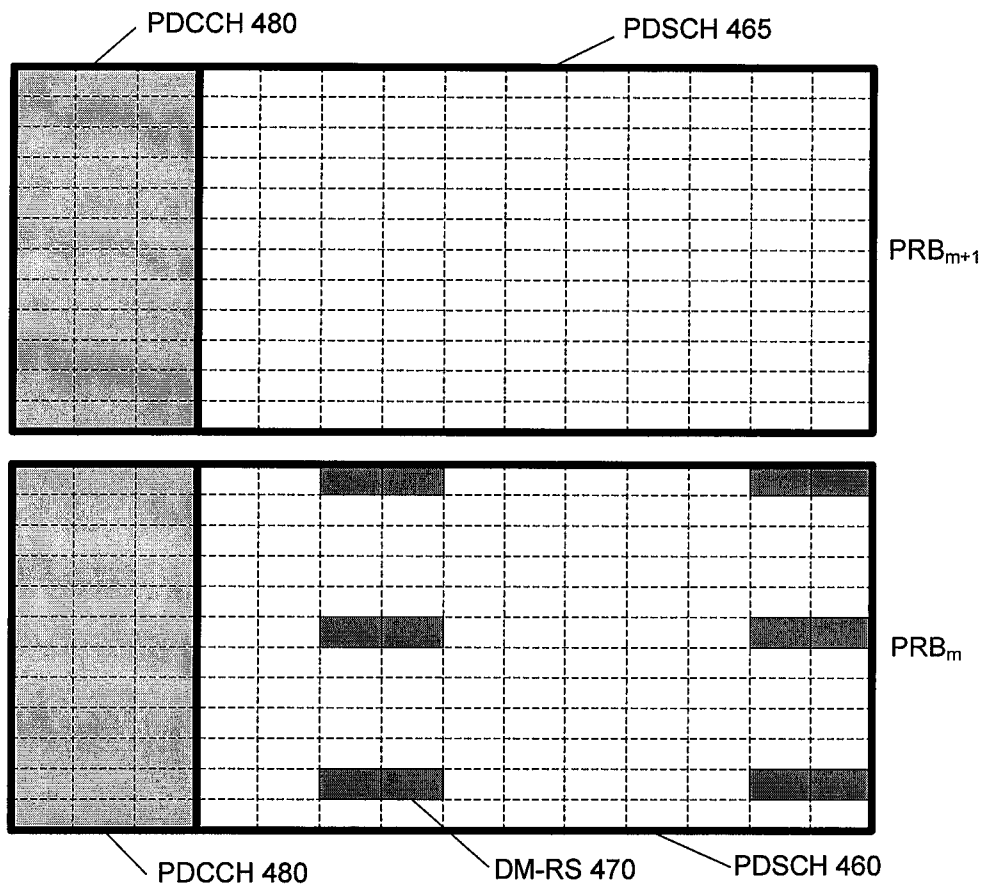


Fig. 4B

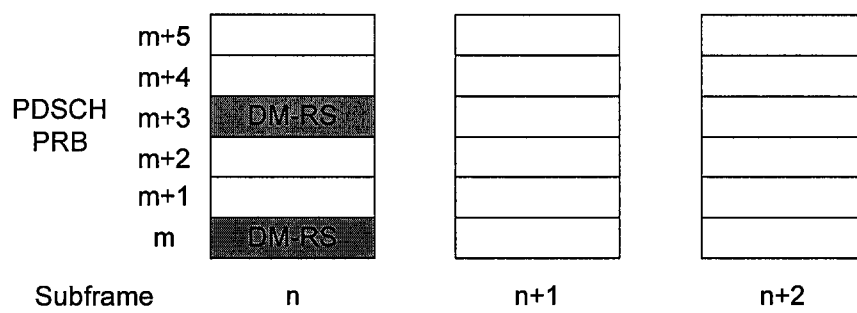
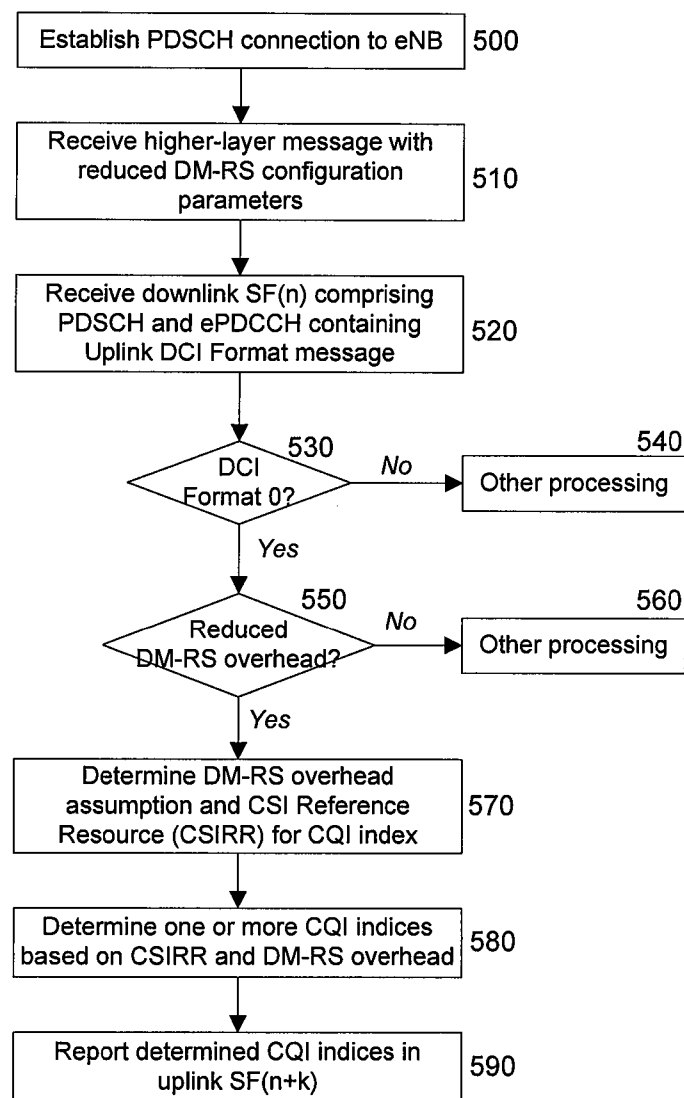
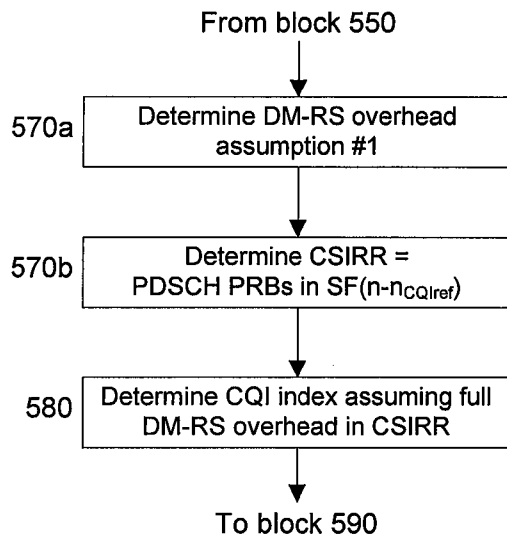
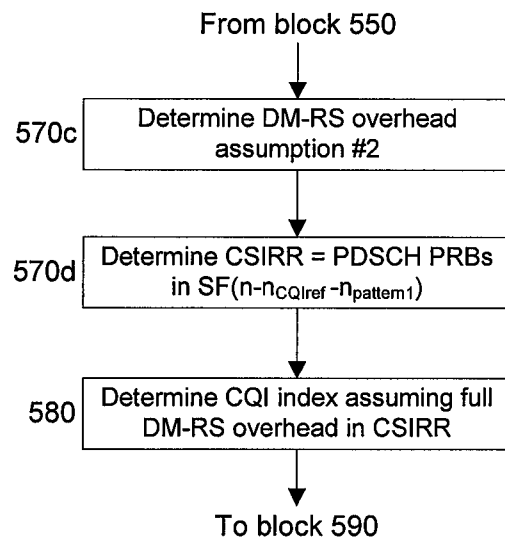
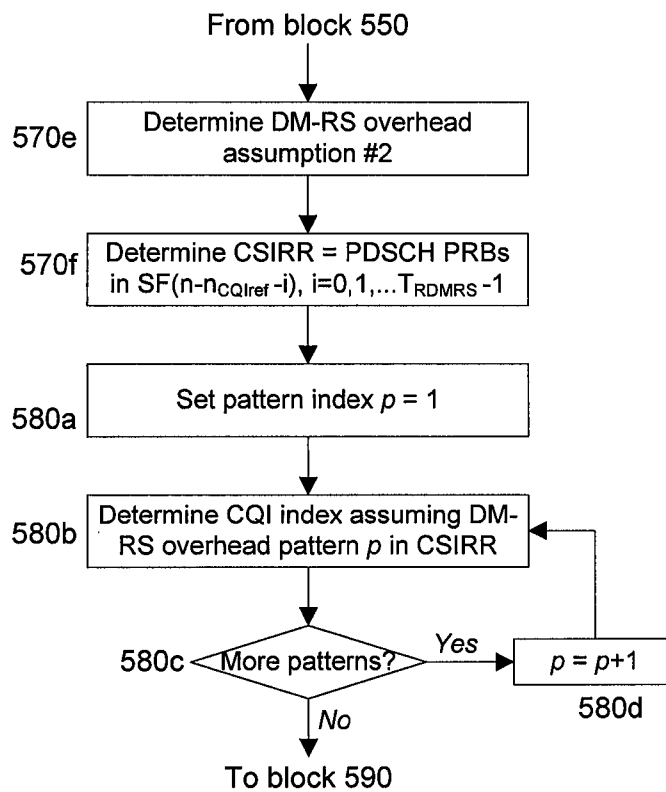
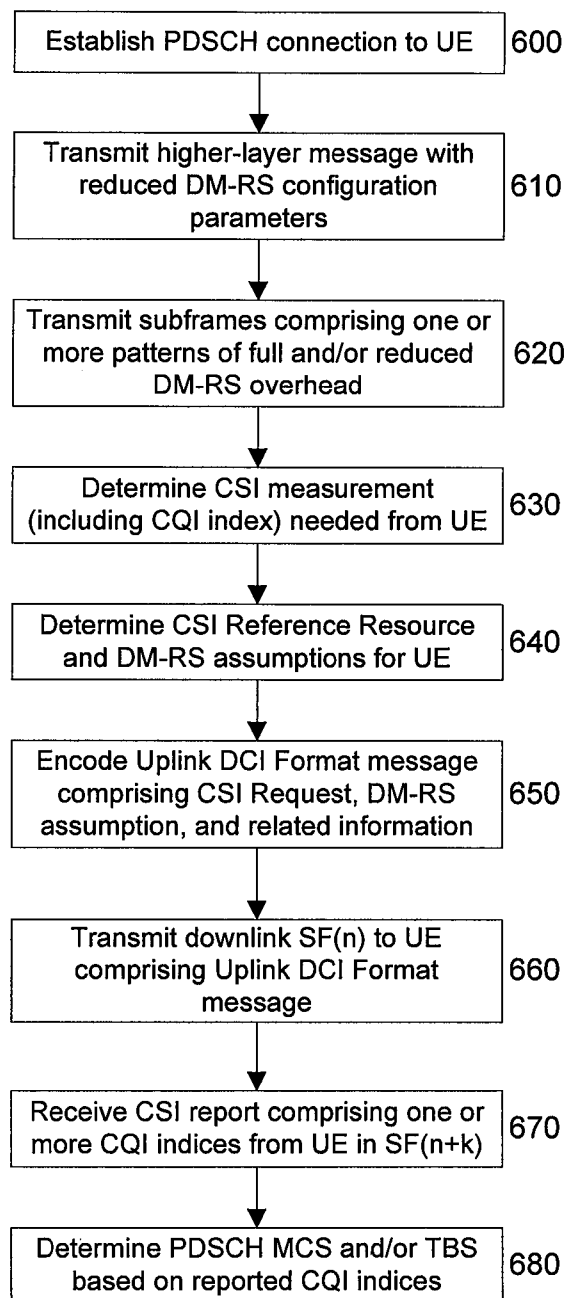


Fig. 4C

**Fig. 5A**

**Fig. 5B****Fig. 5C****Fig. 5D**

**Fig. 6**

Value of CSI request field	Description
'00'	No aperiodic CSI report is triggered
'01'	Aperiodic CSI report is triggered for serving cell c
'10'	Aperiodic CSI report is triggered for a 1 st set of serving cells configured by higher layers with DM RS overhead assumption #1
'11'	Aperiodic CSI report is triggered for a 2 nd set of serving cells configured by higher layers with DM RS overhead assumption #2

Fig. 7A

Value of CSI request field	Description
'00'	No aperiodic CSI report is triggered
'01'	Aperiodic CSI report is triggered for serving cell c
'10'	Aperiodic CSI report is triggered for a 1 st set of serving cells configured by higher layers
'11'	Aperiodic CSI report is triggered for a 2 nd set of serving cells configured by higher layers

Fig. 7B

Value of b_0 field	Description
'0'	Determine CQI index based on DM RS overhead assumption #1
'1'	Determine CQI index based on DM RS overhead assumption #1

Fig. 7C

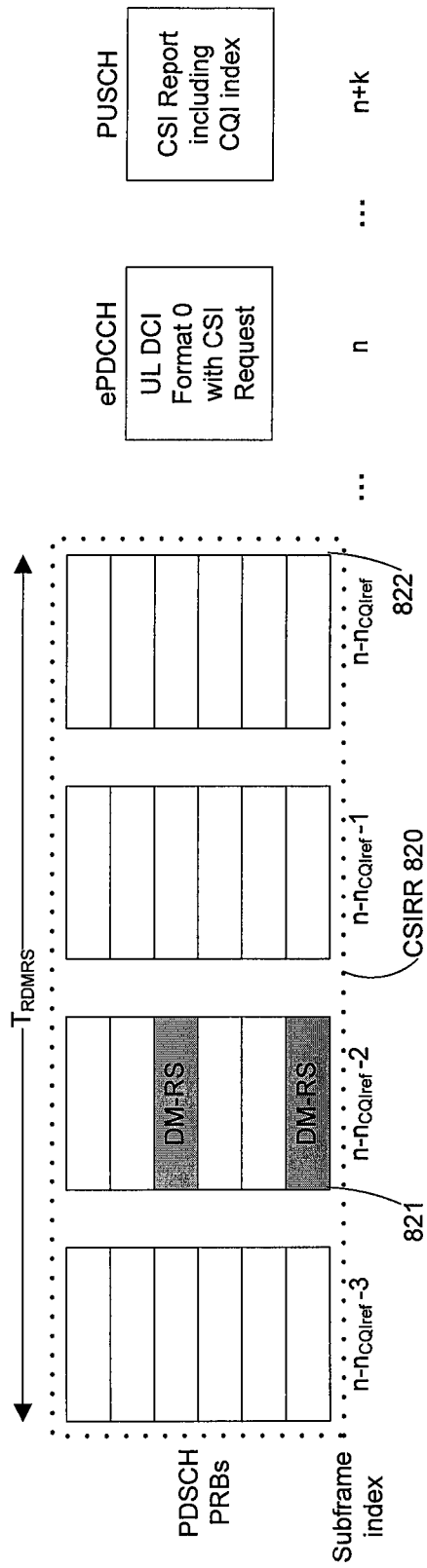


Fig. 8C

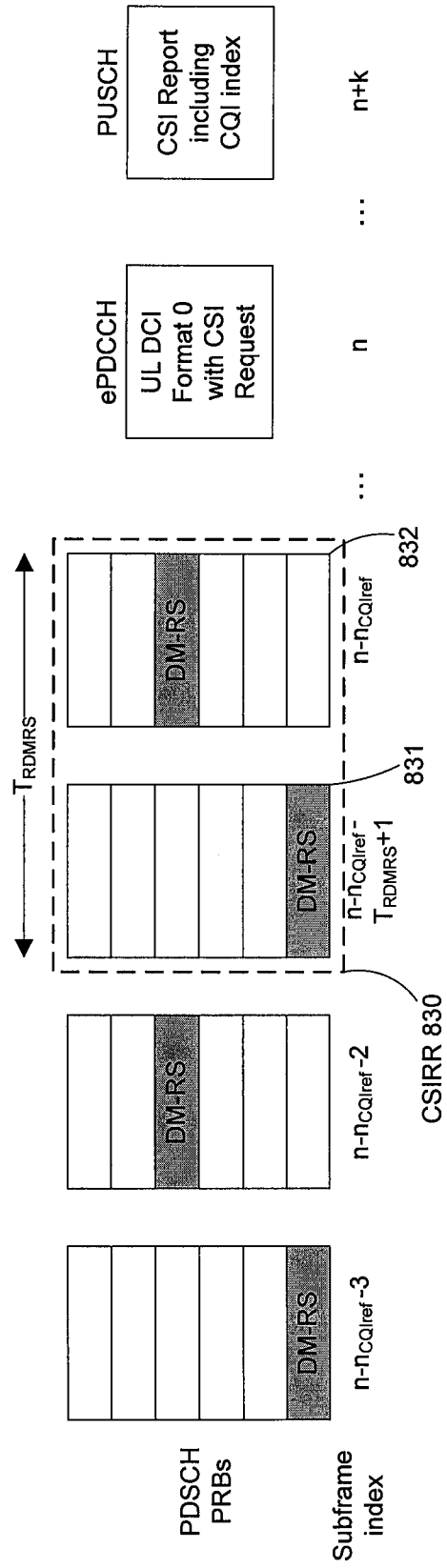


Fig. 8D

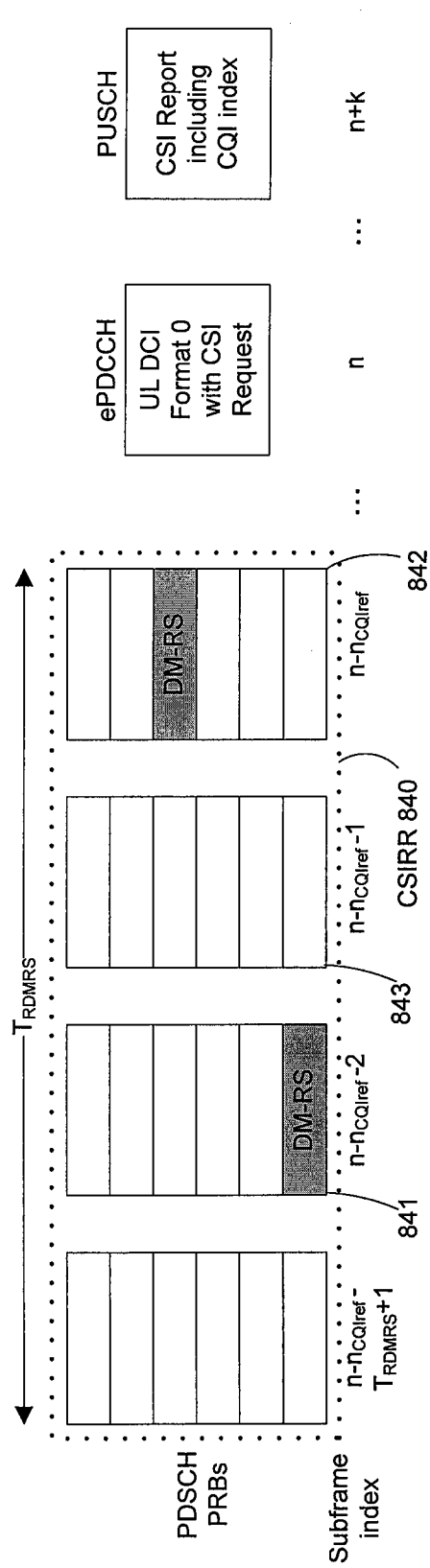


Fig. 8E

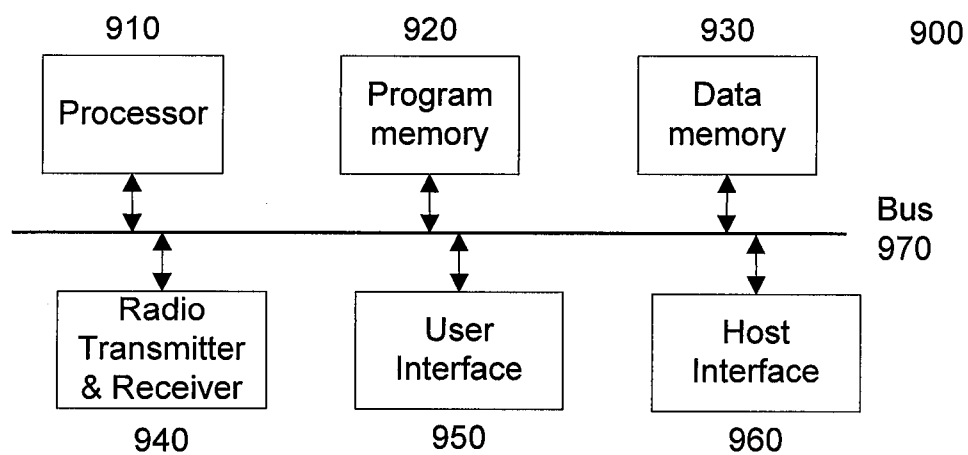


Fig. 9

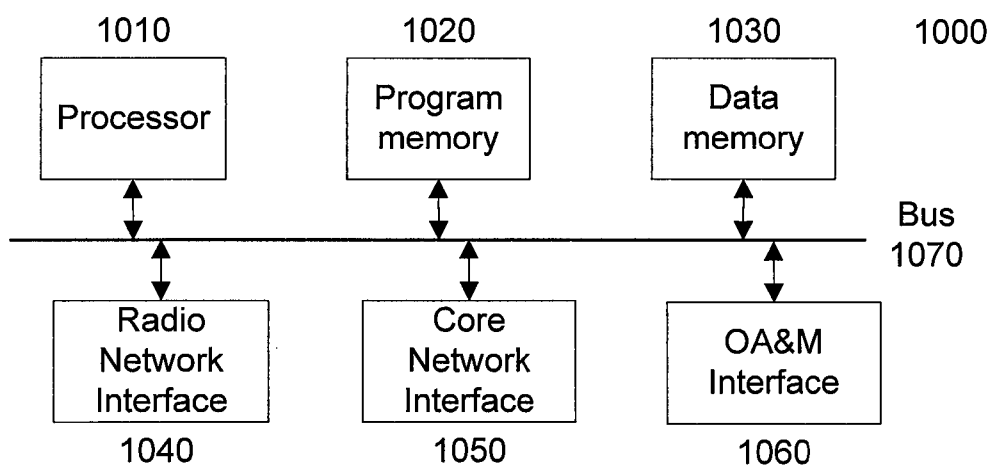


Fig. 10

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2012/087155

A. CLASSIFICATION OF SUBJECT MATTER

H04W 24/10 (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

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)

CPRSABS, CNTXT, CNKI, VEN, WOTXT, GOOGLE: PHY, PDSCH, ePDCCH, PDCCH, CQI, PRB, CSI, DMRS, reduced, overhead, pattern

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	CN 102378275 A (ALCATEL-LUCENT SHANGHAI BELL CO., LTD.), 14 March 2012 (14.03.2012), description, paragraphs 11, 48-55 and 101-107	1-5, 16-21, 32-38, 49-54, 65-71, 82-87, 98-104, 115-120 and 131-132
A	CN 101686554 A (ZTE CORP.), 31 March 2010 (31.03.2010), the whole document	1-132
A	CN 102598760 A (PANASONIC CORP.), 18 July 2012 (18.07.2012), the whole document	1-132

☐ 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 06 September 2013 (06.09.2013)	Date of mailing of the international search report 26 Sep. 2013 (26.09.2013)
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 LI, Qian Telephone No. (86-10)62411283

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CN2012/087155

Patent Documents referred in the Report	Publication Date	Patent Family	Publication Date
CN 102378275 A	14.03.2012	WO 2012020312 A2	16.02.2012
		WO 2012020312 A3	28.06.2012
CN 101686554 A	31.03.2010	CN 101686554 B	19.12.2012
CN 102598760 A	18.07.2012	KR 20120039694 A	25.04.2012
		US 2012147831 A1	14.06.2012
		AU 2010281026 A1	23.02.2012
		WO 2011015331 A1	10.02.2011
		EP 2282576 A1	09.02.2011
		AU 2010281026 A2	23.02.2012
		IN 201200209 P2	30.11.2012
		VN 30631 A	27.08.2012
		EP 2462759 A1	13.06.2012
		JP 2013501441 A	10.01.2013