(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
13 November 2014 (13.11.2014)

WIPO | PCT

(10) International Publication Number
WO 2014/181551 Al

(51) International Patent Classification:
H04W 24/10 (2009.01) *H04W 72/04* (2009.01)

(21) International Application Number:
PCT/JP20 14/002461

(22) International Filing Date:
9 May 2014 (09.05.2014)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
13/891,162 9 May 20 13 (09.05.2013) US

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(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, IR, IS, JP, KE, KG, 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, SA, 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, KM, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:

— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.1 7(H))*

— *as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.1 7(in))*

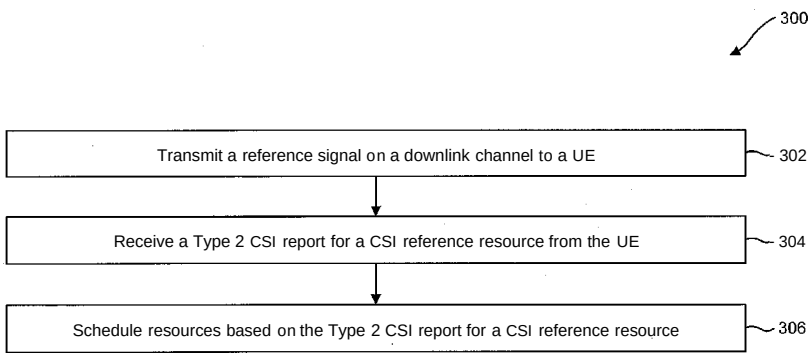
Published:

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

WO 2014/181551 A1

(54) Title: CHANNEL STATE MEASUREMENT AND REPORTING

FIG. 3



(57) Abstract: A method for reporting uplink control information (UCI) on a user equipment (UE) is described. A Type 2 channel state information (CSI) report is generated for a CSI reference resource. The Type 2 CSI report is sent to a base station. The Type 2 CSI report is computed from a channel measurement based on a non-zero power reference signal on a single subframe within a configured CSI-RS resource associated with a CSI process.

Description

Title of Invention: CHANNEL STATE MEASUREMENT AND REPORTING

Technical Field

[0001] The present invention relates generally to wireless communications and wireless communications-related technology. More specifically, the present invention relates to systems and methods for channel state measurement and reporting.

Background Art

[0002] Wireless communication devices have become smaller and more powerful in order to meet consumer needs and to improve portability and convenience. Consumers have become dependent upon wireless communication devices and have come to expect reliable service, expanded areas of coverage and increased functionality. A wireless communication system may provide communication for a number of cells, each of which may be serviced by a base station. A base station may be a fixed station that communicates with mobile stations.

[0003] Various signal processing techniques may be used in wireless communication systems to improve efficiency and quality of wireless communication. Benefits may be realized by improved methods for reporting uplink control information (UCI) by a wireless communication device.

Summary of Invention

[0004] An aspect of the invention provides a method for receiving uplink control information (UCI), comprising: receiving a Type 2 channel state information (CSI) report for a CSI reference resource from a user equipment (UE), wherein the Type 2 CSI report is computed from a channel measurement based on a non-zero power reference signal on a single subframe within a configured CSI-RS resource associated with a CSI process.

[0005] Another aspect of the invention provides a method for reporting uplink control information (UCI), comprising: generating a Type 2 channel state information (CSI) report for a CSI reference resource; and sending the Type 2 CSI report to a base station, wherein the Type 2 CSI report is computed from a channel measurement based on a non-zero power reference signal on a single subframe within a configured CSI-RS resource associated with a CSI process.

[0006] Another aspect of the invention provides a base station configured for receiving uplink control information (UCI), comprising:a processor; memory in electronic communication with the processor; and instructions stored in the memory, the instructions being executable to: receive a Type 2 channel state information (CSI) report for a CSI

reference resource from a user equipment (UE), wherein the Type 2 CSI report is computed from a channel measurement based on a non-zero power reference signal on a single subframe within a configured CSI-RS resource associated with a CSI process.

[0007] Another aspect of the invention provides a user equipment (UE) configured for reporting uplink control information (UCI), comprising: a processor; memory in electronic communication with the processor; andinstructions stored in the memory, the instructions being executable to: generate a Type 2 channel state information (CSI) report for a CSI reference resource; and send the Type 2 CSI report to a base station, wherein the Type 2 CSI report is computed from a channel measurement based on a non-zero power reference signal on a single subframe within a configured CSI-RS resource associated with a CSI process.

Brief Description of Drawings

[0008] [fig.l]Figure 1 is a block diagram illustrating a wireless communication system that utilizes Type 2 CSI reporting;

[fig.2]Figure 2 is a flow diagram of a method for Type 2 measurement/reporting;

[fig.3]Figure 3 is a flow diagram of another method for Type 2 measurement/reporting;

[fig.4]Figure 4 is a block diagram illustrating the layers used by a user equipment (UE);

[fig.5]Figure 5 illustrates the slot and subframe structure for Frame Structure Type 2;

[fig.6]Figure 6 illustrates the procedures for determining the CSI reference resources for periodic Type 2 CSI measurement/reporting;

[fig.7]Figure 7 illustrates the procedures for determining the CSI reference resources for aperiodic Type 2 CSI measurement/reporting;

[fig.8]Figure 8 illustrates various components that may be utilized in a user equipment (UE); and

[fig.9]Figure 9 illustrates various components that may be utilized in an eNB.

Description of Embodiments

[0009] A method for receiving uplink control information (UCI) is described. A Type 2 channel state information (CSI) report for a CSI reference resource is received from a user equipment (UE). The Type 2 CSI report is computed from a channel measurement based on a non-zero power reference signal on a single subframe within a configured CSI-RS resource associated with a CSI process.

[0010] The single subframe may be a subframe of the CSI reference resource. The CSI reference resource for the Type 2 CSI report reported in uplink subframe n may be defined by a valid downlink subframe n-nCQI_ref. The valid downlink subframe may be in a set of subframes for a channel measurement for the Type 2 CSI report. The valid downlink subframe may be in a set of subframes in which the non-zero power

reference signal is configured.

[001 1] The valid downlink subframe may be in a set of subframes for Type 2 channel measurement if the set of subframes for Type 2 channel measurement is configured. The valid downlink subframe may be in a set of subframes in which the non-zero power reference signal is configured if the set of subframes for Type 2 channel measurement is not configured. The Type 2 CSI report may be a periodic CSI report. Type 2 CSI reporting may be configured in a CSI process configuration. The Type 2 CSI report may also be an aperiodic CSI report. A field in a downlink control information (DCI) may specify whether Type 2 aperiodic CSI reporting is triggered. The Type 2 CSI report may correspond to a configured CSI process.

[0012] A method for reporting uplink control information (UCI) is also described. A Type 2 channel state information (CSI) report for a CSI reference resource is generated. The Type 2 CSI report is sent to a base station. The Type 2 CSI report is computed from a channel measurement based on a non-zero power reference signal on a single subframe within a configured CSI-RS resource associated with a CSI process.

[0013] A base station configured for receiving uplink control information (UCI) is described. The base station includes a processor, memory in electronic communication with the processor and instructions stored in the memory. The instructions are executable to receive a Type 2 channel state information (CSI) report for a CSI reference resource from a user equipment (UE). The Type 2 CSI report is computed from a channel measurement based on a non-zero power reference signal on a single subframe within a configured CSI-RS resource associated with a CSI process.

[0014] A user equipment (UE) configured for reporting uplink control information (UCI) is also described. The UE includes a processor, memory in electronic communication with the processor and instructions stored in the memory. The instructions are executable to generate a Type 2 channel state information (CSI) report for a CSI reference resource. The instructions are also executable to send the Type 2 CSI report to a base station. The Type 2 CSI report is computed from a channel measurement based on a non-zero power reference signal on a single subframe within a configured CSI-RS resource associated with a CSI process.

[0015] The 3rd Generation Partnership Project, also referred to as "3GPP, " is a collaboration agreement that aims to define globally applicable technical specifications and technical reports for third and fourth generation wireless communication systems. The 3GPP may define specifications for the next generation mobile networks, systems and devices.

[0016] 3GPP Long Term Evolution (LTE) is the name given to a project to improve the Universal Mobile Telecommunications System (UMTS) mobile phone or device standard to cope with future requirements. In one aspect, UMTS has been modified to

provide support and specification for the Evolved Universal Terrestrial Radio Access (E-UTRA) and Evolved Universal Terrestrial Radio Access Network (E-UTRAN).

[0017] At least some aspects of the systems and methods disclosed herein may be described in relation to the 3GPP LTE and LTE-Advanced standards (e.g., Release-8, Release-9, Release- 10 and Release- 11). However, the scope of the present disclosure should not be limited in this regard. At least some aspects of the systems and methods disclosed herein may be utilized in other types of wireless communication systems.

[0018] The term "simultaneous" may be used herein to denote a situation where two or more events occur in overlapping time frames. In other words, two "simultaneous" events may overlap in time to some extent, but are not necessarily of the same duration. Furthermore, simultaneous events may or may not begin or end at the same time.

[0019] Figure 1 is a block diagram illustrating a wireless communication system 100 that utilizes Type 2 CSI reporting. Downlink and uplink transmissions are organized into radio frames. Two radio frame structures are supported: Type 1 (applicable to frequency division duplex (FDD)) and Type 2 (applicable to time division duplex (TDD)). Type 2 CSI reporting is defined as channel measurements for a CSI report that are based on only either or both of a channel measurement in a single subframe and an interference measurement in a single subframe. The details describing Type 2 CSI reporting are given below. In contrast, Type 1 CSI reporting is defined as channel measurements for a CSI report that are based on unrestricted observations or measurements in time and/or frequency. Thus, Type 1 CSI reporting may provide a CSI report that includes channel measurements for the reference signal over multiple contiguous or non-contiguous subframes.

[0020] It is possible that some of the subframes measured for Type 1 CSI reporting may not carry a reference signal. If a UE 104 measures the channel in multiple subframes, some of which do not carry a reference signal, and then includes both measurements in generating a report (such as a weighted average of measurements), the generated report may include erroneous measurements. Thus, there is a need for Type 2 CSI reporting to provide more accurate and reliable CSI reports to an eNB 102. Even though a UE may not know whether a subframe is an uplink, downlink or special subframe, the resulting report may be useful to the eNB, because the eNB is aware of whether a CSI report is generated based on a measurement on a downlink subframe, an uplink subframe or a special subframe.

[0021] An eNB 102 may be in wireless communication with one or more user equipments (UEs) 104. An eNB 102 may also be referred to as an access point, a Node B, an evolved Node B, a base station or some other terminology. Likewise, a user equipment (UE) 104 may also be referred to as a mobile station, a subscriber station, an access terminal, a remote station, a user terminal, a terminal, a handset, a subscriber unit, a

wireless communication device, or some other terminology.

[0022] Communication between a user equipment (UE) 104 and an eNB 102 may be accomplished using transmissions over a wireless link, including an uplink and a downlink. The uplink refers to communications sent from a user equipment (UE) 104 to an eNB 102. The downlink refers to communications sent from an eNB 102 to a user equipment (UE) 104. The communication link may be established using a single-input and single-output (SISO), multiple-input and single-output (MISO), single-input and multiple-output (SIMO) or a multiple-input and multiple-output (MIMO) system. A MIMO system may include both a transmitter and a receiver equipped with multiple transmit and receive antennas. Thus, an eNB 102 may have multiple antennas 1lOa-n and a user equipment (UE) 104 may have multiple antennas 112a-n. In this way, the eNB 102 and the user equipment (UE) 104 may each operate as either a transmitter or a receiver in a MIMO system. One benefit of a MIMO system is improved performance if the additional dimensionalities created by the multiple transmit and receive antennas are utilized.

[0023] The user equipment (UE) 104 communicates with an eNB 102 using one or more antenna ports, which may be realized by one or more physical antennas 112a-n. The user equipment (UE) 104 may include a transceiver 132, a decoder 124, an encoder 128 and an operations module 116. The transceiver 132 may include a receiver 133 and a transmitter 135. The receiver 133 may receive signals from the eNB 102 using one or more antennas 112a-n. For example, the receiver 133 may receive and demodulate received signals using a demodulator 134. The transmitter 135 may transmit signals to the eNB 102 using one or more antenna ports, which may be realized by one or more physical antennas 112a-n. For example, the transmitter 135 may modulate signals using a modulator 136 and transmit the modulated signals.

[0024] The receiver 133 may provide a demodulated signal to the decoder 124. The user equipment (UE) 104 may use the decoder 124 to decode signals and make downlink decoding results 126. The downlink decoding results 126 may indicate whether data was received correctly. For example, the downlink decoding results 126 may indicate whether a packet was correctly or erroneously received (i.e., positive acknowledgement, negative acknowledgement or discontinuous transmission (no signal)).

[0025] The operations module 116 may be a software and/or hardware module used to control user equipment (UE) 104 communications. For example, the operations module 116 may determine when the user equipment (UE) 104 requires resources to communicate with an eNB 102.

[0026] In 3rd Generation Partnership Project (3GPP) Long Term Evolution (LTE) - Advanced, additional control feedback will have to be sent on control channels to accommodate MIMO and carrier aggregation. Carrier aggregation refers to transmitting

data on multiple component carriers (CCs) (or cells) that are contiguously or separately located. In carrier aggregation (CA), only one uplink component carrier (CC) (or cell) (i.e., PCC or PCell) may be utilized for transmission using the physical uplink control channel (PUCCH). A component carrier (CC) is a carrier frequency to which cells belong.

[0027] To select a suitable modulation scheme and channel coding rate, the transmitter needs information about the radio-link between the transmitter and the receiver (i.e., channel state information (CSI)). The CSI may also be used for channel-dependent scheduling. In an FDD system, only the receiver can accurately and reliably estimate the radio-link channel condition. For downlink transmissions, the base station (e.g., an eNode B, eNB 102, transmission point) sends a signal to the UE 104 that includes time and frequency resources as well as sequence information, antenna port information and transmit power. In release 11 of the 3GPP specification, one reference signal that is used for channel measurement is the CSI-RS.

[0028] The user equipment (UE) 104 may transmit uplink control information (UCI) to an eNB 102 on the uplink. The uplink control information (UCI) may include one or more channel state information (CSI) reports. A CSI report may be a Type 1 CSI report 120 or a Type 2 CSI report 122. A channel state information (CSI) report may include a channel quality indicator (CQI), a precoder matrix indicator (PMI), and/or a rank indicator (RI). The rank indicator (RI) provides a recommendation on the number of spatial layers that should preferably be used for downlink transmission. The precoder matrix indicator (PMI) indicates the precoder matrix that should be used for downlink transmission. The precoder matrix may be determined by considering the number of supported layers indicated in the rank indicator (RI). The CQI indicates the highest modulation and coding scheme (MCS) that can be used for transmission of the PDSCH with a block error rate no larger than 10%.

[0029] A CSI report may be transmitted to an eNB 102 using aperiodic reporting and/or periodic reporting. Aperiodic CSI reports are sent by a UE 104 when explicitly requested (by a field in an uplink DCI (downlink control information)). Periodic CSI reports are configured by the eNB 102 (which may also be referred to as the network) to be sent by the UE 104 periodically.

[0030] The CQI indices and their interpretations are given in Table 1 below.

[0031]

[Table 1]

CQI index	Modulation	Code rate x 1024	Efficiency
0	out of range		
1	QPSK	78	0.1523
2	QPSK	120	0.2344
3	QPSK	193	0.3770
4	QPSK	308	0.6016
5	QPSK	449	0.8770
6	QPSK	602	1.1758
7	16QAM	378	1.4766
8	16QAM	490	1.9141
9	16QAM	616	2.4063
10	64QAM	466	2.7305
11	64QAM	567	3.3223
12	64QAM	666	3.9023
13	64QAM	772	4.5234
14	64QAM	873	5.1152
15	64QAM	948	5.5547

Table 1

[0032] Based on an unrestricted observation interval in time and frequency, the UE 104 may be required to derive, for each CQI value reported in uplink subframe n, the highest CQI index between 1 and 15 which satisfies the condition that a single physical downlink shared channel (PDSCH) transport block with a combination of modulation scheme and transport block size corresponding to the CQI index and occupying a group of downlink physical resource blocks (termed the CSI reference resource) could be received with a transport block error probability not exceeding 0.1. If CQI index 1 does not satisfy this condition, the UE 104 may instead use CQI index 0.

[0033] A UE 104 in transmission mode 10 can be configured with one or more CSI processes per serving cell by higher layers 114. Each CSI process may be associated with a CSI-RS resource and a CSI interference measurement (CSI-IM) resource. A CSI reported by the UE 104 corresponds to a CSI process configured by higher layers 114.

[0034] In the frequency domain, the CSI reference resource is defined by the group of downlink physical resource blocks corresponding to the band to which the CQI value relates. In the time domain, for a UE 104 configured in transmission mode 1-9 or in transmission mode 10 with a single configured CSI process for the serving cell, the CSI reference resource is defined by a single downlink subframe 'n-nCQI_ref . For

periodic CSI reporting, 'nCQI_ref is the smallest value greater than or equal to 4 such that subframe 'n-nCQI_ref corresponds to a valid downlink subframe. For aperiodic CSI reporting, 'nCQI_ref is such that the reference resource is in the same valid downlink subframe as the corresponding CSI request in an uplink DCI format. For aperiodic CSI reporting, 'nCQI_ref is equal to 4 and the downlink subframe 'n-nCQI_ref corresponds to a valid downlink subframe, where the downlink subframe 'n-nCQI_ref is received after the subframe with the corresponding CSI request in a random access response grant.

[0035] For a UE 104 configured in transmission mode 10 with multiple configured CSI processes for the serving cell, the CSI reference resource for a given CSI process may be defined by a single downlink subframe 'n-nCQI_ref . For FDD and periodic or aperiodic CSI reporting, 'nCQI_ref is the smallest value greater than or equal to 5 such that the downlink subframe 'n-nCQI_ref corresponds to a valid downlink subframe. For FDD and aperiodic CSI reporting, 'nCQI_ref is equal to 5 and the downlink subframe 'n-nCQI_ref corresponds to a valid downlink subframe, where the downlink subframe 'n-nCQI_ref is received after the subframe with the corresponding CSI request in a random access response grant.

[0036] For TDD with two or three configured CSI processes and aperiodic or periodic CSI reporting, 'nCQI_ref is the smallest value greater than or equal to 4 such that the downlink subframe 'n-nCQI_ref corresponds to a valid downlink subframe. For TDD with two or three configured CSI processes and aperiodic reporting, 'nCQI_ref is equal to 4 and the downlink subframe 'n-nCQI_ref corresponds to a valid downlink subframe, where the downlink subframe 'n-nCQI_ref is received after the subframe with the corresponding CSI request in a random access response grant.

[0037] For TDD with four configured CSI processes and periodic or aperiodic CSI reporting, 'nCQI_ref is the smallest value greater than or equal to 4 such that the downlink subframe 'n-nCQI_ref corresponds to a valid downlink subframe. For TDD with four configured CSI processes and aperiodic CSI reporting, 'nCQI_ref is equal to 5 and the downlink subframe 'n-nCQI_ref corresponds to a valid downlink subframe, where the downlink subframe 'n-nCQI_ref is received after the subframe with the corresponding CSI request in a random access response grant.

[0038] Upon decoding in subframe n either an uplink DCI (downlink control information) or a random access response grant, the UE 104 may perform aperiodic CSI reporting using the physical uplink shared channel (PUSCH) in subframe n + k on a serving cell, if the respective CSI request field is set to trigger a report and is not reserved. If the CSI request field is 1 bit, the CSI request field is set to 1 and the UE 104 is configured in transmission mode 1-9, a report is triggered for the serving cell. If the CSI request field is 1 bit and the UE 104 is configured in transmission mode 10, a report is

triggered for a set of CSI process(es) for the serving cell corresponding to the higher layer 114 configured set of CSI process(es) associated with the value of the CSI request field in Table 1 below.

[0039] [Table 2]

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

Table 2

[0040] If the CSI request field size is 2 bits and the UE 104 is configured in transmission mode 1-9 for all serving cells, a report is triggered according to the value in Table 2 above corresponding to aperiodic CSI reporting. If the CSI request field size is 2 bits and the UE 104 is configured in transmission mode 10 for at least one serving cell, a report is triggered according to the value in Table 3 below corresponding to aperiodic CSI reporting. For a given serving cell, if the UE 104 is configured in transmission modes 1-9, the "CSI process" in Table 3 refers to the aperiodic CSI configured for the UE 104 on the given serving cell. A UE 104 is not expected to be configured by higher layers 114 with more than 5 CSI processes in each of the 1st and 2nd set of CSI process(es) in Table 3.

[0041] [Table 3]

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

Table 3

[0042] When the CSI request field from an uplink DCI format is set to trigger a report, for FDD k=4, and for TDD UL/DL configuration 1-6, k is given from Table 4 below. TDD UL/DL configuration is a configuration that indicates whether a subframe is uplink, downlink or a special subframe. For TDD UL/DL configuration 0, if the most significant bit (MSB) of the uplink index is set to 1 and the least significant bit (LSB) of the uplink index is set to 0, k is given in Table 5 below.

[0043] [Table 4]

TDD UL/DL Configuration	subframe number *n*									
	0	1	2	3	4	5	6	7	8	9
0	4	6				4	6			
1		6			4		6			4
2				4					4	
3	4								4	4
4									4	4
5									4	
6	7	7				7	7			5

Table 4

[0044] [Table 5]

TDD UL/DL Configuration	subframe number *n*									
	0	1	2	3	4	5	6	7	8	9
0	9	6				9	6			
1		2			3		2			3
6	5	5				6	6			8

Table 5

[0045] If the most significant bit (MSB) of the uplink index is set to 0 and the least significant bit (LSB) of the uplink index is set to 1, k is equal to 7. If both the most significant bit (MSB) and the least significant bit (LSB) of the uplink index are set to 1, k is given in Table 4. For TDD, if a UE 104 is configured with more than one serving cell and if the UL/DL configurations of at least two serving cells are different, the TDD UL/DL Configuration given in Table 4 refers to the UL-reference UL/DL configuration.

[0046] When the CSI request field from a Random Access Response Grant is set to trigger a report and is not reserved, 'k' is equal to 'k_1' if the uplink delay field is set to zero. The UE 104 may postpone aperiodic CSI reporting to the next available uplink subframe if the UL delay field is set to 1.

[0047] A UE 104 may be semi-statically configured by higher layers 114 to periodically feedback different CSI components (CQI, PMI, PTI, and/or RI) on the physical uplink control channel (PUCCH). A UE 104 in transmission mode 10 can be configured by higher layers 114 for multiple periodic CSI reports corresponding to one or more CSI processes per serving cell on the PUCCH.

[0048] The information element CQI-ReportConfig given below is used to specify the CQI reporting configuration.

```
CQI-ReportConfig-r10 ::=SEQUENCE {
    cqi-ReportAperiodic-r10              CQI-ReportAperiodic-r10          OPTIONAL,   -
- Need ON
    nomPDSCH-RS-EPRE-Offset                  INTEGER (-1..6),
    cqi-ReportPeriodic-r10               CQI-ReportPeriodic-r10           OPTIONAL,   -
- Need ON
    pmi-RI-Report-r9                 ENUMERATED {setup}                   OPTIONAL,   -
- Cond PMIRIPCell
    csi-SubframePatternConfig-r10        CHOICE {
        release                          NULL,
        setup                        SEQUENCE {
            csi-MeasSubframeSet1 -r1 0          MeasSubframePattern-r1 0,
            csi-MeasSubframeSet2-r1 0           MeasSubframePattern-r1 0
        }
    }                                                                     OPTIONAL    - Need
ON
}
```

CQI-ReportConfig Information Element

[0049] The "MeasSubframePattern-rlO" is a bit map of size 20, 40, 60, or 70 bits. Each bit in the bit map represents a subframe. The value of each bit determines whether that subframe belongs to the measurement set or not. For example, 1 may indicate inclusion and 0 may indicate exclusion.

[0050] The uplink control information (UCI) (such as a CSI report) may be generated by an uplink control information (UCI) reporting module 118 and transferred to an encoder 128. The encoder 128 may then provide the uplink control information (UCI) to the transmitter 135.

[0051] The time and frequency resources may be quantized to create a grid known as the time-frequency grid. In the time domain, 10 milliseconds (ms) is referred to as one radio frame. One radio frame may include 10 subframes, each with a duration of 1 ms, which is the duration of transmission in the uplink and/or downlink. Every subframe may be divided into two slots, each with a duration of 0.5 ms. Each slot may be divided into 7 symbols. The frequency domain may be divided into bands with a 15 kilohertz (kHz) width, referred to as a subcarrier. One resource element has a duration of one symbol in the time domain and the bandwidth of one subcarrier in the frequency domain.

[0052] The minimum amount of resource that can be allocated for the transmission of information in the uplink or downlink in any given subframe is two resource blocks (RBs), with one RB at each slot. One RB has a duration of 0.5 ms (7 symbols or one slot) in the time domain and a bandwidth of 12 subcarriers (180 kHz) in the frequency domain. At any given subframe, a maximum of two RBs (one RB at each slot) can be used by a given user equipment (UE) 104 for the transmission of uplink control information (UCI) in the physical uplink control channel (PUCCH).

[0053] In LTE Release-8, only one uplink component carrier (CC) 106 or serving cell 107

and one downlink component carrier (CC) 108 or serving cell 107 can be used for transmission to and reception from each user equipment (UE) 104.

[0054] In 3GPP Long Term Evolution (LTE) Release-10 (LTE-A or Advanced EUTRAN), carrier aggregation was introduced. Carrier aggregation may also be referred to as cell aggregation. Carrier aggregation is supported in both the uplink and the downlink with up to five component carriers (CCs) 106, 108. Each component carrier (CC) 106, 108 or cell 107 may have a transmission bandwidth of up to 110 resource blocks (i.e., up to 20 megahertz (MHz)). In carrier aggregation, two or more component carriers (CCs) 106, 108 are aggregated to support wider transmission bandwidths up to one hundred megahertz (MHz). A user equipment (UE) 104 may simultaneously receive and/or transmit on one or multiple component carriers (CCs) 106, 108, depending on the capabilities of the user equipment (UE) 104.

[0055] A user equipment (UE) 104 may communicate with an eNB 102 using multiple component carriers (CCs) 108 at the same time. For example, a user equipment (UE) 104 may communicate with an eNB 102 using a primary cell (PCell) 107a while simultaneously communicating with the eNB 102 using secondary cell(s) (SCell) 107b. Similarly, an eNB 102 may communicate with a user equipment (UE) 104 using multiple component carriers (CCs) 108 at the same time. For example, an eNB 102 may communicate with a user equipment (UE) 104 using a primary cell (PCell) 107a while simultaneously communicating with the user equipment (UE) 104 using secondary cell(s) (SCell) 107b.

[0056] An eNB 102 may include a transceiver 137 that includes a receiver 138 and a transmitter 140. An eNB 102 may additionally include a decoder 142, an encoder 144 and an operations module 146. An eNB 102 may receive uplink control information (UCI) 121 using its one or more antenna ports, which may be realized by one or more physical antennas 110a-n, and its receiver 138. The receiver 138 may use the demodulator 139 to demodulate the uplink control information (UCI) 121.

[0057] The decoder 142 may include an uplink control information (UCI) receiving module 143. An eNB 102 may use the uplink control information (UCI) receiving module 143 to decode and interpret the uplink control information (UCI) 121 received by the eNB 102. The eNB 102 may use the decoded uplink control information (UCI) 121 to perform certain operations, such as retransmit one or more packets based on scheduled communication resources for the user equipment (UE) 104.

[0058] The operations module 146 may include a retransmission module 147 and a scheduling module 148. The retransmission module 147 may determine which packets to retransmit (if any) based on the uplink control information (UCI) 121. The scheduling module 148 may be used by the eNB 102 to schedule communication resources (e.g., bandwidth, time slots, frequency channels, spatial channels, etc.). The

scheduling module 148 may use the uplink control information (UCI) 121 to determine whether (and when) to schedule communication resources for the user equipment (UE) 104.

[0059] The operations module 146 may provide data 145 to the encoder 144. For example, the data 145 may include packets for retransmission and/or a scheduling grant for the user equipment (UE) 104. The encoder 144 may encode the data 145, which may then be provided to the transmitter 140. The transmitter 140 may modulate the encoded data using the modulator 141. The transmitter 140 may transmit the modulated data to the user equipment (UE) 104 using one or more antenna ports, which may be realized by the one or more physical antennas 1lOa-n.

[0060] When carrier aggregation is configured, a user equipment (UE) 104 may have only one radio resource control (RRC) connection with the network. At the radio resource control (RRC) connection establishment/re-establishment/handover, one serving cell 107 (i.e., the primary cell (PCell) 107a) provides the non-access stratum (NAS) mobility information (e.g., Tracking Area Identity (TAI)) and the security input.

[0061] In the downlink, the component carrier (CC) 108 corresponding to the primary cell (PCell) 107a is the downlink primary component carrier (DL PCC) 108a. In the uplink, the component carrier (CC) 106 corresponding to the primary cell (PCell) 107a is the uplink primary component carrier (UL PCC) 106a. Depending on the capabilities of the user equipment (UE) 104, one or more secondary component carriers (SCC) 106b, 108b or secondary cells (SCell) 107b may be configured to form a set of serving cells with the primary cell (PCell) 107a. In the downlink, the component carrier (CC) 108 corresponding to the secondary cell (SCell) 107b is the downlink secondary component carrier (DL SCC) 108b. In the uplink, the component carrier (CC) 106 corresponding to the secondary cell (SCell) 107b is the uplink secondary component carrier (UL SCC) 106b. The number of downlink component carriers (CCs) 108 may be different from the number of uplink component carriers (CCs) 106 because multiple cells may share one uplink component carrier (CC) 106.

[0062] If carrier aggregation is configured, a user equipment (UE) 104 may have multiple serving cells: a primary cell (PCell) 107a and one or more secondary cells (SCell) 107b. From a network perspective, a serving cell 107 may be used as the primary cell (PCell) 107a by one user equipment (UE) 104 and used as a secondary cell (SCell) 107b by another user equipment (UE) 104. If carrier aggregation is not configured, a primary cell (PCell) 107a operates a single serving cell. There may be one or more secondary cells (SCell) 107b in addition to the primary cell (PCell) 107a if carrier aggregation is configured. One benefit of using carrier aggregation is that additional downlink and/or uplink data may be transmitted. As a result of the additional downlink data, additional uplink control information (UCI) may be needed.

[0063] A UE 104 is in RRC_CONNECTED state when an RRC (radio resource control) connection has been established. If no RRC connection has been established, the UE 104 is in RRCJDLE state.

[0064] A number of spatial channels may be available on each serving cell 107 by using multiple antenna ports at a transmitter and a receiver. Therefore, multiple codewords (up to two codewords) may be transmitted simultaneously.

[0065] A channel state information (CSI) report may be used to inform the eNB 102 to adjust the transmission rate (modulation scheme and coding rate) dynamically based on the existing channel conditions at the user equipment (UE) 104. For example, if a channel state information (CSI) report indicates a good channel quality at the user equipment (UE) 104, the eNB 102 may select a higher order modulation and coding rate, thereby achieving a higher transmission rate for the downlink transmission of data on the physical downlink shared channel (PDSCH). If a channel state information (CSI) report indicates a poor channel quality at the user equipment (UE) 104, the eNB 102 may select a lower order modulation and coding rate, thereby achieving higher reliability for the transmission.

[0066] In Type 1 CSI measurement/reporting (the existing measurement used in Release 11 of the 3GPP specification), a UE 104 in transmission mode 10 may derive the channel measurements for computing the CQI value reported in uplink subframe n (that corresponds to a CSI process) based on only the non-zero power CSI-RS within a configured CSI-RS resource associated with the CSI process. However, it is possible that subframe n carries the CSI-RS in radio frame k and does not carry the CSI-RS in radio frame k + m. If the UE 104 measures the channel in both subframes and includes both measurements in generating a report (such as a weighted averaging of measurements), then the generated report includes erroneous measurements.

[0067] The use of Type 2 CSI measurement/reporting provides meaningful and reliable reports to the eNB 102 regardless of whether the CSI-RS is transmitted on the subframe corresponding to the CSI report. Furthermore, since the eNB 102 schedules the transmission of the CSI-RS, the eNB 102 is aware of whether the reported measurement is a valid channel state measurement or simply an interference measurement.

[0068] A UE 104 may be configured with multiple CSI processes. A UE 104 in transmission mode 10 can be configured with one or more CSI processes per serving cell by higher layers 114. Each CSI process may be associated with a CSI-RS resource (including time and frequency resources allocated for transmission of CSI-RS, a CSI-RS sequence, an antenna port at which the CSI-RS is transmitted and the transmit power of the CSI-RS) and with a CSI-interference measurement (CSI-IM) resource (including the time and frequency resources on which the UE should perform interference measurement). Each CSI process is also associated with a reporting configuration which

includes configurations for periodic and aperiodic reporting such as the CQI format (sub-band or wideband CQI), the resource indices (SI or S2), the periodicity of periodic reports, the subframe offset associated with the periodic reports, etc. For simplicity, only one CSI process is considered, with the configured CSI resource and periodic and aperiodic CSI reporting configurations.

[0069] In one configuration, the same CSI process may be used for both Type 1 measurement/reporting and Type 2 measurement/reporting. The measurement configuration may be semi-static, dynamic or periodic. If the measurement configuration is semi-static, this enables Type 2 measurement/reporting in a CSI process. A set of subframes for Type 2 channel measurement may also be configured.

[0070] If the measurement configuration is dynamic, triggering may be used for Type 2 aperiodic CSI reporting. In this configuration, a field (which may be one bit or two bits) in the uplink DCI (e.g., DCI format 0 or DCI format 4) may specify whether Type 2 aperiodic reporting is triggered.

[0071] Downlink control information may be sent in packets of pre-specified length, known as DCI. The DCI may be carried by the PDCCH or the enhanced physical downlink control channel (EPDCCH). DCIs may carry different information. For example, one DCI may be used to inform UEs 104 about downlink resource allocation and another DCI may be used to inform a specific UE 104 about uplink resource allocation. Depending on the functionality of a DCI, different DCIs may have different lengths. Different DCIs may be distinguished by the way they are formatted and coded, which is referred to as the DCI format. A DCI may be used to transport downlink or uplink scheduling information, requests for periodic CQI reports, notifications of multicast control channel (MCCH) changes or uplink power control commands for one cell and one Radio Network Temporary Identifier (RNTI). The RNTI may be implicitly encoded in the cyclic redundancy check (CRC).

[0072] An uplink DCI allocates resources for uplink transmission. An uplink DCI may also be referred to as an uplink grant (e.g., DCI format 0/4). A downlink DCI allocates resources for downlink transmission. A downlink DCI may also be referred to as a downlink grant (e.g., DCI format 1/1A/2/2A/2B/2C/2D).

[0073] A bit field in the DCI indicates which reports of a type (i.e., Type 1 and/or Type 2) should be included in the UCI. The bit field may include multiple bits (e.g., 2 bits for a set of CSI reports corresponding to one or more CSI processes, 1 bit for a type 2 trigger, etc.). If Type 1 aperiodic CSI reporting is triggered, the UE 104 may be required to include a Type 1 CSI report 120 in the UCI. If Type 2 aperiodic CSI reporting is triggered, the UE 104 may be required to include a specified number of Type 2 CSI reports 122 (predefined or signaled by RRC) and a Type 1 CSI report 120 for each CSI process within the set of CSI processes with corresponding CSI reports

include in the UCI.

[0074] If the measurement configuration is periodic, the UE 104 may periodically generate and send CSI reports to the eNB 102. For Type 1 periodic CSI reporting, the periodicity and relative reporting offset for the subframe set S1 and the periodicity and relative reporting offset for the subframe set S2 are configured for each CSI process. For Type 2 periodic CSI reporting, additional periodicity and relative reporting offset is configured for each CSI process.

[0075] In another configuration, two CSI processes are used for Type 1 measurement/reporting and Type 2 measurement/reporting. One CSI process may be dedicated for Type 1 CSI reporting and another CSI process may be dedicated for Type 2 CSI reporting. If the measurement configuration is semi-static, a CSI process configuration may include a configuration of either Type 1 CSI reporting or Type 2 CSI reporting. Furthermore, a set of subframes for Type 2 channel measurement may be configured.

[0076] The triggering for Type 2 aperiodic CSI reporting is included in a DCI. A bit field in the DCI may indicate which CSI processes should be included in the UCI. If a triggered CSI process is for Type 2 aperiodic CSI reporting, the UE 104 may be required to include X numbers of Type 2 reports (X may be predefined or signaled by the RRC).

[0077] For CSI processes for Type 1 periodic CSI reporting, the periodicity and relative reporting offset for the subframe set 1 (SI) and the periodicity and relative reporting offset for subframe set 2 (S2) are configured. For CSI processes for Type 2 periodic CSI reporting, the periodicity and relative reporting offset is configured.

[0078] Figure 2 is a flow diagram of a method 200 for Type 2 measurement/reporting. The method 200 may be performed by a UE 104. The UE 104 may receive 202 a non-zero reference signal on a downlink channel. The UE 104 may measure 204 the downlink channel for a single subframe. The UE 104 may then generate a Type 2 CSI report 122 for a CSI reference resource based on the measured downlink channel for the single subframe. The Type 2 CSI report 122 may be computed from a channel measurement based on a non-zero reference signal on a single subframe within a configured CSI-RS resource associated with a CSI process. The UE 104 may send 208 the Type 2 CSI report to an eNB 102.

[0079] Figure 3 is a flow diagram of another method 300 for Type 2 measurement/reporting. The method 300 may be performed by an eNB 102. The eNB 102 may transmit 302 a reference signal on a downlink channel to a UE 104. The eNB 102 may receive 304 a Type 2 CSI report 122 for a CSI reference resource from the UE 104. The Type 2 CSI report 122 may be computed from a channel measurement based on a non-zero power reference signal on a single subframe within a configured CSI-RS resource associated with a CSI process. The eNB 102 may schedule 306 resources based on the Type 2

CSI report 122 for a CSI reference resource.

[0080] Figure 4 is a block diagram illustrating the layers realized by a user equipment (UE) 404. The user equipment (UE) 404 of Figure 4 may be one configuration of the user equipment (UE) 104 of Figure 1. The user equipment (UE) 404 may include a radio resource control (RRC) layer 450, a radio link control (RLC) layer 451, a medium access control (MAC) layer 452 and a physical (PHY) layer 453. The RRC layer 450, RLC layer 451 and MAC layer 452 may be referred to as higher layers 118. Mainly the procedures described herein relate to the PHY layer 453. As used herein, the phrase "configured by higher layers" means that the PHY layer 453 is configured by the higher layer. The user equipment (UE) 404 may include additional layers not shown in Figure 4.

[0081] Figure 5 illustrates the slot and subframe structure for Frame Structure Type 2. Frame Structure Type 2 may be applicable to TDD. Each radio frame 554 of length

$T_f = 307200 \cdot T_s = 10ms$,

includes two half-frames of length

$153600 \cdot \wedge = 5ms$

each. Each half-frame includes five subframes 555 of length

$30720\text{-}T_s = lms$.

[0082] The Type 2 Frame Structure may be a downlink subframe 555, an uplink subframe 555 or a special subframe 555. The special subframe 555 may be preceded by a downlink subframe 555 and succeeded by an uplink subframe 555. The special subframe 555 may be divided into three parts: DwPTS, GP and UpPTS. DwPTS is the downlink part of the special subframe 555, GP is the guard period and UpPTS is the uplink part of the special subframe 555.

[0083] Figure 6 illustrates the procedures for determining the CSI reference resources for periodic Type 2 CSI measurement/reporting. The computation of PMI and RI of a CSI report may be linked to the value of the CQI. Multiple radio frames 654 are illustrated. Each radio frame includes 654 ten subframes 655, numbered from 0 to 9. The radio frame number may also be referred to as the System Frame Number (SFN).

[0084] In Release 10 and 11 of the 3GPP specification, a UE 104 is configured with two subframe sets for measuring CSI. The first subframe set '$C_{CSI,0}$' is referred to as SI 656 herein. The second subframe set '$C_{CSI,1}$' is referred to as S2 657 herein. For a UE 104 in transmission mode 10, one subframe 655 belongs to either SI 656 or S2 657 but not both. A dedicated RRC configuration can identify the set of subframes 655 for Type 2 channel measurement, which is referred to as S3 662. In one example, the UE 104 may assume that S3 662 is the same as the set of subframes 655 associated with the CSI-RS

resources corresponding to the CSI process. In another example, the UE 104 is configured with S3 662 independent of the set of subframes 655 associated with the CSI-RS resources corresponding to the CSI process. A dedicated RRC configuration can identify the set of subframes 655 for Type 2 interference measurement, which is referred to as S4.

[0085] The valid downlink subframes 658 for S1 656 are illustrated. The valid downlink subframes 659 for S2 657 are also illustrated. The subframes 660 that the UE 104 is configured to receive a reference signal are labeled with 'z' and the observations/measurements 661 of the reference signal by the UE 104 are labeled m. The valid downlink subframes 663 for S3 662 are also illustrated.

[0086] The procedure for periodic reporting of Type 2 CSI reports is the same for cases when one CSI process is used for both Type 1 measurement/reporting and Type 2 measurement/reporting and for cases when a dedicated CSI process is used for either Type 1 CSI reporting or Type 2 CSI reporting. A dedicated RRC configuration may determine the periodicity 666 and relative reporting offset 667. For each reporting instance 664, the UE 104 may identify the corresponding CSI reference resource 665. The UE 104 may then generate the Type 2 periodic CSI report 122 based on the non-zero power CSI-RS corresponding to the CSI process in the CSI reference resource 665. The UE 104 may further include interference measurement when generating the Type 2 periodic CSI report 122 based on at least the configured resources for interference measurement in the CSI reference resource 665.

[0087] In the Figure, the UE 104 is configured for periodic reporting with a periodicity 666 of 4 ms (4 subframes 655, where each subframe 655 has a duration of 1 ms) and an offset of 3 subframes 655 (or 3 ms). For the periodic Type 2 CSI reporting scheduled in the uplink subframe 7 of radio frame k + 3, the UE 104 identifies the CSI reference resource 665 for Type 2 CSI reporting to be the subframe 3 in radio frame k + 3. The UE 104 generates the periodic Type 2 CSI report 122 for the CSI reference resource 665 (i.e., subframe 3 in radio frame k + 3) based on the non-zero power CSI-RS and the CSI-RS resources corresponding to the CSI process in subframe 3 of radio frame k + 3. The UE 104 may also include the interference measurement when generating the Type 2 periodic CSI report 122, based on at least the configured resources for interference measurement in subframe 3 of radio frame k + 3.

[0088] For a UE 104 in transmission mode 10 or transmission mode 11 (or any transmission mode that enables Type 2 measurement), the UE 104 may derive the interference measurements for computing the CQI value reported in uplink subframe n and corresponding to a CSI process based on the interference measurement signal only on subframe n - delta within the configured CSI-IM resource associated with the CSI process. The subframe n - delta may be a CSI reference resource 665 subframe (i.e.,

subframe 'n-nCQI_ref). This interference measurement is referred to as a Type 2 interference measurement. The interference measurement signal may be a zero-power CSI-RS.

[0089] For a UE 104 in transmission mode 10 or transmission mode 11 (or any transmission mode that enables Type 2 measurement), the UE 104 may derive the channel measurement for computing the CQI value reported in uplink subframe n and corresponding to a CSI process based on only a non-zero power CSI-RS only on subframe n - delta within the configured CSI-RS resource associated with the CSI process. The subframe n - delta may be a CSI reference resource 665 subframe (i.e., subframe 'n-nCQI_ref). This channel measurement is referred to as a Type 2 channel measurement. A Type 2 CSI measurement may include a Type 2 channel measurement, a Type 2 interference measurement, or both.

[0090] For Type 1 and Type 2 periodic CSI reporting, 'nCQI_ref is the smallest value greater than or equal to p, such that the subframe 'n-nCQI_ref corresponds to a valid downlink subframe 665. For FDD, p=5. For TDD with up to three CSI processes, p=4. For TDD with more than three CSI processes, p=5.

[0091] In Type 1 channel measurement, a UE 104 may derive the channel measurement for computing the CQI value reported in uplink subframe n (and corresponding to a CSI process) based on only the non-zero power CSI-RS within a configured CSI-RS resource associated with the CSI process.

[0092] As used herein, Type 2 CSI reporting may be computed based on a) a combination of Type 1 channel measurement and Type 2 interference measurement, b) a combination of Type 2 channel measurement and Type 2 interference measurement or c) a combination of Type 2 channel measurement and Type 2 interference measurement. The valid downlink subframe 665 may be in a set of subframes 665 for a Type 1 interference measurement. The valid downlink subframe 665 may also be in a set of subframes 665 in which the CSI-IM resource is configured. Type 1 interference measurement is defined by the UE 104 deriving the interference measurements for computing the CQI value reported in uplink subframe n (corresponding to a CSI process) based on only the zero power CSI-RS within the configured CSI-IM resource associated with the CSI process. Unlike a Type 1 interference measurement, a Type 2 interference measurement may not be restricted to the zero power CSI-RS within the configured CSI-IM resource associated with the CSI process and may be based on the interference measurement signal only on subframe n - delta within the configured CSI-IM resource associated with the CSI process.

[0093] Figure 7 illustrates the procedures for determining the CSI reference resources for aperiodic Type 2 CSI measurement/reporting. Multiple radio frames 775 are illustrated. Each radio frame 775 may include ten subframes 755, numbered from 0 to 9.

The subframe set S1 756, the subframe set S2 757 and the subframe set S3 762 are illustrated. Further, the valid downlink subframes 758 for S1 756, the valid downlink subframes 759 for S2 757 and the valid downlink subframes 763 for S3 are illustrated.

[0094] To trigger aperiodic CSI reporting, the eNB 102 sends an uplink DCI (e.g., DCI format 0 or 4) that includes a field requesting aperiodic CSI reporting. If one CSI process is used for both Type 1 CSI reporting and Type 2 CSI reporting, then the aperiodic CSI report may include only Type 1, only Type 2 or both Type 1 and Type 2 CSI reports. The CSI report may also include multiple Type 2 CSI reports. In one configuration, one bit may indicate whether the report includes Type 2 reports or not, as illustrated in Table 6 below.

[0095] [Table 6]

Type Indicator Bit	Aperiodic Report Includes
0	Only Type 1 CSI reports
1	Both Type 1 and Type 2 CSI reports

Table 6

[0096] An additional one or two bits can be used to signal a collection of CSI reports as given in Table 3 above. It is also possible to not include the type indicator bit. Thus, the CSI request field of two bits may indicate sets of CSI reports including Type 1, Type 2 or both Type 1 and Type 2 CSI reports as illustrated in Table 7 below

[0097] [Table 7]

Value of CSI request field	Description
'00'	Aperiodic CSI report of Type 1 for a set of CSI process(es) configured by higher layers for serving cell
'01'	Aperiodic CSI reports of Type 1 and Type 2 is triggered for a set of CSI process(es) configured by higher layers for serving cell
'10'	Aperiodic CSI report is triggered for a 1st set of CSI process(es) configured by higher layers
'11'	Aperiodic CSI report of Type 2 for a set of CSI process(es) configured by higher layers for serving cell

Table 7

[0098] If a CSI process can be configured with only one CSI reporting type, then there is no need for the type indicator bit in the uplink DCI. In this case, the CSI request field in the uplink DCI can be used for identifying the aperiodic CSI reports as illustrated in Table 8 below.

[0099]

[Table 8]

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

Table 8

[0100] The number of Type 2 CSI reports in an aperiodic CSI report may be configured by dedicated RRC signaling.

[0101] The subframes 769 where an aperiodic Type 2 CSI request is transmitted are illustrated. The scheduled subframes 770 for aperiodic CSI reporting are also illustrated. The CSI reference resource subframes 771 are further illustrated. For aperiodic reporting with X number of Type 2 CSI reports 122 (i.e., rl, r2, r3,... rX) included in the UCI, 'nCQI_ref is evaluated for each Type 2 CSI report 122. For report rl, 'nCQI_ref_l' is the smallest value greater than or equal to p, such that subframe 'n-nCQI_ref_l' corresponds to a valid downlink subframe 763, with the above candidates for p. Likewise, for report r2, 'nCQI_ref_2' is the smallest value greater than or equal to 'nCQI_ref_l', such that subframe 'n-nCQI_ref_2' corresponds to a valid downlink subframe 763. The ith report (i.e., ri), l<i<=X, denoted by 'nCQI_ref_i' , is the smallest value greater than 'nCQI_ref_i-l' such that subframe 'n-nCQI_ref_i' corresponds to a valid downlink subframe 763.

[0102] A downlink subframe 755 is considered to be valid if a) the downlink subframe 755 is configured as a downlink subframe 755 for that UE 104, b) except for transmission mode 9 or 10, the downlink subframe 755 is not an MBSFN subframe (discussed below), c) the downlink subframe 755 does not include a DwPTS field in cases where the length of DwPTS is

$$7680 \cdot T_s$$

and less, d) the downlink subframe 755 does not fall within a configured measurement gap for that UE 104, and e) specific parameters for Type 1 CSI reporting and Type 2 CSI reporting are met. For Type 1 periodic CSI reporting, the additional specific parameters required are that a downlink subframe 755 is considered to be valid if the downlink subframe 755 is an element of the CSI subframe set linked to the periodic CSI report when that UE 104 is configured with CSI subframe sets.

[0103] In a multimedia broadcast/multicast service (MBMS) network, the same content may be transmitted simultaneously in a specific area (referred to as an MBMS service area)

which may geographically include multiple transmission points (TPs) or eNBs 102. If the transmissions of all transmission points (TPs) are time synchronized, from the perspective of a UE 104, the transmissions appear to originate from a single transmission point (TP). This transmission is referred to as a MBMBS single-frequency network (MBSFN).

[0104] For Type 2 periodic and aperiodic CSI reporting, the additional specific criteria required (for a subframe 755 to be considered a valid downlink subframe 755) are a) that the downlink subframe 755 is in the set of subframes 755 for Type 2 channel measurement (i.e., S3 762), b) the downlink subframe 755 is in the set of subframes 755 in which the reference signal (e.g., the CSI-RS resource associated with the CSI process) is configured, c) the downlink subframe 755 is in the set of subframes 755 for Type 2 channel measurement if the set of subframes 755 for Type 2 channel measurement is configured, d) the downlink subframe 755 is in the set of subframes 755 for a Type 2 interference measurement (i.e., the subset S4 which is similar to the subset S3 762) or e) the downlink subframe 755 is in the set of subframes 755 in which the CSI-IM resource is configured.

[0105] Depending on the method for computing a Type 2 CSI report (e.g., based on a Type 1 channel measurement and a Type 2 interference measurement, based on a Type 2 channel measurement and a Type 2 interference measurement, or based on a Type 2 channel measurement and a Type 1 interference measurement), a combination of the above criteria might be applied for determining a valid downlink subframe 755.

[0106] As an example, the UE 104 may receive an uplink DCI with an aperiodic CSI reporting request in subframe 1 of radio frame k + 3. The PUSCH resources are scheduled for a transmission of an aperiodic CSI report in subframe 6 of radio frame k + 3. Moreover, the UE 104 is configured by RRC signaling to include two Type 2 CSI reports 122 in the aperiodic CSI reporting. The UE 104 may identify the CSI reference resource 771 for the first Type 2 CSI report 122 (which is subframe 8 of radio frame k + 2) and the second CSI reference resource 771 for the second Type 2 CSI report 122 (which is subframe 9 of radio frame k + 2) (e.g., based on 'nCQI_ref and the valid downlink subframe 775 definition described above).

[0107] The UE 104 may generate a first Type 2 CSI report 122 based on the non-zero power CSI-RS within the configured CSI-RS resource corresponding to the CSI process in subframe 8 of radio frame k + 2. The UE 102 may further include interference measurements when generating the first Type 2 CSI report 122, based on at least the configured resources for interference measurement in subframe 8 of radio frame k + 2. The UE 104 may also generate a second Type 2 CSI report 122 based on the non-zero power CSI-RS within the configured CSI-RS resource corresponding to the CSI process in subframe 9 of radio frame k + 2. The UE 104 may include interference mea-

surements when generating the second Type 2 CSI report 122, based on at least the configured resources for interference measurement in subframe 9 of radio frame k + 2. For this example, a combination of Type 2 channel measurement and Type 1 interference measurement is used. However, a similar method may also be applied to a combination of Type 1 channel measurement and Type 2 interference measurement by replacing the valid downlink subframe 763 for S3 762 with a valid downlink subframe for S4 (not shown). The UE 104 may generate a first Type 2 CSI report 122 based on the CSI-IM resources corresponding to the CSI process in subframe 8 of radio frame k + 2. The UE 104 may also generate a second Type 2 CSI report 122 based on the CSI-IM corresponding to the CSI process in subframe 9 of radio frame k + 2. Also, a similar method may be applied using a combination of Type 2 channel measurement and Type 2 interference measurement on a CSI reference resource that is a valid downlink subframe 755 considering the criteria related to both channel measurement and interference measurements.

[0108] Figure 8 illustrates various components that may be utilized in a user equipment (UE) 804. The user equipment (UE) 804 may be utilized as the user equipment (UE) 104 illustrated previously. The user equipment (UE) 804 includes a processor 854 that controls operation of the user equipment (UE) 804. The processor 854 may also be referred to as a CPU. Memory 874, which may include both read-only memory (ROM), random access memory (RAM) or any type of device that may store information, provides instructions 856a and data 858a to the processor 854. A portion of the memory 874 may also include non-volatile random access memory (NVRAM). Instructions 856b and data 858b may also reside in the processor 854. Instructions 856b and/or data 858b loaded into the processor 854 may also include instructions 856a and/or data 858a from memory 874 that were loaded for execution or processing by the processor 854. The instructions 856b may be executed by the processor 854 to implement the systems and methods disclosed herein.

[0109] The user equipment (UE) 804 may also include a housing that includes a transmitter 872 and a receiver 873 to allow transmission and reception of data. The transmitter 872 and receiver 873 may be combined into a transceiver 871. One or more antennas 806a-n are attached to the housing and electrically coupled to the transceiver 871. An antenna port may be realized by one or more antennas.

[01 10] The various components of the user equipment (UE) 804 are coupled by a bus system 877, which may include a power bus, a control signal bus, and a status signal bus, in addition to a data bus. However, for the sake of clarity, the various buses are illustrated in Figure 8 as the bus system 877. The user equipment (UE) 804 may also include a digital signal processor (DSP) 875 for use in processing signals. The user equipment (UE) 804 may also include a communications interface 876 that provides user access

to the functions of the user equipment (UE) 804. The user equipment (UE) 804 illustrated in Figure 8 is a functional block diagram rather than a listing of specific components.

[0111] Figure 9 illustrates various components that may be utilized in an eNB 902. The eNB 902 may be utilized as the eNode B 102 illustrated previously. The eNB 902 may include components that are similar to the components discussed above in relation to the user equipment (UE) 804, including a processor 978, memory 986 that provides instructions 979a and data 980a to the processor 978, instructions 979b and data 980b that may reside in or be loaded into the processor 978, a housing that includes a transmitter 982 and a receiver 984 (which may be combined into a transceiver 981), one or more antenna ports 908a-n electrically coupled to the transceiver 981, a bus system 992, a DSP 988 for use in processing signals, a communications interface 990, antennas 910a-n and so forth.

[01 12] Unless otherwise noted, the use of '/' above represents the phrase "and/or. "

[0113] The functions described herein may be implemented in hardware, software, firmware or any combination thereof. If implemented in software, the functions may be stored as one or more instructions on a computer-readable medium. The term "computer-readable medium" refers to any available medium that can be accessed by a computer or a processor. The term "computer-readable medium, " as used herein, may denote a computer- and/or processor-readable medium that is non-transitory and tangible. By way of example, and not limitation, a computer-readable or processor-readable medium may comprise RAM, ROM, EEPROM, CD-ROM or other optical disk storage, magnetic disk storage or other magnetic storage devices, or any other medium that can be used to carry or store desired program code in the form of instructions or data structures and that can be accessed by a computer or processor. Disk and disc, as used herein, includes compact disc (CD), laser disc, optical disc, digital versatile disc (DVD), floppy disk and Blu-ray (registered trademark) disc where disks usually reproduce data magnetically, while discs reproduce data optically with lasers.

[0114] Each of the methods disclosed herein comprises one or more steps or actions for achieving the described method. The method steps and/or actions may be interchanged with one another and/or combined into a single step without departing from the scope of the claims. In other words, unless a specific order of steps or actions is required for proper operation of the method that is being described, the order and/or use of specific steps and/or actions may be modified without departing from the scope of the claims.

[0115] As used herein, the term "determining" encompasses a wide variety of actions and, therefore, "determining" can include calculating, computing, processing, deriving, investigating, looking up (e.g., looking up in a table, a database or another data structure), ascertaining and the like. In addition, "determining" can include receiving

(e.g., receiving information), accessing (e.g., accessing data in a memory) and the like. Also, "determining" can include resolving, selecting, choosing, establishing and the like.

[0116] The phrase "based on" does not mean, "based only on, " unless expressly specified otherwise. In other words, the phrase "based on" describes both "based only on" and "based at least on. "

[01 17] The term "processor" should be interpreted broadly to encompass a general purpose processor, a central processing unit (CPU), a microprocessor, a digital signal processor (DSP), a controller, a microcontroller, a state machine and so forth. Under some circumstances, a "processor" may refer to an application specific integrated circuit (ASIC), a programmable logic device (PLD), a field programmable gate array (FPGA), etc. The term "processor" may refer to a combination of processing devices, e.g., a combination of a DSP and a microprocessor, a plurality of microprocessors, one or more microprocessors in conjunction with a DSP core or any other such configuration.

[0118] The term "memory" should be interpreted broadly to encompass any electronic component capable of storing electronic information. The term memory may refer to various types of processor-readable media such as random access memory (RAM), read-only memory (ROM), non-volatile random access memory (NVRAM), programmable read-only memory (PROM), erasable programmable read-only memory (EPROM), electrically erasable PROM (EEPROM), flash memory, magnetic or optical data storage, registers, etc. Memory is said to be in electronic communication with a processor if the processor can read information from and/or write information to the memory. Memory may be integral to a processor and still be said to be in electronic communication with the processor.

[0119] The terms "instructions" and "code" should be interpreted broadly to include any type of computer-readable statement(s). For example, the terms "instructions" and "code" may refer to one or more programs, routines, sub-routines, functions, procedures, etc. "Instructions" and "code" may comprise a single computer-readable statement or many computer-readable statements.

[0120] Software or instructions may also be transmitted over a transmission medium. For example, if the software is transmitted from a website, server, or other remote source using a coaxial cable, fiber optic cable, twisted pair, digital subscriber line (DSL) or wireless technologies such as infrared, radio, and microwave, then the coaxial cable, fiber optic cable, twisted pair, DSL, or wireless technologies such as infrared, radio and microwave are included in the definition of transmission medium.

[0121] It is to be understood that the claims are not limited to the precise configuration and components illustrated above. Various modifications, changes and variations may be made in the arrangement, operation and details of the systems, methods, and apparatus

described herein without departing from the scope of the claims.

Claims

[Claim 1] A method for receiving uplink control information (UCI), comprising: receiving a Type 2 channel state information (CSI) report for a CSI reference resource from a user equipment (UE), wherein the Type 2 CSI report is computed from a channel measurement based on a non-zero power reference signal on a single subframe within a configured CSI-RS resource associated with a CSI process.

[Claim 2] The method of claim 1, wherein the single subframe is a subframe of the CSI reference resource.

[Claim 3] The method of claim 2, wherein the CSI reference resource for the Type 2 CSI report reported in uplink subframe n is defined by a valid downlink subframe n-nCQI_ref.

[Claim 4] The method of claim 3, wherein the valid downlink subframe is in a set of subframes for a channel measurement for the Type 2 CSI report.

[Claim 5] The method of claim 3, wherein the valid downlink subframe is in a set of subframes in which the non-zero power reference signal is configured.

[Claim 6] The method of claim 3, wherein the valid downlink subframe is in a set of subframes for Type 2 channel measurement if the set of subframes for Type 2 channel measurement is configured, and wherein the valid downlink subframe is in a set of subframes in which the non-zero power reference signal is configured if the set of subframes for Type 2 channel measurement is not configured.

[Claim 7] The method of claim 1, wherein the Type 2 CSI report is a periodic CSI report.

[Claim 8] The method of claim 7, wherein Type 2 CSI reporting is configured in a CSI process configuration.

[Claim 9] The method of claim 1, wherein the Type 2 CSI report is an aperiodic CSI report.

[Claim 10] The method of claim 9, wherein a field in a downlink control information (DCI) specifies whether Type 2 aperiodic CSI reporting is triggered.

[Claim 11] The method of claim 1, wherein the Type 2 CSI report corresponds to a configured CSI process.

[Claim 12] A method for reporting uplink control information (UCI), comprising: generating a Type 2 channel state information (CSI) report for a CSI reference resource; and

sending the Type 2 CSI report to a base station, wherein the Type 2 CSI report is computed from a channel measurement based on a non-zero power reference signal on a single subframe within a configured CSI-RS resource associated with a CSI process.

[Claim 13] The method of claim 12, wherein the single subframe is a subframe of the CSI reference resource.

[Claim 14] The method of claim 13, wherein the CSI reference resource for the Type 2 CSI report reported in uplink subframe n is defined by a valid downlink subframe n-nCQI_ref.

[Claim 15] The method of claim 14, wherein the valid downlink subframe is in a set of subframes for a channel measurement for the Type 2 CSI report.

[Claim 16] The method of claim 14, wherein the valid downlink subframe is in a set of subframes in which the non-zero power reference signal is configured.

[Claim 17] The method of claim 14, wherein the valid downlink subframe is in a set of subframes for Type 2 channel measurement if the set of subframes for Type 2 channel measurement is configured, and wherein the valid downlink subframe is in a set of subframes in which the non-zero power reference signal is configured if the set of subframes for Type 2 channel measurement is not configured.

[Claim 18] The method of claim 12, wherein the Type 2 CSI report is a periodic CSI report.

[Claim 19] The method of claim 18, wherein Type 2 CSI reporting is configured in a CSI process configuration.

[Claim 20] The method of claim 12, wherein the Type 2 CSI report is an aperiodic CSI report.

[Claim 21] The method of claim 20, wherein a field in a downlink control information (DCI) specifies whether Type 2 aperiodic CSI reporting is triggered.

[Claim 22] The method of claim 12, wherein the Type 2 CSI report corresponds to a configured CSI process.

[Claim 23] A base station configured for receiving uplink control information (UCI), comprising:

a processor;

memory in electronic communication with the processor; and

instructions stored in the memory, the instructions being executable to:

receive a Type 2 channel state information (CSI) report for a CSI reference resource from a user equipment (UE), wherein the Type 2

CSI report is computed from a channel measurement based on a non-zero power reference signal on a single subframe within a configured CSI-RS resource associated with a CSI process.

[Claim 24] The base station of claim 23, wherein the single subframe is a subframe of the CSI reference resource.

[Claim 25] The base station of claim 24, wherein the CSI reference resource for the Type 2 CSI report reported in uplink subframe n is defined by a valid downlink subframe n-nCQI_ref.

[Claim 26] The base station of claim 25, wherein the valid downlink subframe is in a set of subframes for a channel measurement for the Type 2 CSI report.

[Claim 27] The base station of claim 25, wherein the valid downlink subframe is in a set of subframes in which the non-zero power reference signal is configured.

[Claim 28] The base station of claim 25, wherein the valid downlink subframe is in a set of subframes for Type 2 channel measurement if the set of subframes for Type 2 channel measurement is configured, and wherein the valid downlink subframe is in a set of subframes in which the non-zero power reference signal is configured if the set of subframes for Type 2 channel measurement is not configured.

[Claim 29] The base station of claim 23, wherein the Type 2 CSI report is a periodic CSI report.

[Claim 30] The base station of claim 29, wherein Type 2 CSI reporting is configured in a CSI process configuration.

[Claim 31] The base station of claim 23, wherein the Type 2 CSI report is an aperiodic CSI report.

[Claim 32] The base station of claim 31, wherein a field in a downlink control information (DCI) specifies whether Type 2 aperiodic CSI reporting is triggered.

[Claim 33] The base station of claim 22, wherein the Type 2 CSI report corresponds to a configured CSI process.

[Claim 34] A user equipment (UE) configured for reporting uplink control information (UCI), comprising:

a processor;

memory in electronic communication with the processor; and

instructions stored in the memory, the instructions being executable to:

generate a Type 2 channel state information (CSI) report for a CSI reference resource; and send the Type 2 CSI report to a base station,

wherein the Type 2 CSI report is computed from a channel measurement based on a non-zero power reference signal on a single subframe within a configured CSI-RS resource associated with a CSI process.

[Claim 35] The UE of claim 34, wherein the single subframe is a subframe of the CSI reference resource.

[Claim 36] The UE of claim 35, wherein the CSI reference resource for the Type 2 CSI report reported in uplink subframe n is defined by a valid downlink subframe n-nCQI_ref.

[Claim 37] The UE of claim 36, wherein the valid downlink subframe is in a set of subframes for a channel measurement for the Type 2 CSI report.

[Claim 38] The UE of claim 36, wherein the valid downlink subframe is in a set of subframes in which the non-zero power reference signal is configured.

[Claim 39] The UE of claim 36, wherein the valid downlink subframe is in a set of subframes for Type 2 channel measurement if the set of subframes for Type 2 channel measurement is configured, and wherein the valid downlink subframe is in a set of subframes in which the non-zero power reference signal is configured if the set of subframes for Type 2 channel measurement is not configured.

[Claim 40] The UE of claim 34, wherein the Type 2 CSI report is a periodic CSI report.

[Claim 41] The UE of claim 40, wherein Type 2 CSI reporting is configured in a CSI process configuration.

[Claim 42] The UE of claim 34, wherein the Type 2 CSI report is an aperiodic CSI report.

[Claim 43] The UE of claim 42, wherein a field in a downlink control information (DCI) specifies whether Type 2 aperiodic CSI reporting is triggered.

[Claim 44] The UE of claim 34, wherein the Type 2 CSI report corresponds to a configured CSI process.

[Fig. 1]

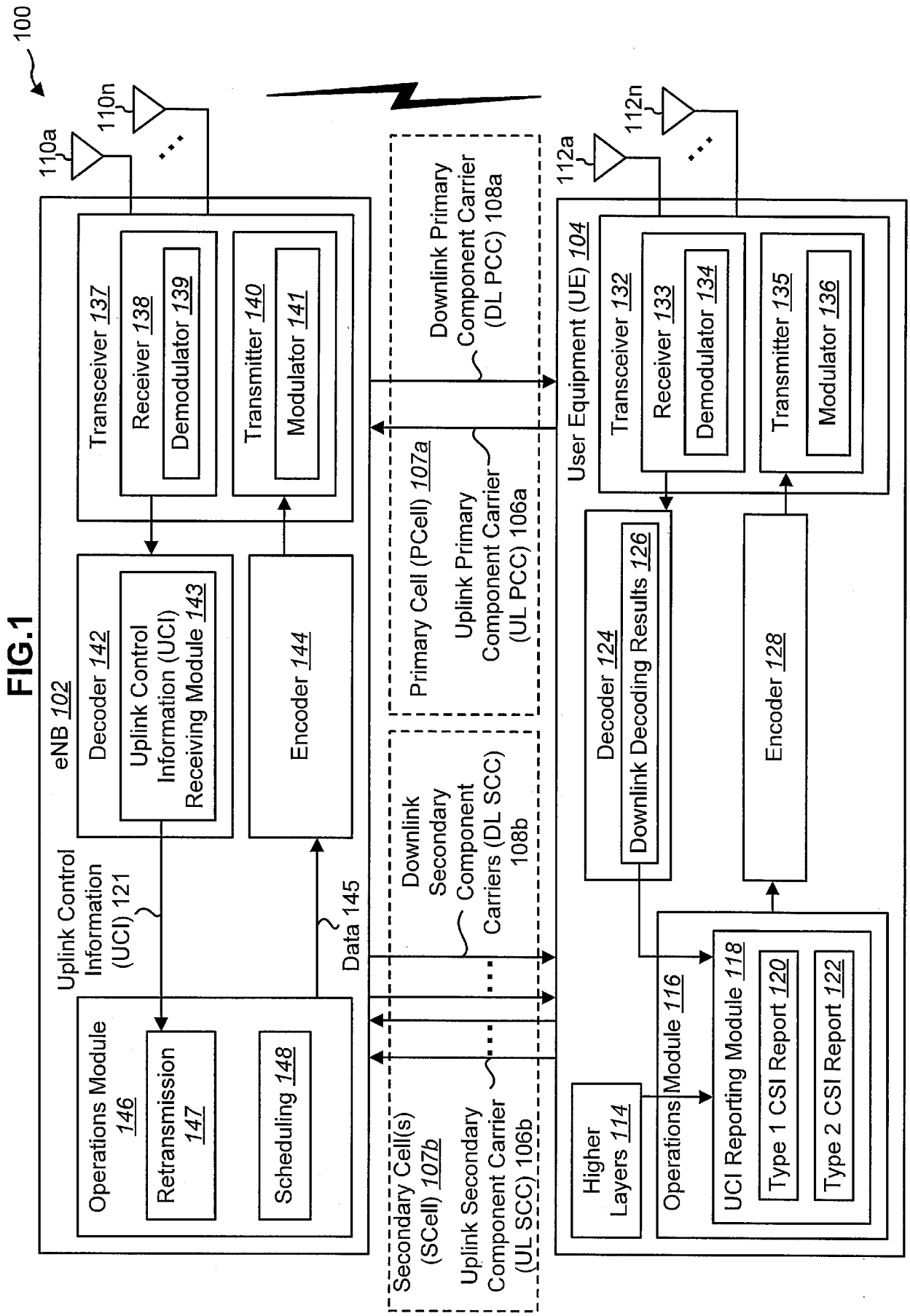

100
110a
110n
112a
112n
eNB 102
Transceiver 137
Receiver 138
Demodulator 139
Transmitter 140
Modulator 141
Decoder 142
Uplink Control Information (UCI) Receiving Module 143
Encoder 144
Uplink Control Information (UCI) 121
Data 145
Operations Module 146
Retransmission 147
Scheduling 148
Downlink Primary Component Carrier (DL PCC) 108a
Primary Cell (PCell) 107a
Uplink Primary Component Carrier (UL PCC) 106a
Downlink Secondary Component Carriers (DL SCC) 108b
Secondary Cell(s) (SCell) 107b
Uplink Secondary Component Carrier (UL SCC) 106b
User Equipment (UE) 104
Transceiver 132
Receiver 133
Demodulator 134
Transmitter 135
Modulator 136
Decoder 124
Downlink Decoding Results 126
Encoder 128
Higher Layers 114
Operations Module 116
UCI Reporting Module 118
Type 1 CSI Report 120
Type 2 CSI Report 122

FIG.1

[Fig. 2]

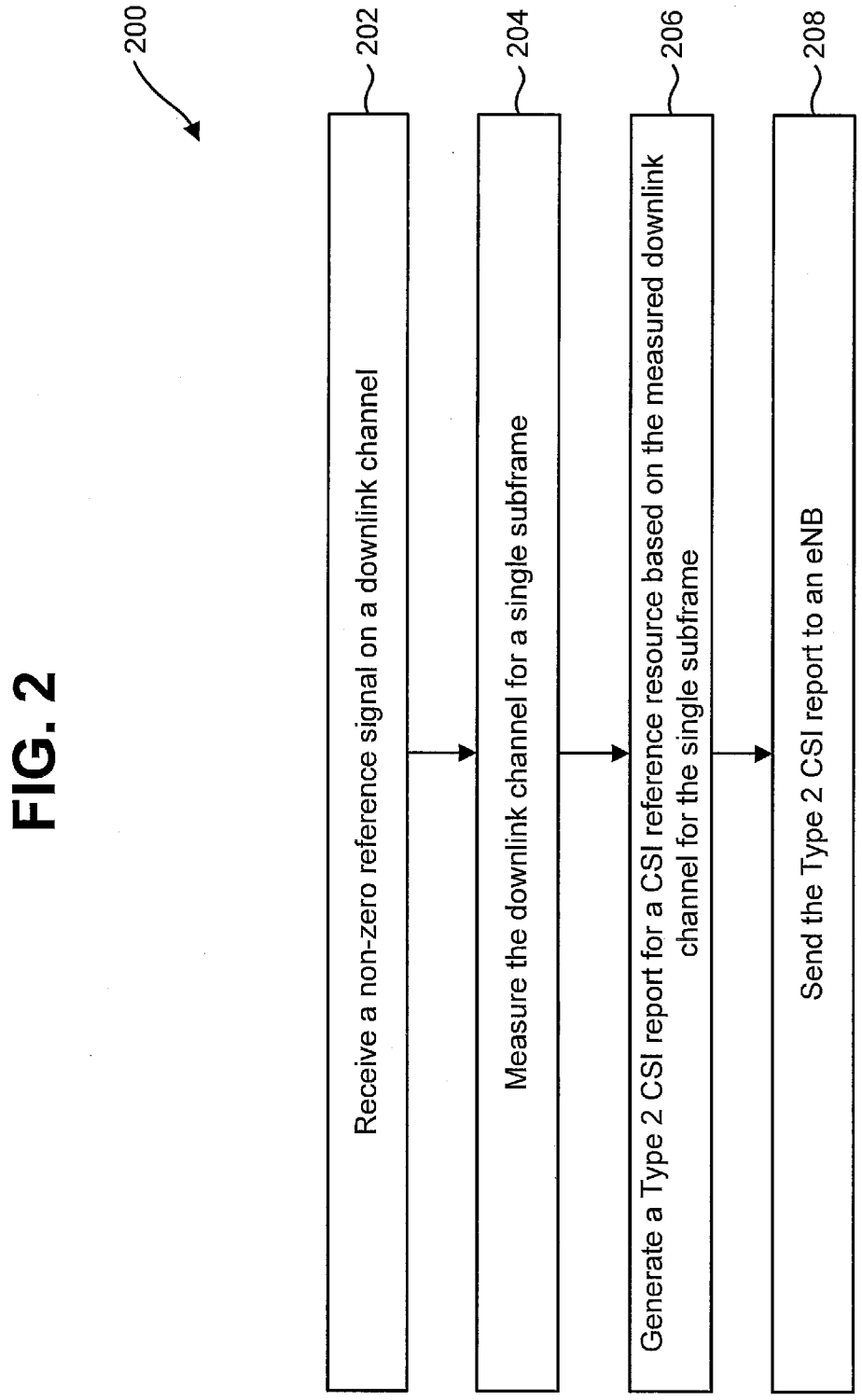

200
202
Receive a non-zero reference signal on a downlink channel
204
Measure the downlink channel for a single subframe
206
Generate a Type 2 CSI report for a CSI reference resource based on the measured downlink channel for the single subframe
208
Send the Type 2 CSI report to an eNB

FIG. 2

[Fig. 3]

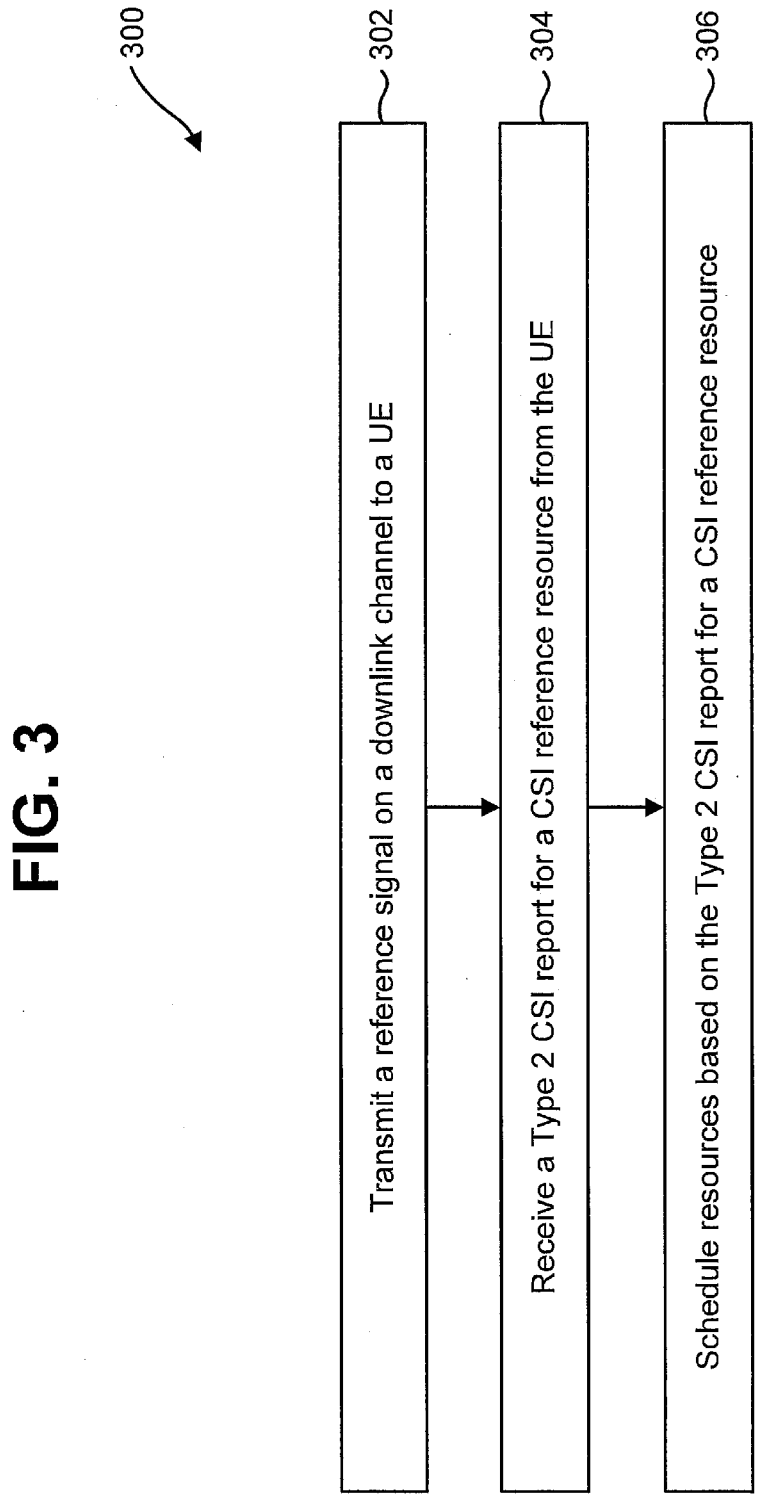
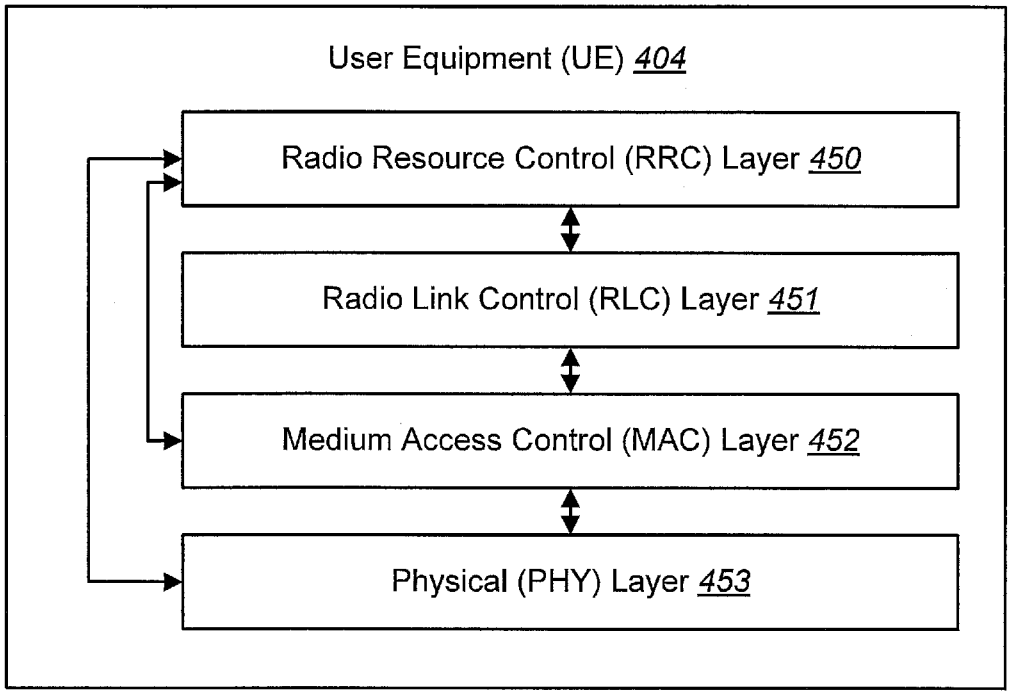

300
302
304
306
Transmit a reference signal on a downlink channel to a UE
Receive a Type 2 CSI report for a CSI reference resource from the UE
Schedule resources based on the Type 2 CSI report for a CSI reference resource

FIG. 3

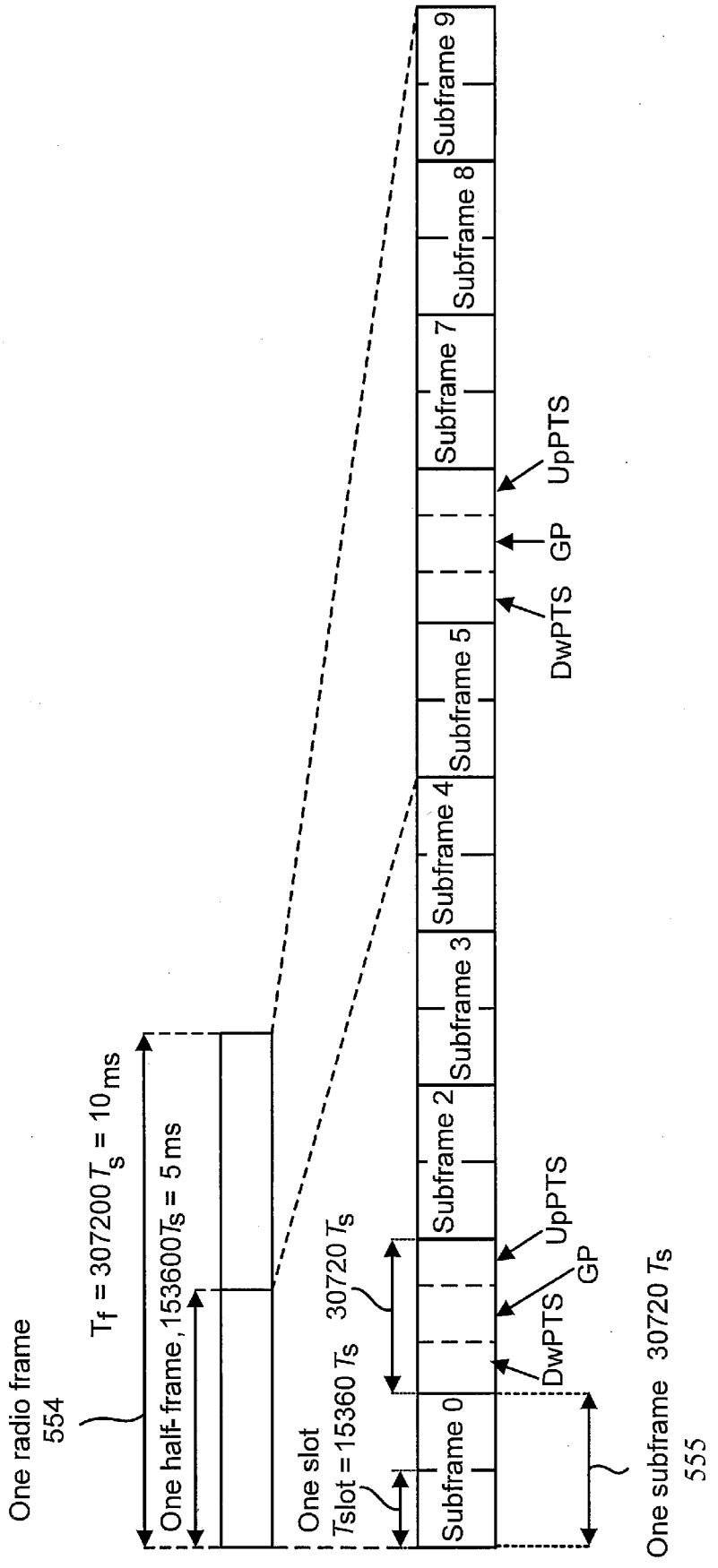
[Fig. 4]

FIG. 4


User Equipment (UE) 404
Radio Resource Control (RRC) Layer 450
Radio Link Control (RLC) Layer 451
Medium Access Control (MAC) Layer 452
Physical (PHY) Layer 453

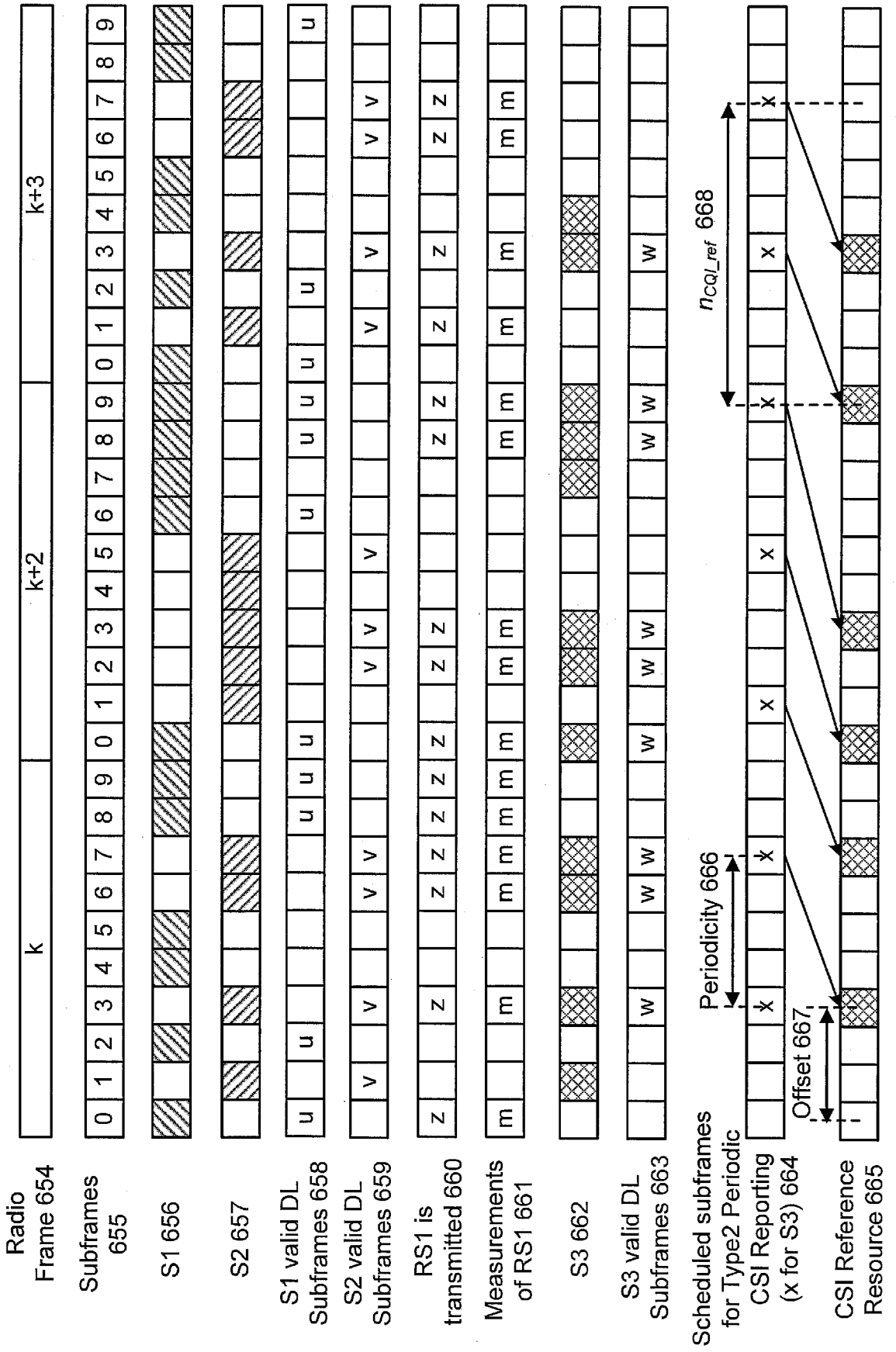
[Fig. 5]

FIG. 5


One radio frame
554
$T_f = 307200\,T_s = 10$ ms
One half-frame, $153600\,T_s = 5$ ms
One slot
$T_{slot} = 15360\,T_s$
$30720\,T_s$
Subframe 0
Subframe 2
Subframe 3
Subframe 4
Subframe 5
Subframe 7
Subframe 8
Subframe 9
DwPTS
GP
UpPTS
DwPTS
GP
UpPTS
One subframe $30720\,T_s$
555

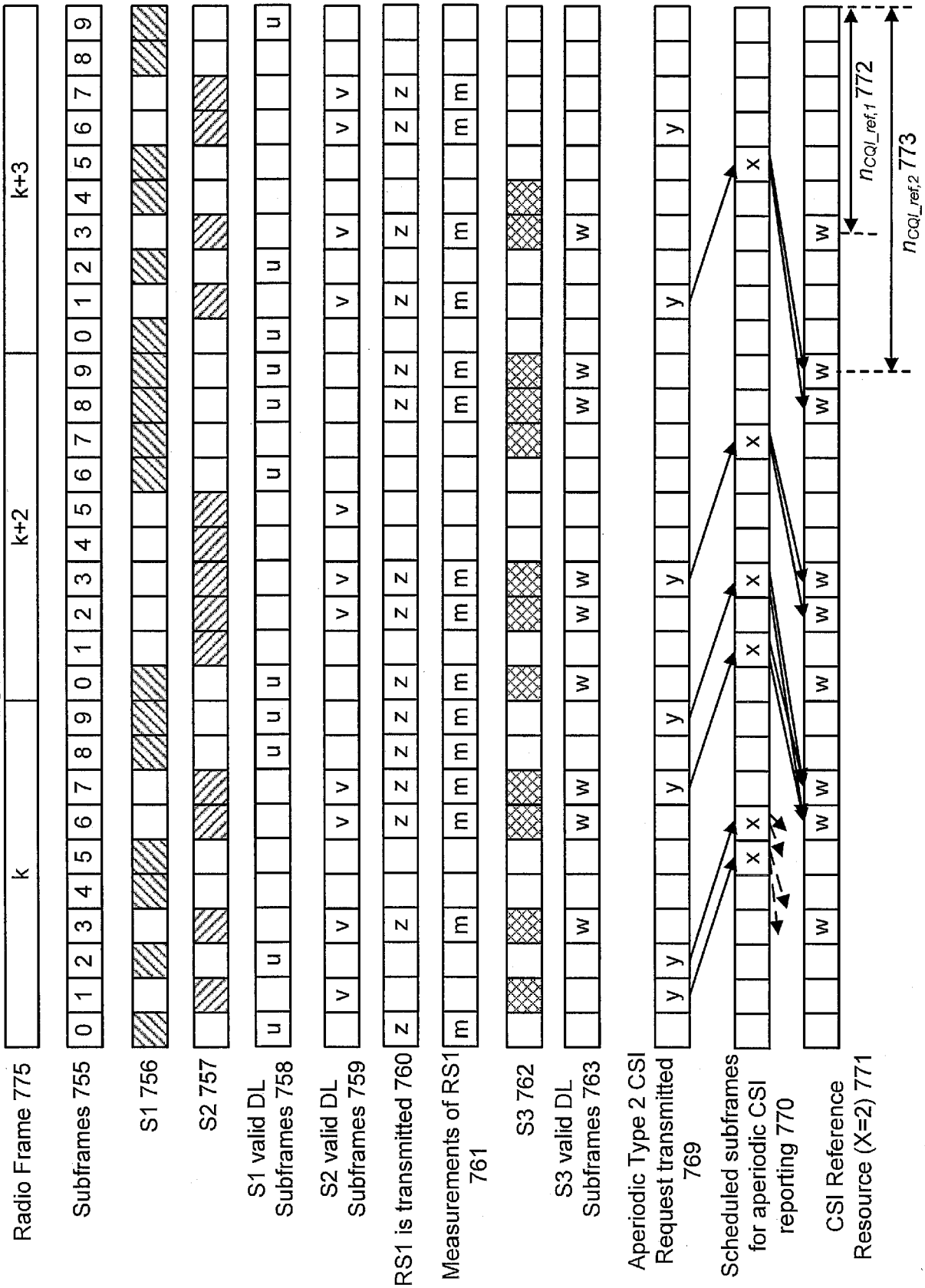
[Fig. 6]

FIG. 6


Radio Frame 654
k
k+2
k+3
Subframes 655
0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9
S1 656
S2 657
S1 valid DL Subframes 658
S2 valid DL Subframes 659
RS1 is transmitted 660
Measurements of RS1 661
S3 662
S3 valid DL Subframes 663
Scheduled subframes for Type2 Periodic CSI Reporting (x for S3) 664
CSI Reference Resource 665
Periodicity 666
Offset 667
n_{CQI_ref} 668

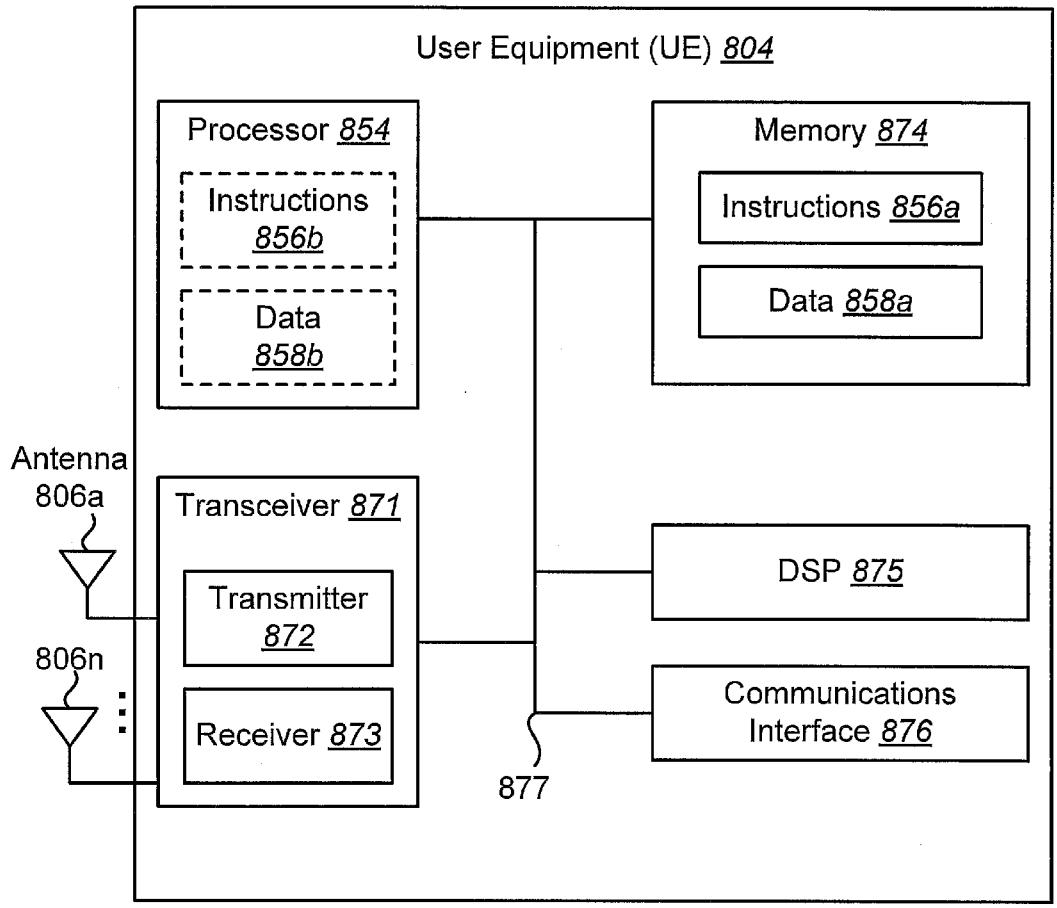
[Fig. 7]

FIG. 7


Radio Frame 775
k
k+2
k+3
Subframes 755
S1 756
S2 757
S1 valid DL Subframes 758
S2 valid DL Subframes 759
RS1 is transmitted 760
Measurements of RS1 761
S3 762
S3 valid DL Subframes 763
Aperiodic Type 2 CSI Request transmitted 769
Scheduled subframes for aperiodic CSI reporting 770
CSI Reference Resource (X=2) 771
$n_{CQI_ref,1}$ 772
$n_{CQI_ref,2}$ 773

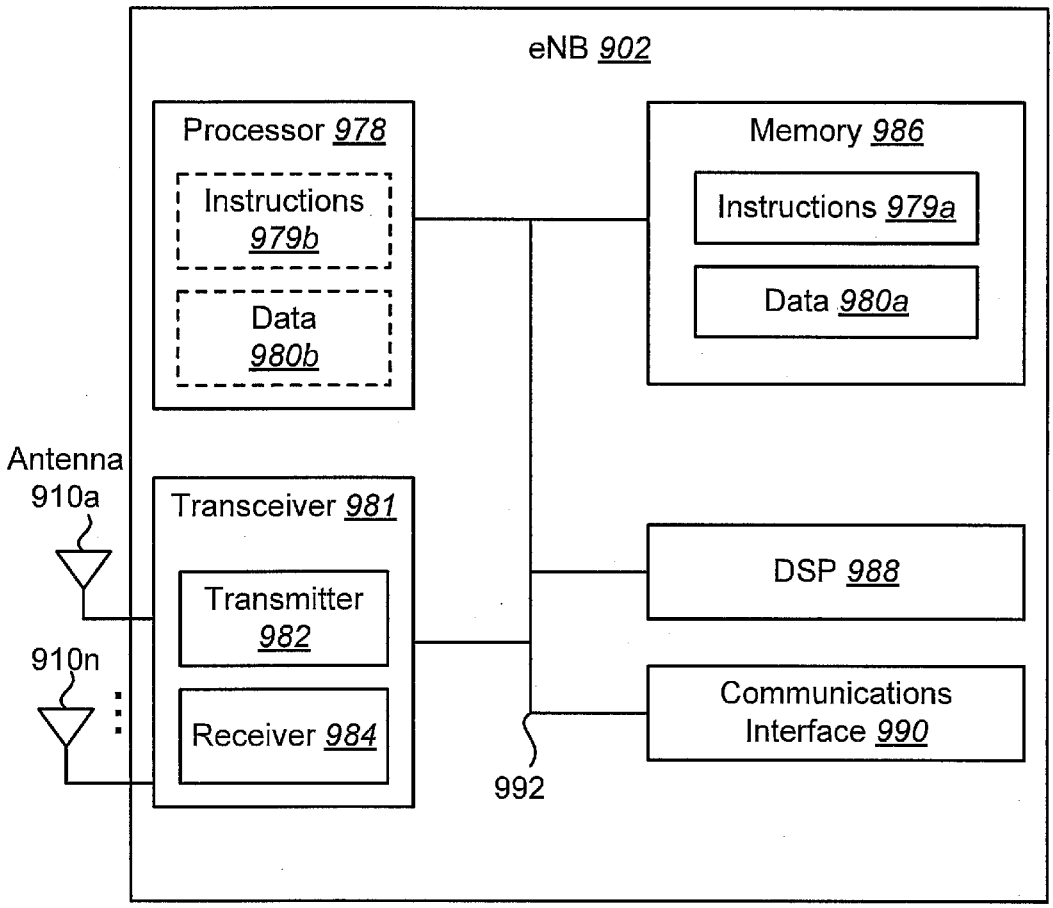
[Fig. 8]

FIG. 8


User Equipment (UE) 804
Processor 854
Instructions 856b
Data 858b
Memory 874
Instructions 856a
Data 858a
Antenna 806a
806n
Transceiver 871
Transmitter 872
Receiver 873
DSP 875
Communications Interface 876
877

[Fig. 9]

FIG. 9


eNB 902
Processor 978
Instructions 979b
Data 980b
Memory 986
Instructions 979a
Data 980a
Antenna 910a
910n
Transceiver 981
Transmitter 982
Receiver 984
DSP 988
Communications Interface 990
992

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2014/002461

A. CLASSIFICATION OF SUBJECT MATTER

Int.Cl. H04W24/10 (2009.01)i, H04W72/04 (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)

Int.Cl. H04W4/00-99/00, H04B7/24-7/26

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

Published examined utility model applications of Japan 1922-1996
Published unexamined utility model applications of Japan 1971-2014
Registered utility model specifications of Japan 1996-2014
Published registered utility model applications of Japan 1994-2014

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	"Evolved Universal Terrestrial Radio Access (E-UTRA); Physical layer procedures (Release 11)", 3GPP TS 36.213 V11.2.0, 2013.02, pp. 52-86	1-44
Y	Samsung, "CQI Reference Resource Timing for LTE-A", 3GPP TSG RAN WG1 #63bis, R1-110089, 2011.01, pp. 1-5	1-44
A	"Evolved Universal Terrestrial Radio Access (E-UTRA); Physical Channels and Modulation (Release 11)", 3GPP TS 36.211 V11.2.0, 2013.02, pp. 93-97	1-44

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

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
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"P" document published prior to the international filing date but later than the priority date claimed
"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
"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
"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
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
31.07.2014	12.08.2014

Name and mailing address of the ISA/JP	Authorized officer
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3-4-3, Kasumigaseki, Chiyoda-ku, Tokyo 100-8915, Japan	Telephone No. **+81-3-3581-1101 Ext.** 3534