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(54) **DEMODULATION REFERENCE SIGNAL BASED CHANNEL STATE INFORMATION FEEDBACK IN OFDM-MIMO SYSTEMS**

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CPC .... ***H04L 25/0226*** (2013.01); ***H04B 7/0417*** (2013.01); ***H04B 7/0626*** (2013.01); (Continued)

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See application file for complete search history.

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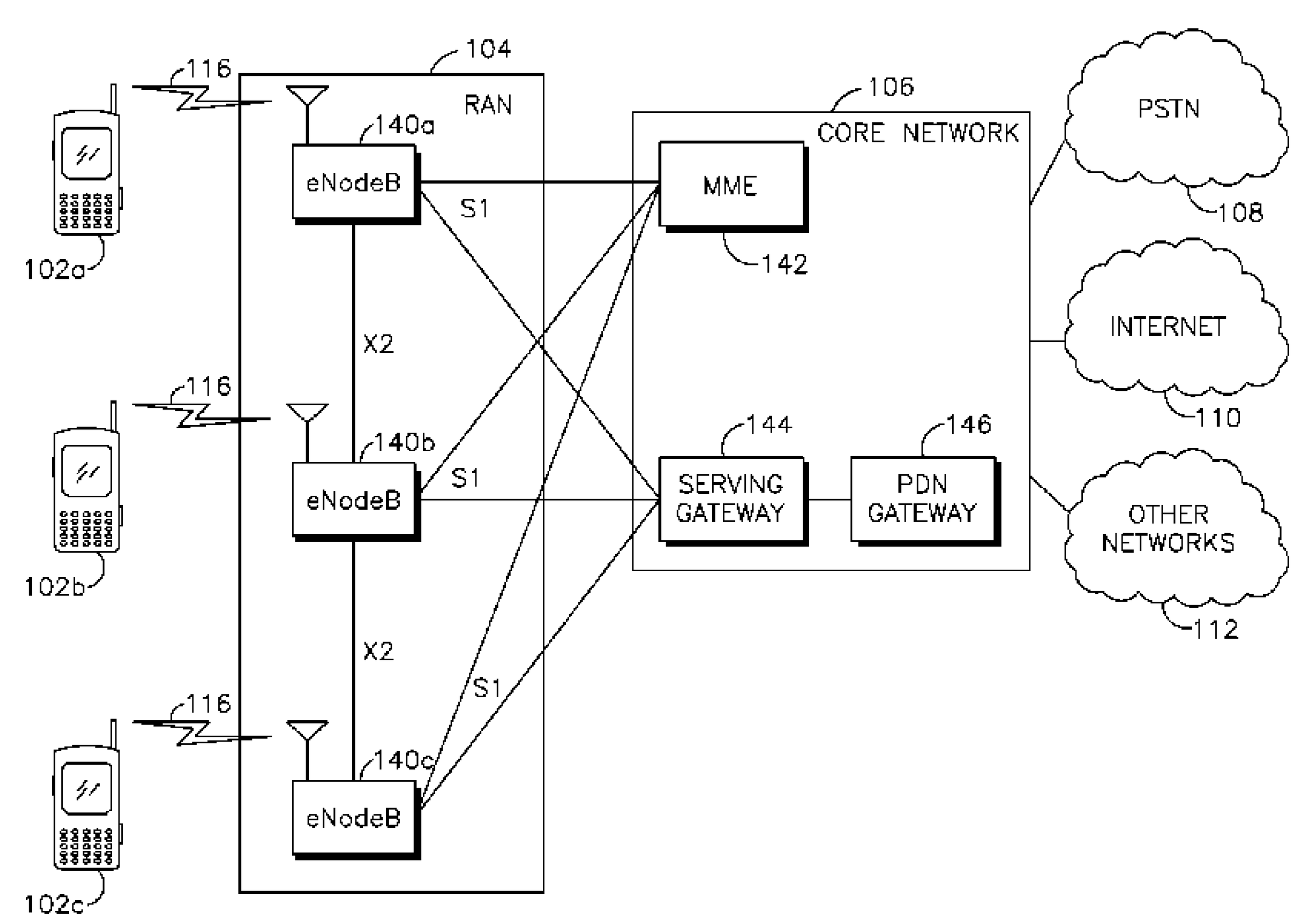
(57) **ABSTRACT**

A method and apparatus for using demodulation reference signal (DM-RS) based channel state information (CSI) feedback in Orthogonal Frequency Division Multiplexing-multiple-input multiple-output (OFDM-MIMO) systems is disclosed. The wireless transmit/receive unit (WTRU) receives one or more resource blocks from a base station, wherein the resource blocks (RBs) include demodulating reference signals (DM-RS) and precoder information. The precoder information is sent unicast or broadcasted over a common control channel. The WTRU estimates an effective channel estimate based on the DM-RS, derives an unprecoded channel based on the effective channel and the precoder information, generates CSI feedback based on the unprecoded channel, and transmits the CSI feedback to the base station. Alternatively, the WTRU estimates an effective channel estimate based on the DM-RS, quantizes the effective channel estimate and transmits the CSI feedback to the base station.

11 Claims, 6 Drawing Sheets



(51) **Int. Cl.**
H04B 7/04 (2006.01)
H04B 7/06 (2006.01)
H04L 5/00 (2006.01)
H04L 25/03 (2006.01)

(52) **U.S. Cl.**
CPC ***H04B7/0639*** (2013.01); ***H04L 5/005*** (2013.01); ***H04L 5/0007*** (2013.01); ***H04L 25/0204*** (2013.01); ***H04L 25/0224*** (2013.01); ***H04L 25/03343*** (2013.01); *H04L 5/0023* (2013.01); *H04L 5/0091* (2013.01); *H04L 25/03891* (2013.01)

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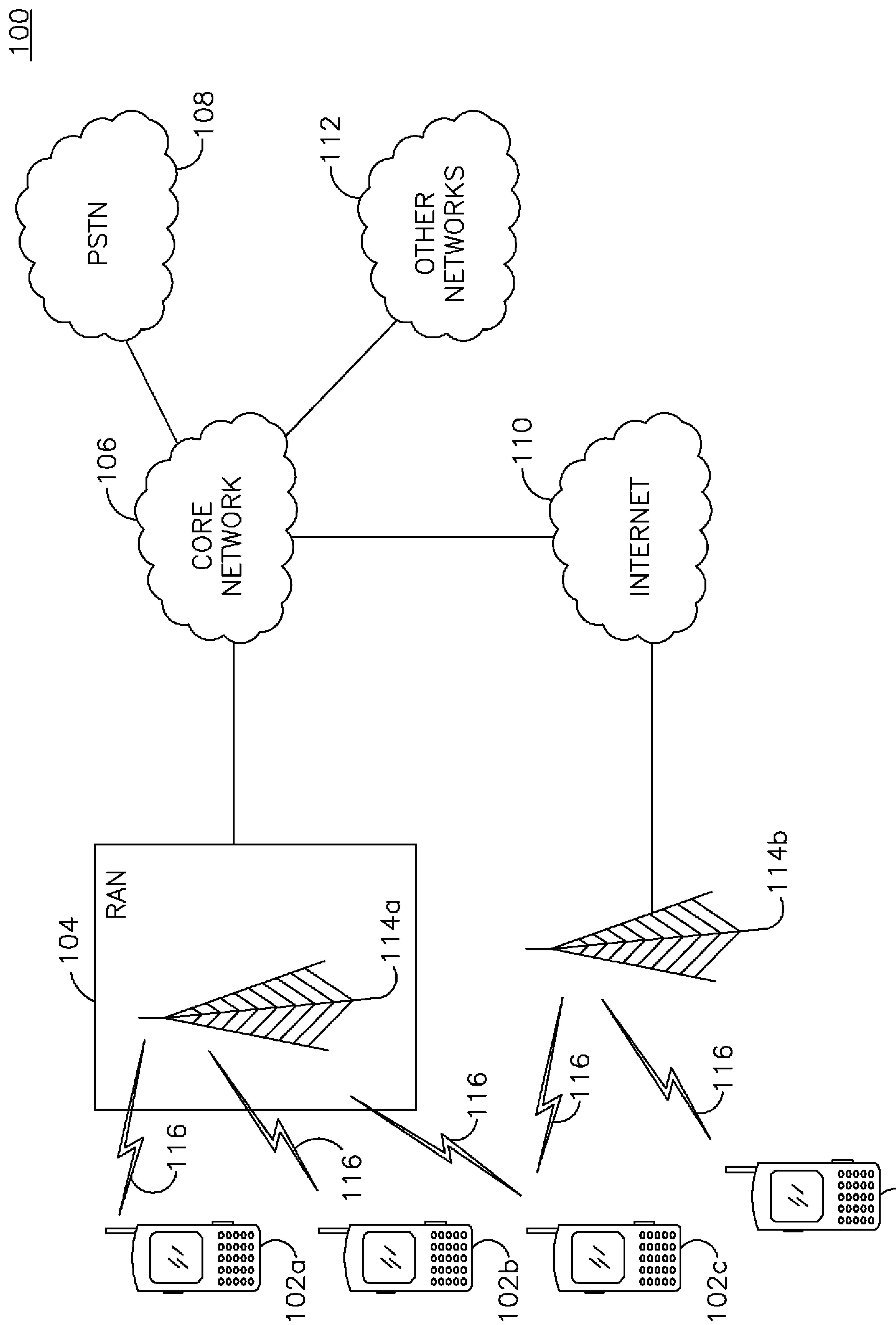
100
PSTN
108
OTHER NETWORKS
112
CORE NETWORK
106
INTERNET
110
RAN
104
114a
114b
116
116
116
116
116
102a
102b
102c
102d

FIG. 1A

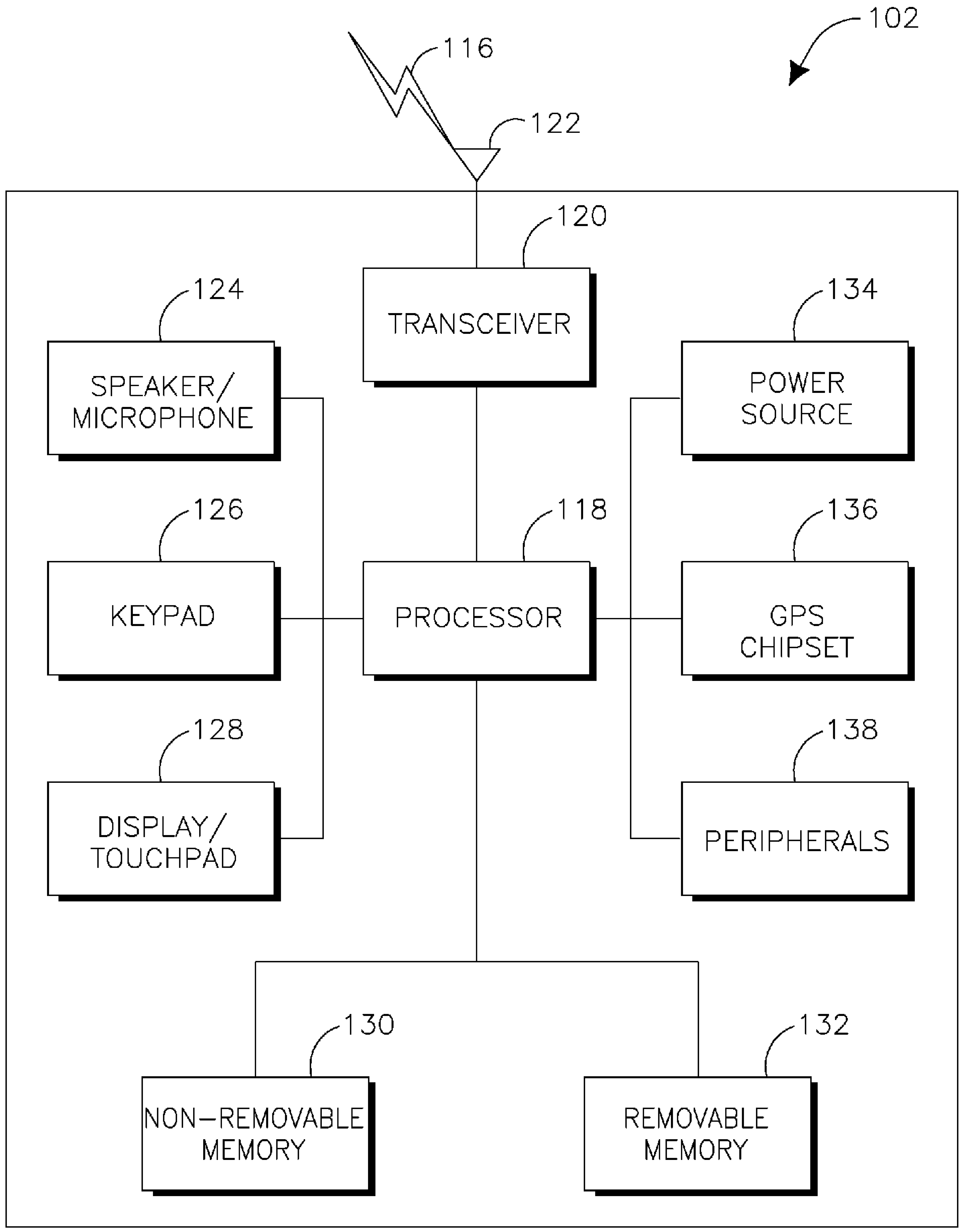
102
116
122
120
TRANSCEIVER
124
SPEAKER/
MICROPHONE
134
POWER
SOURCE
126
KEYPAD
118
PROCESSOR
136
GPS
CHIPSET
128
DISPLAY/
TOUCHPAD
138
PERIPHERALS
130
NON-REMOVABLE
MEMORY
132
REMOVABLE
MEMORY

FIG. 1B

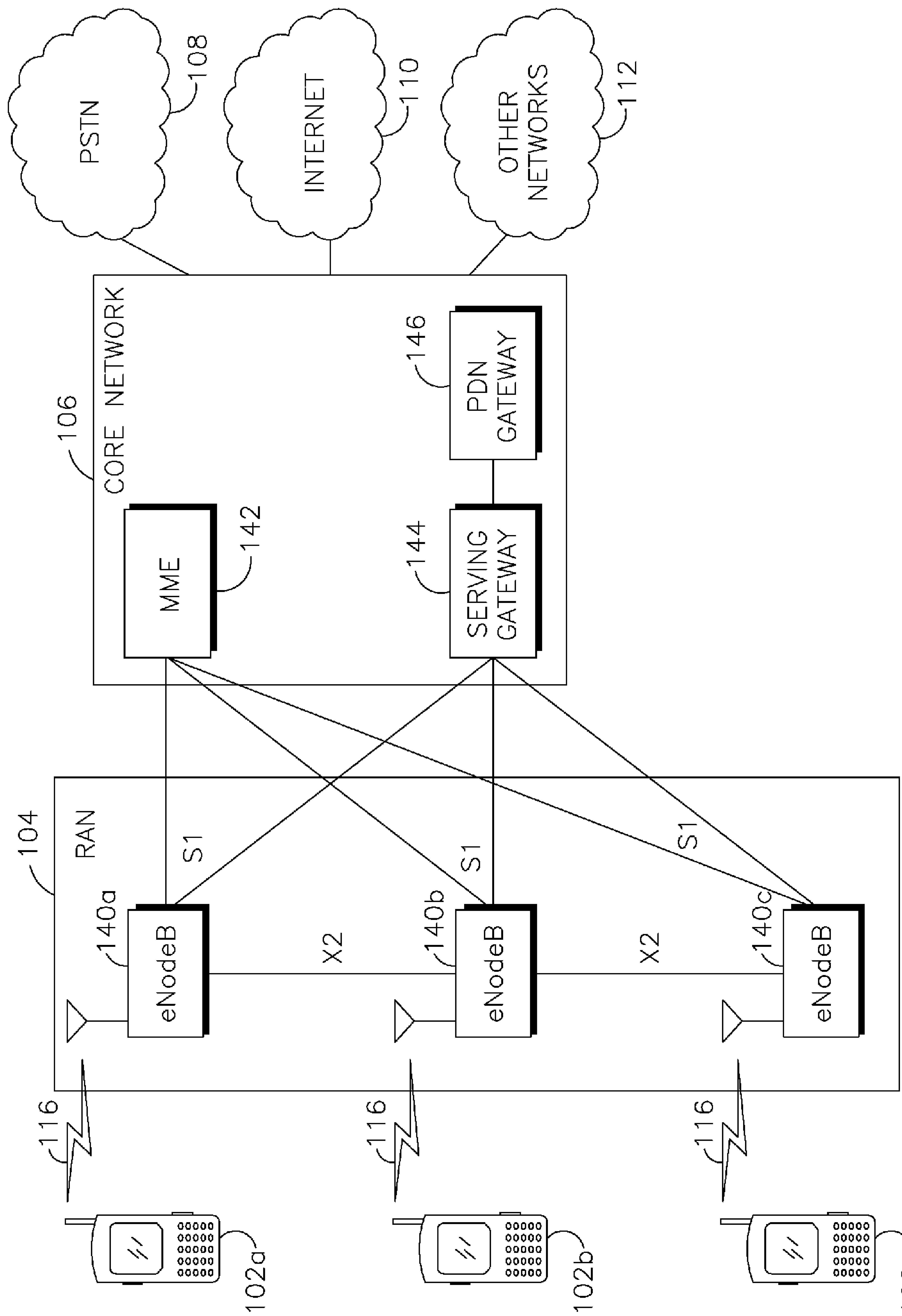
PSTN
108
INTERNET
110
OTHER NETWORKS
112
CORE NETWORK
106
MME
142
SERVING GATEWAY
144
PDN GATEWAY
146
RAN
104
S1
S1
S1
eNodeB
140a
eNodeB
140b
eNodeB
140c
X2
X2
116
116
116
102a
102b
102c

FIG. 1C

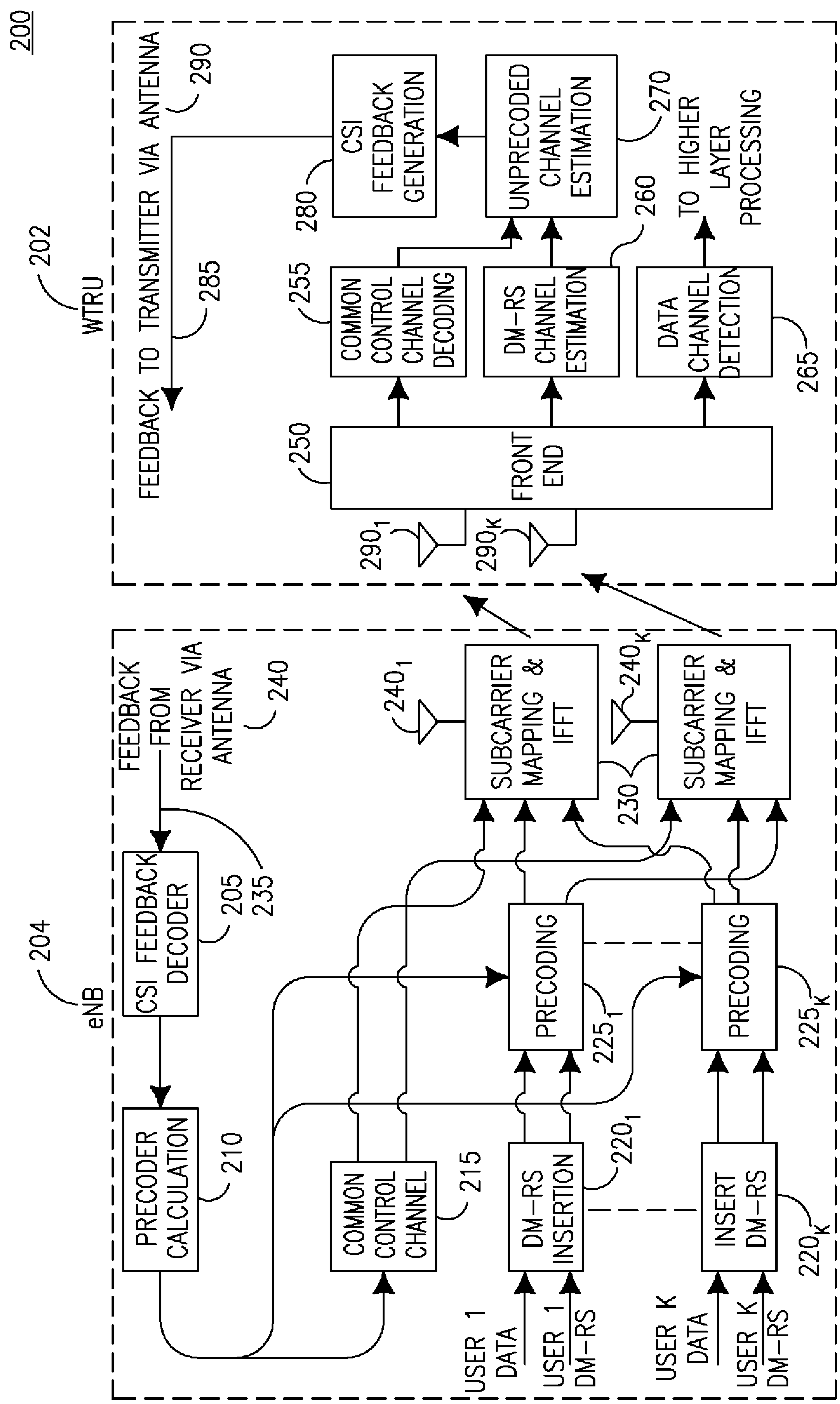
200
WTRU
202
FEEDBACK TO TRANSMITTER VIA ANTENNA
285
290
CSI FEEDBACK GENERATION
280
UNPRECODED CHANNEL ESTIMATION
270
COMMON CONTROL CHANNEL DECODING
255
DM-RS CHANNEL ESTIMATION
260
TO HIGHER LAYER PROCESSING
DATA CHANNEL DETECTION
265
FRONT END
250
290_1
290_K
eNB
204
FEEDBACK FROM RECEIVER VIA ANTENNA
240
CSI FEEDBACK DECODER
205
235
PRECODER CALCULATION
210
COMMON CONTROL CHANNEL
215
DM-RS INSERTION
220_1
INSERT DM-RS
220_K
PRECODING
225_1
PRECODING
225_K
SUBCARRIER MAPPING & IFFT
240_1
SUBCARRIER MAPPING & IFFT
240_K
230
USER 1 DATA
USER 1 DM-RS
USER K DATA
USER K DM-RS

FIG. 2

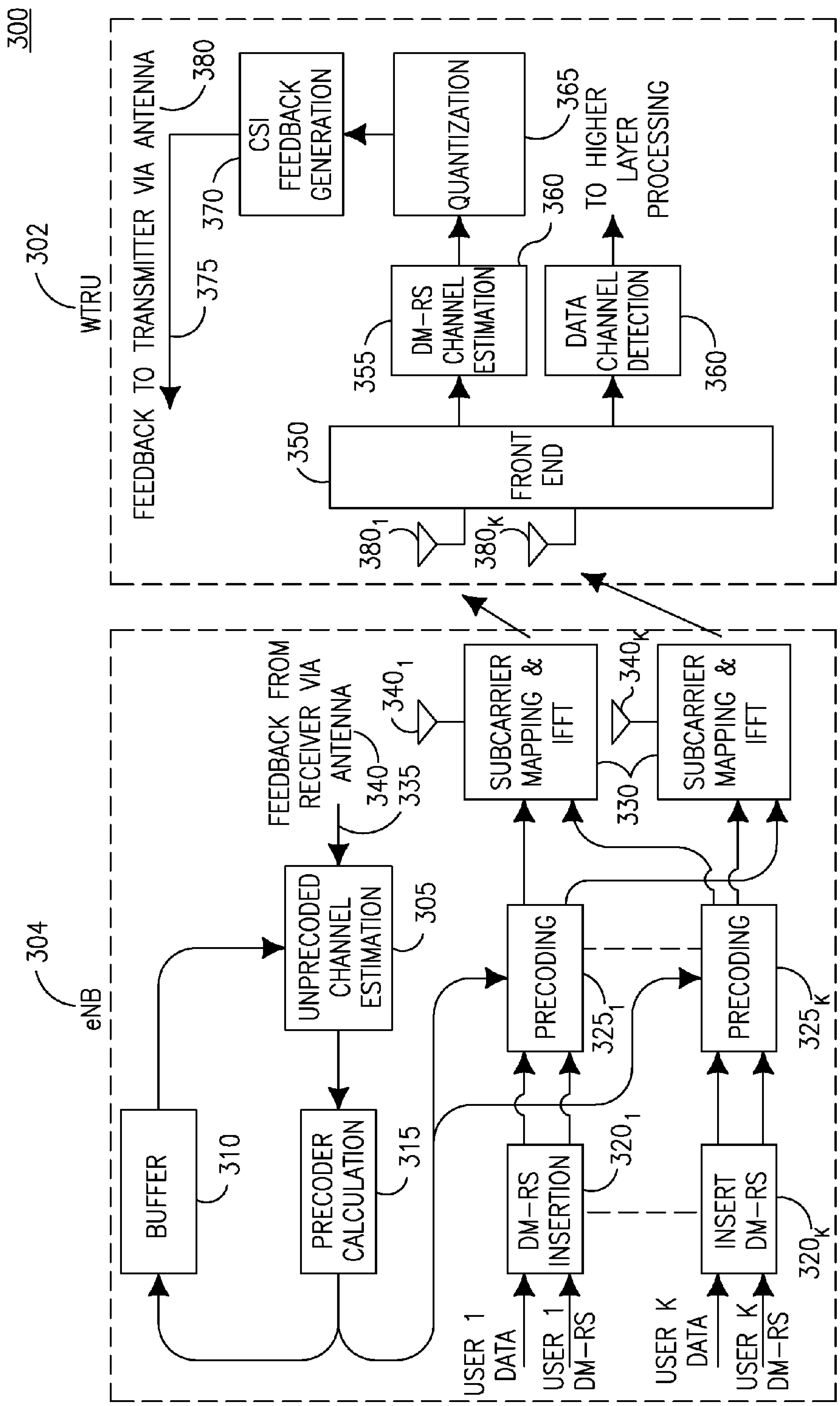
300
302
WTRU
FEEDBACK TO TRANSMITTER VIA ANTENNA
380
CSI FEEDBACK GENERATION
370
375
QUANTIZATION
365
360
TO HIGHER LAYER PROCESSING
DM-RS CHANNEL ESTIMATION
355
DATA CHANNEL DETECTION
360
350
FRONT END
380_1
380_K
304
eNB
BUFFER
310
UNPRECODED CHANNEL ESTIMATION
305
PRECODER CALCULATION
315
FEEDBACK FROM RECEIVER VIA ANTENNA
340
335
340_1
340_K
SUBCARRIER MAPPING & IFFT
SUBCARRIER MAPPING & IFFT
330
PRECODING
325_1
PRECODING
325_K
DM-RS INSERTION
320_1
INSERT DM-RS
320_K
USER 1 DATA
USER 1 DM-RS
USER K DATA
USER K DM-RS

FIG. 3

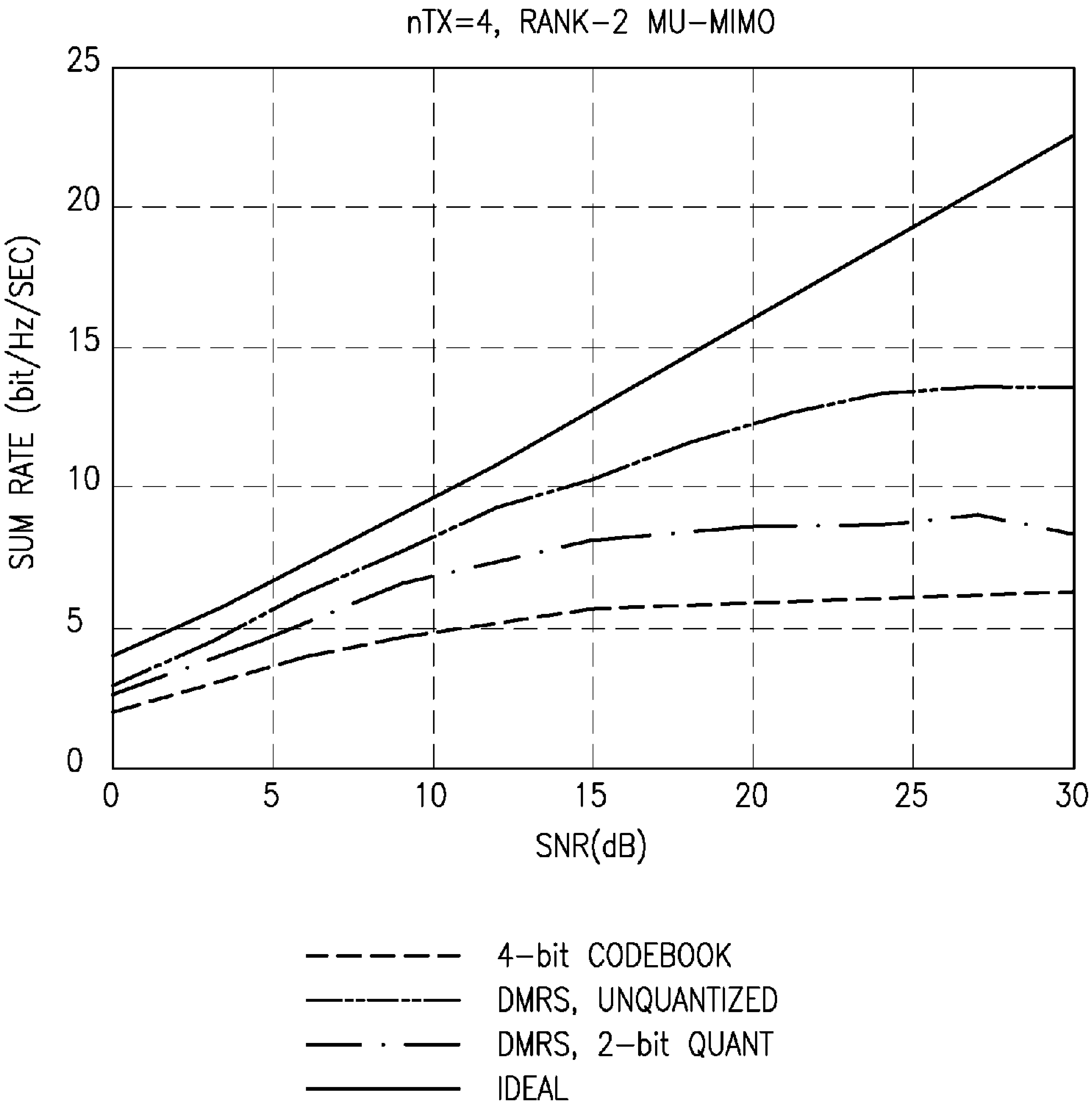
nTX=4, RANK-2 MU-MIMO
SUM RATE (bit/Hz/SEC)
25
20
15
10
5
0
0
5
10
15
20
25
30
SNR(dB)
4-bit CODEBOOK
DMRS, UNQUANTIZED
DMRS, 2-bit QUANT
IDEAL

FIG. 4

DEMODULATION REFERENCE SIGNAL BASED CHANNEL STATE INFORMATION FEEDBACK IN OFDM-MIMO SYSTEMS

CROSS REFERENCE TO RELATED APPLICATIONS

This application is a continuation of U.S. non-provisional application Ser. No. 13/169,529 filed on Jun. 27, 2011, which claims the benefit of U.S. Provisional Patent Application Nos. 61/359,605, filed on Jun. 29, 2010, and 61/421,116, filed on Dec. 8, 2010, the contents of each of which are hereby incorporated by reference herein.

TECHNICAL FIELD

This disclosed subject matter relates to wireless communications.

BACKGROUND

Orthogonal Frequency Division Multiplex (OFDM) is a multicarrier modulation scheme, where a data stream is transmitted using a number of multiplexed subcarriers. In OFDM multiple-input multiple-output (OFDM-MIMO) technology, multiple antennas are used to communicate OFDM data. According to some approaches to OFDM-MIMO, a wireless transmit/receive unit (WTRU) that is in communication with a base station may provide channel state information (CSI) to the base station to indicate properties of the air-link between the WTRU and the base station. In other approaches to OFDM-MIMO, a WTRU may provide CSI to a base station based on unprecoded channel state information reference signals (CSI-RS). While improvements have been made in recent years over previous approaches to the communication of CSI, further improvements to the generation, processing, and/or communication of CSI (such as but not limited to improvements that enhance the accuracy of CSI), may be needed.

SUMMARY

A method and apparatus for using demodulation reference signal (DM-RS) based channel state information (CSI) feedback in Orthogonal Frequency Division Multiplexing-multiple-input multiple-output (OFDM-MIMO) systems are disclosed. The wireless transmit/receive unit (WTRU) receives one or more resource blocks from a base station, where the resource blocks (RBs) include demodulating reference signals (DM-RS) and precoder information. The precoder information is sent unicast or broadcast over a common control channel. The WTRU estimates an effective channel estimate based on the DM-RS, derives an unprecoded channel based on the effective channel and the precoder information, generates CSI feedback based on the unprecoded channel, and transmits the CSI feedback to the base station. Alternatively, the WTRU estimates an effective channel estimate based on the DM-RS, quantizes the effective channel estimate and transmits the CSI feedback to the base station.

BRIEF DESCRIPTION OF THE DRAWINGS

A more detailed understanding may be had from the following description, given by way of example in conjunction with the accompanying drawings wherein:

FIG. **1**A is a system diagram of an example communications system in which one or more disclosed embodiments may be implemented;

FIG. **1**B is a system diagram of an example wireless transmit/receive unit (WTRU) that may be used within the communications system illustrated in FIG. **1**A;

FIG. **1**C is a system diagram of an example radio access network and an example core network that may be used within the communications system illustrated in FIG. **1**A;

FIG. **2** is an example of the channel state information feedback based on an unprecoded channel;

FIG. **3** is an example of a method to feedback an effective channel; and

FIG. **4** shows a performance comparison between an example scheme and existing schemes.

DETAILED DESCRIPTION

FIG. **1**A is a diagram of an example communications system **100** in which one or more disclosed embodiments may be implemented. The communications system **100** may be a multiple access system that provides content, such as voice, data, video, messaging, broadcast, etc., to multiple wireless users. The communications system **100** may enable multiple wireless users to access such content through the sharing of system resources, including wireless bandwidth. For example, the communications systems **100** may employ one or more channel access methods, such as code division multiple access (CDMA), time division multiple access (TDMA), frequency division multiple access (FDMA), orthogonal FDMA (OFDMA), single-carrier FDMA (SC-FDMA), and the like.

As shown in FIG. **1**A, the communications system **100** may include wireless transmit/receive units (WTRUs) **102***a*, **102***b*, **102***c*, **102***d*, a radio access network (RAN) **104**, a core network **106**, a public switched telephone network (PSTN) **108**, the Internet **110**, and other networks **112**, though it will be appreciated that the disclosed embodiments contemplate any number of WTRUs, base stations, networks, and/or network elements. Each of the WTRUs **102***a*, **102***b*, **102***c*, **102***d* may be any type of device configured to operate and/or communicate in a wireless environment. By way of example, the WTRUs **102***a*, **102***b*, **102***c*, **102***d* may be configured to transmit and/or receive wireless signals and may include user equipment (UE), a mobile station, a fixed or mobile subscriber unit, a pager, a cellular telephone, a personal digital assistant (PDA), a smartphone, a laptop, a netbook, a personal computer, a wireless sensor, consumer electronics, and the like.

The communications systems **100** may also include a base station **114***a* and a base station **114***b*. Each of the base stations **114***a*, **114***b* may be any type of device configured to wirelessly interface with at least one of the WTRUs **102***a*, **102***b*, **102***c*, **102***d* to facilitate access to one or more communication networks, such as the core network **106**, the Internet **110**, and/or the networks **112**. By way of example, the base stations **114***a*, **114***b* may be a base transceiver station (BTS), a Node-B (nodeB), an eNode B (eNodeB) or (eNB), a Home Node B (HNB), a Home eNode B (HeNB), a site controller, an access point (AP), a wireless router, and the like. While the base stations **114***a*, **114***b* are each depicted as a single element, it will be appreciated that the base stations **114***a*, **114***b* may include any number of interconnected base stations and/or network elements.

The base station **114***a* may be part of the RAN **104**, which may also include other base stations and/or network elements (not shown), such as a base station controller (BSC), a radio network controller (RNC), relay nodes, etc. The base station

114*a* and/or the base station **114***b* may be configured to transmit and/or receive wireless signals within a particular geographic region, which may be referred to as a cell (not shown). The cell may further be divided into cell sectors. For example, the cell associated with the base station **114***a* may be divided into three sectors. Thus, in one embodiment, the base station **114***a* may include three transceivers, i.e., one for each sector of the cell. In another embodiment, the base station **114***a* may employ multiple-input multiple-output (MIMO) technology and, therefore, may utilize multiple transceivers for each sector of the cell.

The base stations **114***a*, **114***b* may communicate with one or more of the WTRUs **102***a*, **102***b*, **102***c*, **102***d* over an air interface **116**, which may be any suitable wireless communication link (e.g., radio frequency (RF), microwave, infrared (IR), ultraviolet (UV), visible light, etc.). The air interface **116** may be established using any suitable radio access technology (RAT).

More specifically, as noted above, the communications system **100** may be a multiple access system and may employ one or more channel access schemes, such as CDMA, TDMA, FDMA, OFDMA, SC-FDMA, and the like. For example, the base station **114***a* in the RAN **104** and the WTRUs **102***a*, **102***b*, **102***c* may implement a radio technology such as Universal Mobile Telecommunications System (UMTS) Terrestrial Radio Access (UTRA), which may establish the air interface **116** using wideband CDMA (WCDMA). WCDMA may include communication protocols such as High-Speed Packet Access (HSPA) and/or Evolved HSPA (HSPA+). HSPA may include High-Speed Downlink Packet Access (HSDPA) and/or High-Speed Uplink Packet Access (HSUPA).

In another embodiment, the base station **114***a* and the WTRUs **102***a*, **102***b*, **102***c* may implement a radio technology such as Evolved UMTS Terrestrial Radio Access (E-UTRA), which may establish the air interface **116** using Long Term Evolution (LTE) and/or LTE-Advanced (LTE-A).

In other embodiments, the base station **114***a* and the WTRUs **102***a*, **102***b*, **102***c* may implement radio technologies such as IEEE 802.16 (i.e., Worldwide Interoperability for Microwave Access (WiMAX)), CDMA2000, CDMA2000 1×, CDMA2000 EV-DO, Interim Standard 2000 (IS-2000), Interim Standard 95 (IS-95), Interim Standard 856 (IS-856), Global System for Mobile communications (GSM), Enhanced Data rates for GSM Evolution (EDGE), GSM EDGE (GERAN), and the like.

The base station **114***b* in FIG. **1**A may be a wireless router, Home Node B, Home eNode B, or access point, for example, and may utilize any suitable RAT for facilitating wireless connectivity in a localized area, such as a place of business, a home, a vehicle, a campus, and the like. In one embodiment, the base station **114***b* and the WTRUs **102***c*, **102***d* may implement a radio technology such as IEEE 802.11 to establish a wireless local area network (WLAN). In another embodiment, the base station **114***b* and the WTRUs **102***c*, **102***d* may implement a radio technology such as IEEE 802.15 to establish a wireless personal area network (WPAN). In yet another embodiment, the base station **114***b* and the WTRUs **102***c*, **102***d* may utilize a cellular-based RAT (e.g., WCDMA, CDMA2000, GSM, LTE, LTE-A, etc.) to establish a picocell or femtocell. As shown in FIG. **1**A, the base station **114***b* may have a direct connection to the Internet **110**. Thus, the base station **114***b* may not be required to access the Internet **110** via the core network **106**.

The RAN **104** may be in communication with the core network **106**, which may be any type of network configured to provide voice, data, applications, and/or voice over internet protocol (VoIP) services to one or more of the WTRUs **102***a*, **102***b*, **102***c*, **102***d*. For example, the core network **106** may provide call control, billing services, mobile location-based services, pre-paid calling, Internet connectivity, video distribution, etc., and/or perform high-level security functions, such as user authentication. Although not shown in FIG. **1**A, it will be appreciated that the RAN **104** and/or the core network **106** may be in direct or indirect communication with other RANs that employ the same RAT as the RAN **104** or a different RAT. For example, in addition to being connected to the RAN **104**, which may be utilizing an E-UTRA radio technology, the core network **106** may also be in communication with another RAN (not shown) employing a GSM radio technology.

The core network **106** may also serve as a gateway for the WTRUs **102***a*, **102***b*, **102***c*, **102***d* to access the PSTN **108**, the Internet **110**, and/or other networks **112**. The PSTN **108** may include circuit-switched telephone networks that provide plain old telephone service (POTS). The Internet **110** may include a global system of interconnected computer networks and devices that use common communication protocols, such as the transmission control protocol (TCP), user datagram protocol (UDP) and the internet protocol (IP) in the TCP/IP internet protocol suite. The networks **112** may include wired or wireless communications networks owned and/or operated by other service providers. For example, the networks **112** may include another core network connected to one or more RANs, which may employ the same RAT as the RAN **104** or a different RAT.

Some or all of the WTRUs **102***a*, **102***b*, **102***c*, **102***d* in the communications system **100** may include multi-mode capabilities, i.e., the WTRUs **102***a*, **102***b*, **102***c*, **102***d* may include multiple transceivers for communicating with different wireless networks over different wireless links. For example, the WTRU **102***c* shown in FIG. **1**A may be configured to communicate with the base station **114***a*, which may employ a cellular-based radio technology, and with the base station **114***b*, which may employ an IEEE 802 radio technology.

FIG. **1**B is a system diagram of an example WTRU **102**. As shown in FIG. **1**B, the WTRU **102** may include a processor **118**, a transceiver **120**, a transmit/receive element **122**, a speaker/microphone **124**, a keypad **126**, a display/touchpad **128**, non-removable memory **106**, removable memory **132**, a power source **134**, a global positioning system (GPS) chipset **136**, and other peripherals **138**. It will be appreciated that the WTRU **102** may include any sub-combination of the foregoing elements while remaining consistent with an embodiment.

The processor **118** may be a general purpose processor, a special purpose processor, a conventional processor, a digital signal processor (DSP), a plurality of microprocessors, one or more microprocessors in association with a DSP core, a controller, a microcontroller, Application Specific Integrated Circuits (ASICs), Field Programmable Gate Array (FPGAs) circuits, any other type of integrated circuit (IC), a state machine, and the like. The processor **118** may perform signal coding, data processing, power control, input/output processing, and/or any other functionality that enables the WTRU **102** to operate in a wireless environment. The processor **118** may be coupled to the transceiver **120**, which may be coupled to the transmit/receive element **122**. While FIG. **1**B depicts the processor **118** and the transceiver **120** as separate components, it will be appreciated that the processor **118** and the transceiver **120** may be integrated together in an electronic package or chip.

The transmit/receive element **122** may be configured to transmit signals to, or receive signals from, a base station (e.g., the base station **114***a*) over the air interface **116**. For example, in one embodiment, the transmit/receive element **122** may be an antenna configured to transmit and/or receive RF signals. In another embodiment, the transmit/receive element **122** may be an emitter/detector configured to transmit and/or receive IR, UV, or visible light signals, for example. In yet another embodiment, the transmit/receive element **122** may be configured to transmit and receive both RF and light signals. It will be appreciated that the transmit/receive element **122** may be configured to transmit and/or receive any combination of wireless signals.

In addition, although the transmit/receive element **122** is depicted in FIG. **1**B as a single element, the WTRU **102** may include any number of transmit/receive elements **122**. More specifically, the WTRU **102** may employ MIMO technology. Thus, in one embodiment, the WTRU **102** may include two or more transmit/receive elements **122** (e.g., multiple antennas) for transmitting and receiving wireless signals over the air interface **116**.

The transceiver **120** may be configured to modulate the signals that are to be transmitted by the transmit/receive element **122** and to demodulate the signals that are received by the transmit/receive element **122**. As noted above, the WTRU **102** may have multi-mode capabilities. Thus, the transceiver **120** may include multiple transceivers for enabling the WTRU **102** to communicate via multiple RATs, such as UTRA and IEEE 802.11, for example.

The processor **118** of the WTRU **102** may be coupled to, and may receive user input data from, the speaker/microphone **124**, the keypad **126**, and/or the display/touchpad **128** (e.g., a liquid crystal display (LCD) display unit or organic light-emitting diode (OLED) display unit). The processor **118** may also output user data to the speaker/microphone **124**, the keypad **126**, and/or the display/touchpad **128**. In addition, the processor **118** may access information from, and store data in, any type of suitable memory, such as the non-removable memory **106** and/or the removable memory **132**. The non-removable memory **106** may include random-access memory (RAM), read-only memory (ROM), a hard disk, or any other type of memory storage device. The removable memory **132** may include a subscriber identity module (SIM) card, a memory stick, a secure digital (SD) memory card, and the like. In other embodiments, the processor **118** may access information from, and store data in, memory that is not physically located on the WTRU **102**, such as on a server or a home computer (not shown).

The processor **118** may receive power from the power source **134**, and may be configured to distribute and/or control the power to the other components in the WTRU **102**. The power source **134** may be any suitable device for powering the WTRU **102**. For example, the power source **134** may include one or more dry cell batteries (e.g., nickel-cadmium (NiCd), nickel-zinc (NiZn), nickel metal hydride (NiMH), lithium-ion (Li-ion), etc.), solar cells, fuel cells, and the like.

The processor **118** may also be coupled to the GPS chipset **136**, which may be configured to provide location information (e.g., longitude and latitude) regarding the current location of the WTRU **102**. In addition to, or in lieu of, the information from the GPS chipset **136**, the WTRU **102** may receive location information over the air interface **116** from a base station (e.g., base stations **114***a*, **114***b*) and/or determine its location based on the timing of the signals being received from two or more nearby base stations. It will be appreciated that the WTRU **102** may acquire location information by way of any suitable location-determination method while remaining consistent with an embodiment.

The processor **118** may further be coupled to other peripherals **138**, which may include one or more software and/or hardware modules that provide additional features, functionality and/or wired or wireless connectivity. For example, the peripherals **138** may include an accelerometer, an e-compass, a satellite transceiver, a digital camera (for photographs or video), a universal serial bus (USB) port, a vibration device, a television transceiver, a hands free headset, a Bluetooth® module, a frequency modulated (FM) radio unit, a digital music player, a media player, a video game player module, an Internet browser, and the like.

FIG. **1**C is a system diagram of the RAN **104** and the core network **106** according to an embodiment. As noted above, the RAN **104** may employ an E-UTRA radio technology to communicate with the WTRUs **102***a*, **102***b*, and **102***c* over the air interface **116**. The RAN **104** may also be in communication with the core network **106**.

The RAN **104** may include eNodeBs **140***a*, **140***b*, **140***c*, though it will be appreciated that the RAN **104** may include any number of eNBs while remaining consistent with an embodiment. The eNBs **140***a*, **140***b*, **140***c* may each include one or more transceivers for communicating with the WTRUs **102***a*, **102***b*, **102***c* over the air interface **116**. In one embodiment, the eNBs **140***a*, **140***b*, **140***c* may implement MIMO technology. Thus, the eNB **140***a*, for example, may use multiple antennas to transmit wireless signals to, and receive wireless signals from, the WTRU **102***a*.

Each of the eNBs **140***a*, **140***b*, and **140***c* may be associated with a particular cell (not shown) and may be configured to handle radio resource management decisions, handover decisions, scheduling of users in the uplink and/or downlink, and the like. As shown in FIG. **1**C, the eNBs **140***a*, **140***b*, **140***c* may communicate with one another over an X2 interface.

The core network **106** shown in FIG. **1**C may include a mobility management gateway (MME) **142**, a serving gateway **144**, and a packet data network (PDN) gateway **146**. While each of the foregoing elements are depicted as part of the core network **106**, it will be appreciated that any one of these elements may be owned and/or operated by an entity other than the core network operator.

The MME **142** may be connected to each of the eNBs **142***a*, **142***b*, and **142***c* in the RAN **104** via an S1 interface and may serve as a control node. For example, the MME **142** may be responsible for authenticating users of the WTRUs **102***a*, **102***b*, **102***c*, bearer activation/deactivation, selecting a particular serving gateway during an initial attach of the WTRUs **102***a*, **102***b*, **102***c*, and the like. The MME **142** may also provide a control plane function for switching between the RAN **104** and other RANs (not shown) that employ other radio technologies, such as GSM or WCDMA.

The serving gateway **144** may be connected to each of the eNode Bs **140***a*, **140***b*, **140***c* in the RAN **104** via the S1 interface. The serving gateway **144** may generally route and forward user data packets to/from the WTRUs **102***a*, **102***b*, **102***c*. The serving gateway **144** may also perform other functions, such as anchoring user planes during inter-eNode B handovers, triggering paging when downlink data is available for the WTRUs **102***a*, **102***b*, **102***c*, managing and storing contexts of the WTRUs **102***a*, **102***b*, **102***c*, and the like.

The serving gateway **144** may also be connected to the PDN gateway **146**, which may provide the WTRUs **102***a*, **102***b*, **102***c* with access to packet-switched networks, such as the Internet **110**, to facilitate communications between the WTRUs **102***a*, **102***b*, **102***c* and IP-enabled devices.

The core network **106** may facilitate communications with other networks. For example, the core network **106** may provide the WTRUs **102***a*, **102***b*, **102***c* with access to circuit-switched networks, such as the PSTN **108**, to facilitate communications between the WTRUs **102***a*, **102***b*, **102***c* and traditional land-line communications devices. For example, the core network **106** may include, or may communicate with, an IP gateway (e.g., an IP multimedia subsystem (IMS) server) that serves as an interface between the core network **106** and the PSTN **108**. In addition, the core network **106** may provide the WTRUs **102***a*, **102***b*, **102***c* with access to the networks **112**, which may include other wired or wireless networks that are owned and/or operated by other service providers.

The eNBs **140***a*, **140***b*, **140***c* and the WTRUs **102***a*, **102***b*, **102***c* may communicate a number of different types of downlink signaling in order to provide feedback on the quality, reliability, and throughout of the communication that takes place over the air interface **116**. The control information may include channel state information reference signal (CSI-RS) information, demodulation reference signal (DM-RS) information, information related to precoding matrices, and/or other types of information. Examples of this downlink signaling will be provided in detail below with reference to eNB **140***a* and WTRU **102***a*, though this information may be communicated by any or any combination of the eNBs **140***a*, **140***b*, **140***c* and the WTRUs **102***a*, **102***b*, **102***c* shown in FIG. 1C.

Downlink signaling communicated from the eNB **140***a* to the WTRU **102***a* includes DM-RS information and the WTRU **102***a* may perform channel quality measurements using the DM-RS information. Performing the channel quality measurements may include estimating the non-precoded channel to which the DM-RS information relates, measuring the effective channel, and generating corresponding CSI feedback information. The WTRU **102***a* may then transmit the CSI feedback information to the eNB **140***a*.

In an example where the downlink signaling from the eNB **140***a* to the WTRU **102***a* may include information related to precoding matrices, the eNB **140***a* may broadcast precoding matrices during transmission time interval (TTI) periods. The information included in the broadcast may have been previously used in the prior N TTIs, where the value for N may be a design parameter, or may be presently used in a current TTI, or may pertain to future TTIs. Alternatively or additionally, information included in the broadcast may include one or more of a transmitted precoding matrix indicator (TPMI) parameter, a parameter that indicates a transmission rank M, or a parameter that indicates a scrambling identity (ScID). As one example, a value for ScID may be of 1-bit length for transmission on an antenna port 7 or 8. When operating, for example, in LTE Release 9, multi-user multiple input multiple output system (MU-MIMO) mode; the eNB may send data and DM-RS on either antenna 7 or 8. The value of ScID may indicate whether antenna port 7 or 8 may be used for transmission.

In an example where the downlink signaling includes a TPMI parameter, the eNB **140** a may schedule the frequency of the transmission of the TPMI parameter in a number of different ways. As one example, the eNB **140***a* may schedule (and correspondingly broadcast) in terms of TTIs. In some instances, the eNB **140***a* may use a sparse broadcast of the TPMI (i.e., broadcasting every K TTIs), and in other instances, the eNB **140***a* may use a more frequent broadcast of the TPMI. Alternatively or additionally, the eNB **140***a* may schedule (and correspondingly broadcast) the TPMI on several RBs (associated with resource block bundling). Resource block bundling reduces the amount of overhead associated with TPMI broadcasting. A resource block may be defined as 7 or 6 consecutive OFDM symbols in the time domain depending on the cyclic prefix length and 12 consecutive sub-carriers (180 kHz) in the frequency domain. A RB may carry data for the WTRU **102***a* as well as for one or more other WTRUs. Also, in such an instance, the precoder W(n) may not only be a function of the airlink, channel H, the airlink between the eNB **140***a* and WTRU **102***a*, but also a function of the airlink between the eNB **140***a* and other WTRUs co-scheduled with WTRU **102***a*.

In some approaches to OFDM-MIMO, a precoder W(n) may be used. Further, in some approaches to OFDM-MIMO, such as the approach described in LTE-Advanced (LTE-A)/LTE Release 10, WTRU **102***a* may not have the knowledge of the precoder function W(n). In an example where the eNB **140***a* and the WTRU **102***a* may implement such an approach, the eNB **140***a* and WTRU **102***a* may include certain features. For example, the eNB **140** may transmit data on an RB over consecutive TTI's to any WTRU in the system, including but not limited to WTRU **102***a*. The WTRU **102***a* may then make estimation over consecutive TTI's from DM-RS on the RB to obtain effective channel estimates, and store the effective channel estimates into memory. Also, WTRU **102***a* may make an estimation based on the RB transmitted to other WTRUs. The eNB **140***a* may choose (either periodically, or triggered by certain events) to broadcast the precoding related information for N TTIs. An example event may be when the eNB **140***a* detects a sufficiently large number of WTRUs located in a high signal to noise ratio (SNR) region or area. In such instances, high accuracy of CSI feedback may be desired. When the precoding related information (or precoders, or precoding indexes) are broadcast, a common control channel may be added to the downlink, to which all WTRUs **102***a*, **102***b*, **102***c* have access.

In some instances, the eNB **140** may transmit an RB consisting of no user data. Within such RB, the eNB **140** may choose to transmit DM-RS precoded according to predetermined precoder so that no precoding information is needed to be broadcasted. During normal transmission where user data is transmitted on an RB, there may be a preferred transmission precoder to be used so that the data transmission may be optimized. For proper data reception, the same precoder may be applied to DM-RS on the same RB. However, when no data is present, one may use any precoder for DM-RS. For convenience, one may predefine a set of precoders for use in such cases. An example of a predetermined precoder is a subset of column vectors of an identity matrix.

The eNB **140***a* may also choose to indicate an invalid TTI. An invalid TTI may be a TTI that does not contain a valid DM-RS. This may be due to a mismatch between the eNB **140***a* and WTRU **102***a*, WTRU **102***b*, WTRU **102***c* being on different standard releases. The WTRU **102***a* may not include the invalid TTI in the channel estimation based on DM-RS. Upon receiving information of precoder W(n), along with the channel estimate made in the past TTIs, the WTRU **102***a* may be able to estimate the unprecoded channel. Various channel estimation algorithms may be used, such as least square (LS) or linear minimum mean square error (LMMSE). The precoder may be selected from a predetermined codebook, therefore only the index to the entry of codebook (e.g., TPMI) needs to be sent by broadcast or unicast from the eNB **140***a*. Alternatively, the precoder may be quantized element-wise first, then sent from the eNB **140***a*. In another option, the non-codebook based precoder may be first quantized into a predetermined codebook and its index may then be sent. At the WTRU **102***a*, the quantized precoder may then be treated as if it were used in an actual data transmission.

In addition or as an alternative to the approaches described above, the WTRU **102***a* may use DM-RS alone to generate

CSI. This may be performed at the WTRU **102***a* as follows. The WTRU **102***a* may first determine the effective channel estimate from DM-RS using, for example, least mean square (LMS) approach. The effective channel may be shown below in Equation (1). In Equation (1), for the resource blocks (RBs) of interest, W(n) represents the precoding matrix at nth TTI. $H_m(n)$ represents the vector channel to the mth antenna of the WTRU **102***a*, and $h_{\theta,m}(n)$ represents the effective channel measured by the WTRU **102***a* from DM-RS.

$$h_{\theta,m}(n)=W^T(n)H_m^T(n)+z(n) \quad \text{Equation (1)}$$

In a slow varying channel, it may be assumed that the channel remains constant for a certain period, i.e.: $H_m(1)=H_m(2)= \ldots =H_m$

The system model becomes:

$$\overline{H}_{\theta,m}=\overline{W}H_m^T+Z \quad \text{Equation (2)}$$

where

$\overline{H}_{\theta,m}(h_{\theta,m}(1) \ldots h_{\theta,m}(N))^T$

and

$\overline{W}=W(1) \ldots W(N))^T$

A minimal mean square error estimate (MMSE) of the unprecoded channel becomes:

$$\hat{H}_m^T=\overline{W}^H(\overline{W}\overline{W}^H+\sigma_n^2 I)^{-1}\overline{H}_{\theta,m} \quad \text{Equation (3)}$$

The process continues for each receive antenna m, and the whole matrix channel (unprecoded) may be estimated. Based on this estimated channel matrix, proper feedback may be derived and fed back.

The channel estimation formula in Equation (3) may be extended to cases where the channel may not be constant during the time duration of interest. Assuming the WTRU **102***a* may have knowledge of effective channels and the precoder for TTI numbers from 1 to N, and the WTRU **102***a* may estimate the channel for TTI n, then

$$\hat{H}_m^T(n)=E[H_m^T(n)\overline{H}_{\theta,m}^H](E[\overline{H}_{\theta,m}\overline{H}_{\theta,m}^H])^{-1}\overline{H}_{\theta,m} \quad \text{Equation (4)}$$

The Equation (4) may also be extended to cross multiple resource blocks, and the second order statistics may be calculated based on Doppler frequency and channel delay profile.

In an attempt to make use of all reference symbols available in the operations in Equations (3) and (4), the DM-RS may be combined with the CSI-RS.

Equations (3) and (4) may be physically implemented at the eNB **140**, WTRU **102***a* or both. In a first embodiment, WTRU **102***a* may measure effective channel based on DM-RS, receive precoding matrix information W(n), and perform Equations (3) and (4) to obtain unprecoded channel estimate. Based on unprecoded channel estimate, the WTRU **102***a* may generate CSI feedback to the eNB **140***a*, which in turn may generate transmit the precoding matrix for subsequent data transmission. In a second embodiment, WTRU **102***a* may first quantize the effective channel estimate and feeds it back to eNB **140***a*. Since the eNB has all information regarding the previous precoding matrices, it may perform the operations in Equations (3) and (4) to obtain unprecoded channel, and derive proper a precoding matrix for subsequent transmission accordingly.

The eNB **140***a* may broadcast scheduling information (e.g., the number of WTRUs scheduled in the resource block). The eNB **140***a* may use a simple bit map to indicate that there is at least one WTRU **102***a* transmitted on the resource block or none.

The eNB **140***a* may designate a sub-band for which DM-RS based CSI is fed back. Such a sub-band may be scheduled to a WTRU **102***a* that likely requires high accuracy CSI at the eNB **140***a* (e.g., the WTRUs that are likely to be in MU-MIMO mode, or in coordinated multi-point transmission and reception (CoMP) operation). Only the precoding related information and scheduling information of such a designated sub-band may be broadcast to reduce overall overhead.

The eNB **140***a* may also designate one or several sub-bands on which the transmission may be limited to rank M for certain period of time. The value of M may then be sent to WTRU **102***a*, **102***b*, **102***c* via high level signaling. While reporting DM-RS feedback, the WTRU **102***a*, **102***b*, **102***c* may be transmitted on the sub-band (s) on the corresponding M DM-RS antenna ports.

The eNB **140***a* may choose not to broadcast certain information, such as rank, scheduling information, or ScID, and instead rely on the WTRU **102***a* to retrieve the information via blind detection.

When the eNB **140***a* broadcasts precoder related information, the WTRU **102***a* may monitor and measure an effective channel from DM-RS, even though the WTRU **102***a* may not be the intended recipient of the resource blocks where the DM-RS is located. If some information, such as rank, scheduling or ScID is not signaled to the WTRU **102***a*, the WTRU **102***a* may perform blind detection to determine such parameters. The WTRU **102***a* may perform channel estimation on all DM-RS ports to obtain the precoded downlink channel (or effective channel). The WTRU **102***a* may perform channel estimation on the first M DM-RS ports to obtain the precoded downlink channel (or effective channel). By way of example, the value for M may be equal to 1. The WTRU **102***a* may make consecutive estimations on the resource block, and store the measured effective channel estimates into memory.

Upon receiving broadcasted precoding matrices, along with the channel estimate made in the past TTIs, the WTRU **102***a* may be able to estimate the nonprecoded channel. Various channel estimation algorithms may be used. Based on the estimated channel matrix, proper feedback may be derived and fed back.

The eNB **140***a* may send the precoder information to WTRU **102***a*, **102***b*, **102***c*, either via broadcast or unicast, therefore, increasing downlink channel overhead. In certain circumstances, it may be preferred to eliminate the need to send precoding matrix information from the eNB **140***a*. Under such circumstances, eNB **140***a* may request the WTRU **102***a*, **102***b*, **102***c* to feedback the quantized effective channel estimate, which is measured from DM-RS. Since the eNB **140***a* already has information of past precoding matrices, it may calculate the unprecoded channel estimate based on Equations (3) or (4).

Another approach to calculate unprecoded channel estimates at the eNB **140***a* other than Equations (3) or (4) may be a recursive approach similar to the least mean square (LMS) algorithm, which is outlined below. In this instance, the WTRU **102***a* may measure the effective channel from the DM-RS and feedback the quantized effective channel estimate to the eNB **140***a*. The eNB **140***a* may then reconstruct non-precoded CSI and use the feedback information for downlink scheduling with respect to WTRU **102***a* selection and proper precoding matrices.

There may be a pre-agreement between the eNB **140***a* and WTRU **102***a* that the DM-RS may be non-precoded. In this case the WTRU **102***a* may make use of the non-precoded DM-RS along with the CSI-RS to estimate non-precoded state information. A non-precoded DM-RS may be either due to the eNB **140***a* having other purposes such as interleaving or the WTRU **102***a* may request a non-precoded DM-RS such as for a joint RB channel estimate for the control channel, or that no user data may be carried on the RB. The non-precoded CSI may be quantized for feedback. Compared with channel estimation with only sparse CSI-RS, there may be more DM-RS symbols available to obtain more accurate channel estimates. Since data may still be precoded, the effective channel may be derived from the WTRU **102***a* with the help of the available broadcast precoding matrix. The WTRU **102***a* may also choose to feedback the quantized effective channel estimate to eNB **140***b*, **140***c*, or **140***d* for precoding. This may be done in view of a pre-agreement with the eNB **140***a*.

In the recursive approach, it may be assumed at time instant n, the eNB **140***a* has the current channel knowledge, $H_m(n)$, corresponding to the channel between the mth receive antenna to transmit antennas. Also assume the precoding matrix used by the eNB **140***a* transmitter to be W(n). The eNB **140***a* may then calculate its own version of the effective channel

$$H_{m,\theta_{NB}}(n)=H_m(n)W(n) \quad \text{Equation (5)}$$

Upon receiving the precoded DM-RS, the WTRU **102***a* may make channel estimations based on DM-RS, quantize the channel estimate, and feedback to the eNB **140***a*. Let the DM-RS feedback be, $H_{m,\theta_{UE}}(n)$, the eNB **140***a* may then update its CSI information upon receiving the feedback:

$$H_m(n+1)=H_m(n)+\mu W^H(n)(H_{m,\theta_{UE}}(n)-H_{m,\theta_{NB}}(n))^- \quad \text{Equation (6)}$$

After updating the CSI corresponding to WTRU **102***a*, **102***b*, **102***c* receive antennas, the eNB **140***a* may derive proper precoding matrix based certain criteria.

The aforementioned method may also be extended to combine both DM-RS and CSI-RS in order to provide better performance. If proper care is taken in identifying the precoder associated with CSI-RS with respect to the precoding matrices, both Equations (3) and (4) may be still applicable. The precoding matrix corresponding to CSI-RS from the kth transmit antenna is a column vector with its kth element equal to 1, and other elements equal to 0.

The channel estimation accuracy described above relies on the property of the aggregated precoding matrix defined in Equation (3). A necessary condition is that the rank of this matrix may be no less than the number of eNB **140***a* antennas. To reduce overhead, it may be preferred for an eNB **140***a* to check the property of this matrix, and only send it to WTRU **102***a*, when the rank condition is met. Similarly, it may be preferred for the eNB **140***a* to request WTRU **102***a* feedback only when the precoding matrices to be used may constitute an aggregated precoding matrix with a rank no less than the number of eNB **140***a* transmit antennas.

There may be several options for WTRU **102***a* feedback. For example, the WTRU **102***a* may feedback the quantized precoded downlink channel (or effective channel) on the physical uplink control channel (PUCCH) or the physical uplink shared channel (PUSCH) to the eNB **140***a*. Alternatively, in order to save uplink overhead, an uplink sounding reference signal (SRS) may be modulated with an un-quantized precoded downlink channel (or effective channel). The WTRU **102***a* uplink SRS transmission may alternate between unmodulated SRS and modulated SRS.

The WTRU **102***a* may feedback an effective channel across the whole system bandwidth, and may be directed by the network only to feedback the effective channel on a subband. The network may designate a subband for the WTRU **102***a* that requires high accuracy of CSI at eNB **140***a* transmitter.

The WTRU **102***a* may feedback an effective channel on all M antenna ports that carries data transmission. M may be signaled by the eNB **140***a* or detected by the WTRU **102***a* via blind detection. Alternatively, WTRU **102***a* may choose to feedback a subset of the effective channel, for example, on antenna port 7. Signaling of M may be done at a slower frequency via higher layer signaling, or at fast frequency via downlink control channel.

When the WTRU **102***a* sends feedback for the effective channel, the eNB **140***a* may need to retrieve channel information from effective channels with the knowledge of TPMI. Since the eNB **140***a* already has information of past precoding matrices, it may reconstruct the unprecoded channel based on feedback of the effective channel. Various channel reconstruction methods may be used, such as those described in Equations (3) and (4) above.

FIG. **2** is an example of the CSI feedback method and apparatus **200** based on an unprecoded channel. The eNB **204** may include a CSI feedback decoder unit **205**, a precoder calculation unit **210**, a common control channel **215**, DM-RS insertion units **220**, precoding units **225**, subcarrier mapping and an inverse fast Fourier transfer units **230** and antennas **240**. The WTRU **202** may include antennas **290**, a front end unit **250**, a common control channel decoding unit **255**, a DM-RS channel estimation unit **260**, a data channel detection unit **265**, an unprecoded channel estimation unit **270**, and a CSI feedback generation unit **280**.

In FIG. **2**, the eNB **204** may receive CSI feedback **285**,**235** from the WTRU **202**, (although there is one shown in FIG. **2**, there may be multiple WTRUs **202** via antennas **290** and eNBs antennas **240**, decode the CSI feedback **205** and based on the CSI, calculate the proper precoding matrix **210**. The precoding matrix may be forwarded to the common control channel **215** for decoding by all users in the cell and to each of the precoding units **225**. Each precoding unit **225** may apply the precoding matrix to an output of the corresponding DM-RS insertion unit **220**, where each DM-RS insertion unit output is based on corresponding user data and user DM-RS for all scheduled users in the next transmission. The output of each precoding unit **225** may be forwarded to each subcarrier mapping and IFFT unit **230**, the output of which is transmitted by a corresponding antenna **240**.

The WTRU **202** may obtain the effective channel estimate via the DM-RS channel estimation unit **260** from data received through the antennas **290** and the front end **250**. The DM-RS may be intended for any user, therefore the DM-RS may not be limited to the WTRU **202** currently performing channel estimation.

The WTRU **202** may derive an estimate of the unprecoded channel **270** from the DM-RS estimation unit **260** and precoder information decoded in the common control channel decoding unit **255**, and generate CSI feedback **280** based on unprecoded channel. The CSI feedback **280** may be transmitted back to the eNB **204** through antennas **290**.

The data channel detection unit **265** is identified in FIG. **2** to show that DM-RS may not incur additional downlink overhead. However, the DM-RS may be used for data modulation anyway. The RB may be intended for WTRU **202**, then the data channel detection exists in WTRU **202**; however, if the RB is not intended for WTRU **202**, the data channel detection may exist somewhere else. The output of channel detection unit **265** may be forwarded to higher layer processing, and eventually the application processor of the intended WTRU **202**.

FIG. **3** is an example method and apparatus **300** to feedback an effective channel. The eNB **304** may include a unprecoded channel estimation unit **305**, a precoder calculation unit **315**, a buffer **310**, DM-RS insertion units **320**, precoding units **325**, subcarrier mapping and an inverse fast Fourier transfer units **330** and antennas **340**. The WTRU **302** may include antennas **380**, a front end unit **350**, a DM-RS channel estimation unit **355**, a data channel detection unit **360**, a quantization unit **365**, and a CSI feedback generation unit **370**.

In FIG. **3**, the eNB **304** may receive CSI feedback **375**,**335** regarding the effective channel from the WTRU **302** via antennas **380** and eNB antennas **340**, and combine the information of the previous precoder from a buffer **310** in the unprecoded channel estimation unit **305** to obtain a channel estimate. The precoder calculation unit **315** may derive the proper precoder information for future data and DM-RS transmissions from the channel estimate output of the unprecoded channel estimation unit **305**, and store the precoder information in a buffer **310**. Each precoding unit **325** may apply the precoder information to an output of the corresponding DM-RS insertion unit **320**, where each DM-RS insertion unit output is based on corresponding user data and user DM-RS for all scheduled users in the next transmission. The output of each precoding unit **325** may be forwarded to each subcarrier mapping and IFFT unit **330**, the output of which is transmitted by a corresponding antenna **340**.

The WTRU **302** may obtain the effective channel via the DM-RS channel estimation unit **355** from data received through the antennas **380** and the front end **350**. The estimated DM-RS signals may be quantized by quantization unit **365** and sent to the CSI feedback generation unit **370**. The CSI feedback **375** may be transmitted back to the eNB **304** through antennas **380** and **340**. The WTRU **302** may also obtain the user data via the data channel detection unit **360** from data received through the antennas **380** and the front end **350**. The detected user data may then be forwarded to higher layers.

FIG. **4** is an example of the performance comparison between the proposed scheme and existing schemes. In a multi-user multiple input multiple output (MU-MIMO) system. There are 20 WTRUs in the cell to be scheduled to a certain resource block. The 20 WTRUs are grouped into 10 pairs randomly. The RB of interest is assigned to the 10 pairs in a round robin fashion. The eNB is equipped with 4 antennas, and each WTRU has a single antenna. In the conventional embodiment, each WTRU feeds back a 4 bit precoding matrix index (PMI) for each TTI (assume a CSI-RS is available for each TTI); in the proposed embodiment, each WTRU feeds back the quantized effective channel estimate with 2 bits. FIG. **4** shows the results. Noticeably, the proposed embodiment performs better with less feedback overhead even if there is a CSI-RS available for the WTRU to generate a PMI. In practical LTE-A systems, the CSI-RS may not be available at each TTI, so the performance gap may be greater than shown.

Although examples are provided above with reference to LTE Release 10, the principles described above may be used in the context of other wireless technologies, including but not limited to technologies based on LTE Release 11, IEEE 802.16m, any technology that includes the use of OFDM and/or MIMO, and/or any other appropriate technology.

Although features and elements are described above in particular combinations, one of ordinary skill in the art will appreciate that each feature or element may be used alone or in any combination with the other features and elements. In addition, the methods described herein may be implemented in a computer program, software, or firmware incorporated in a computer-readable medium for execution by a computer or processor. Examples of computer-readable media include electronic signals (transmitted over wired or wireless connections) and computer-readable storage media. Examples of computer-readable storage media include, but are not limited to, a read only memory (ROM), a random access memory (RAM), a register, cache memory, semiconductor memory devices, magnetic media such as internal hard disks and removable disks, magneto-optical media, and optical media such as CD-ROM disks, and digital versatile disks (DVDs). A processor in association with software may be used to implement a radio frequency transceiver for use in a WTRU, UE, terminal, base station, RNC, or any host computer.

What is claimed is:

1. A wireless transmit/receive unit (WTRU) comprising:

at least one antenna; and

a processor, operatively coupled to the antenna, configured to receive from an eNodeB information designating a first plurality of sub-bands; wherein the designated first plurality of sub-bands include a demodulation reference signal (DM-RS) for use by a plurality of WTRUs; wherein a second plurality of sub-bands include data for a single WTRU; wherein the DM-RS for the plurality of WTRUs is transmitted over an antenna port; wherein the antenna port has a selected precoding; and wherein the processor is further configured to utilize the DM-RS to estimate a channel of the designated first plurality of sub-bands; wherein the eNodeB transmits the DM-RS in the first plurality of sub-bands and the data for the single WTRU in the second plurality of sub-bands in a same transmission time interval (TTI).

2. The WTRU of claim **1** wherein the processor is further configured to receive a scrambling indication associated with the DM-RS.

3. The WTRU of claim **1** wherein a plurality of DM-RSs are used to estimate a channel for a plurality of antenna ports of the eNodeB.

4. The WTRU of claim **1** wherein the processor is further configured to receive a channel state information reference signal (CSI-RS) and to estimate a channel using the CSI-RS.

5. A method comprising:

receiving, by a wireless transmit/receive unit (WTRU), information designating a first plurality of sub-bands; wherein the designated first plurality of sub-bands include a demodulation reference signal (DM-RS) for use by a plurality of WTRUs; wherein a second plurality of sub-bands include data for a single WTRU; wherein the DM-RS for the plurality of WTRUs is transmitted over an antenna port; wherein the antenna port has a selected precoding; and

utilizing, by the WTRU, the DM-RS to estimate a channel of the designated first plurality of sub-bands; wherein an eNodeB transmits the DM-RS in the first plurality of sub-bands and the data for the single WTRU in the second plurality of sub-bands in a same transmission time interval (TTI).

6. The method of claim **5** further comprising receiving, by the WTRU, a scrambling indication associated with the DM-RS.

7. The method of claim **5** wherein a plurality of DM-RSs are used to estimate a channel for a plurality of antenna ports of an eNodeB.

8. The method of claim **5** further comprising receiving a channel state information reference signal (CSI-RS) and to estimate a channel using the CSI-RS.

9. An eNodeB comprising:

at least one antenna port; and

a processor, operatively coupled to the antenna port, configured to transmit to each of a plurality of wireless transmit/receive units (WTRUs) information designating a first plurality of sub-bands; wherein the processor is further configured to transmit a demodulation reference signal (DM-RS) in the designated first plurality of sub-bands for use by the plurality of WTRUs to estimate a channel of the designated first plurality of sub-bands; and wherein a second plurality of sub-bands include data for a single WTRU; wherein the DM-RS for the plurality of WTRUs is transmitted over an antenna port; wherein the antenna port has a selected precoding; wherein the DM-RS in the first plurality of sub-bands and the data for the single WTRU in the second plurality of sub-bands is transmitted in a same transmission time interval (TTI).

10. The eNodeB of claim **9** wherein the processor is further configured to transmit a scrambling indication associated with the DM-RS.

11. The eNodeB of claim **9** wherein the processor is further configured to transmit a channel state information reference signal (CSI-RS) to the plurality of WTRUs.

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