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(54) **APPARATUS AND METHOD FOR CHANNEL-STATE-INFORMATION PILOT DESIGN FOR AN ADVANCED WIRELESS NETWORK**

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(73) Assignee: **Samsung Electronics Co., Ltd.**, Suwon-si (KR)

(21) Appl. No.: **15/422,408**

(22) Filed: **Feb. 1, 2017**

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(51) **Int. Cl.**
H04W 72/04 (2009.01)
H04L 1/00 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC ***H04W 72/046*** (2013.01); ***H04B 7/0469*** (2013.01); ***H04L 1/0053*** (2013.01);
(Continued)

(58) **Field of Classification Search**
CPC ... H04W 72/046; H04W 72/04; H04W 88/02; H04W 88/08; H04L 1/0053; H04B 7/0469
See application file for complete search history.

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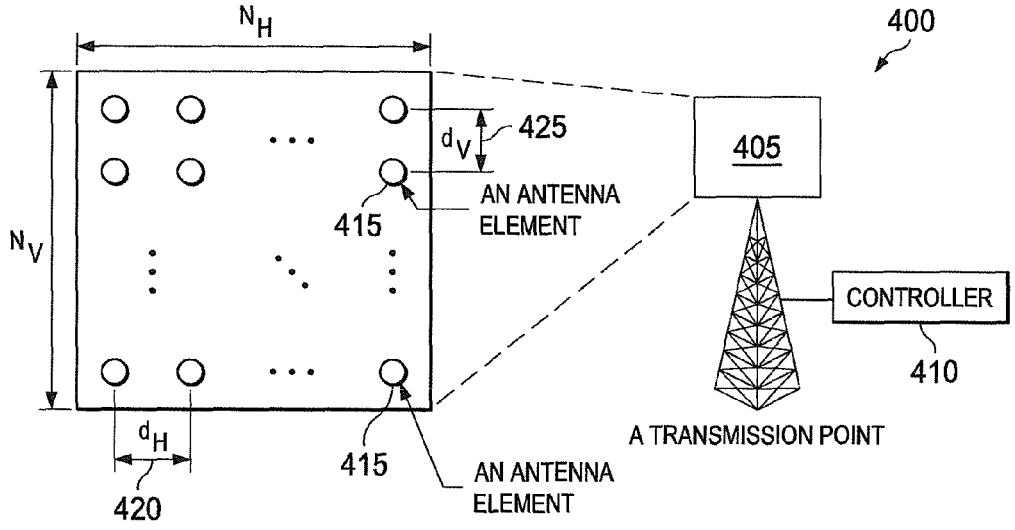
(Continued)

Primary Examiner — Ovidio Escalante

(57) **ABSTRACT**

A base station and mobile station communicate using a multiple input multiple output (MIMO) communication. The base station includes a two dimensional (2D) antenna array comprising a number N of antenna elements configured in a 2D grid. The 2D antenna array is configured to communicate with at least one subscriber station. The base station also includes a controller configured to transmit N channel-state-information reference-signal (CSI-RS) antenna ports (APs) associated with each of the N antenna elements. The subscriber station includes an antenna array configured to communicate with at least one base station. The subscriber station also includes processing circuitry configured receives physical downlink shared channels (PDSCHs) from a 2D active antenna array at the at least one base station. The 2D active antenna array includes a number N antenna elements. The processing circuitry further configured to estimate a full CSI associated with the N antenna elements.

42 Claims, 13 Drawing Sheets



(51) **Int. Cl.**

H04W 88/02	(2009.01)
H04W 88/08	(2009.01)
H04B 7/0456	(2017.01)

(52) **U.S. Cl.**

CPC ***H04W 72/04*** (2013.01); *H04W 88/02* (2013.01); *H04W 88/08* (2013.01)

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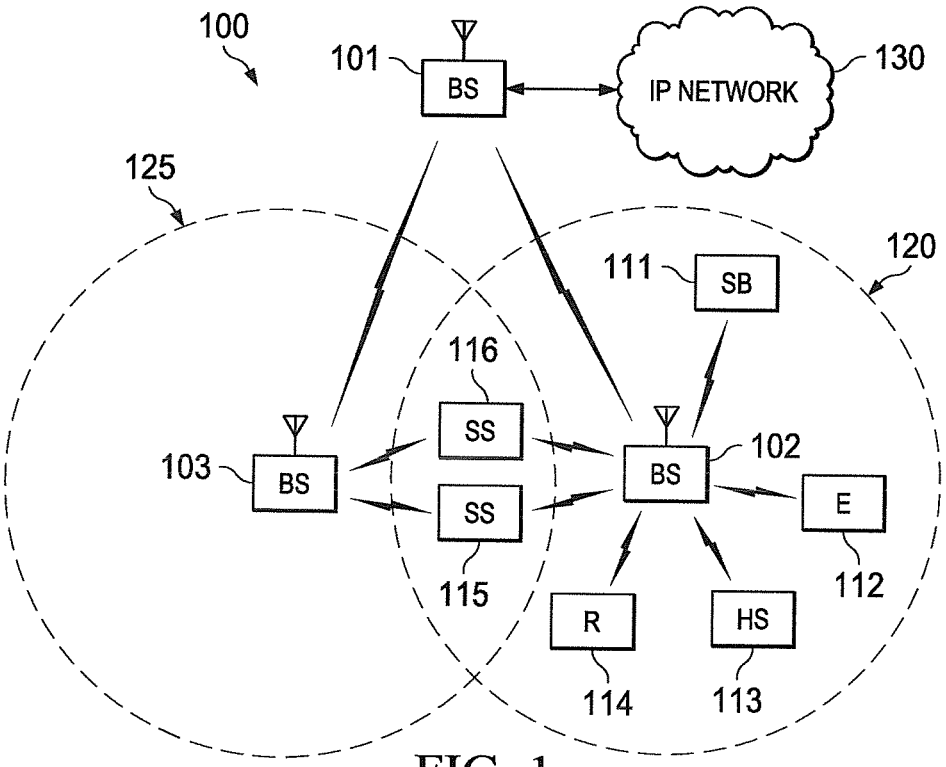
100
101
BS
IP NETWORK
130
125
120
111
SB
116
SS
SS
103
BS
BS
102
E
112
115
R
HS
114
113

FIG. 1

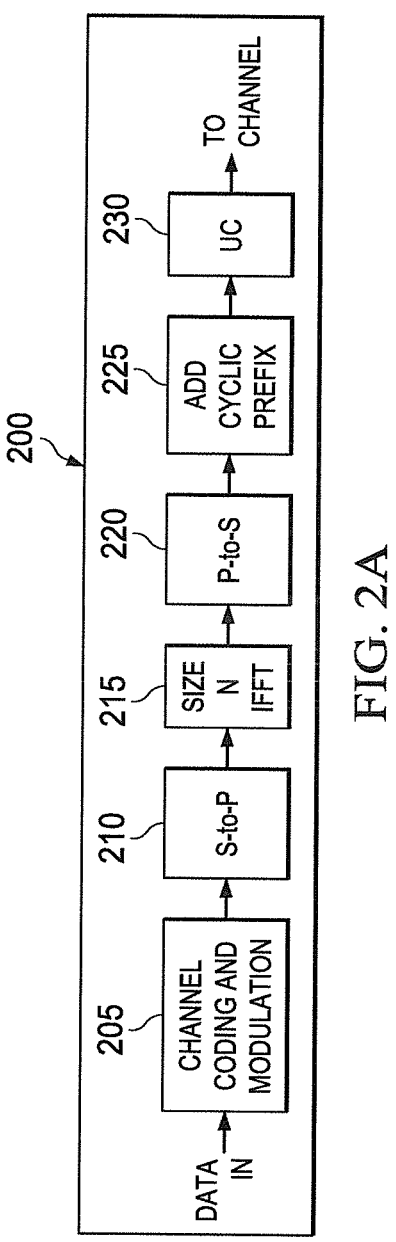
200
205
CHANNEL CODING AND MODULATION
210
S-to-P
215
SIZE N IFFT
220
P-to-S
225
ADD CYCLIC PREFIX
230
UC
DATA IN
TO CHANNEL

FIG. 2A

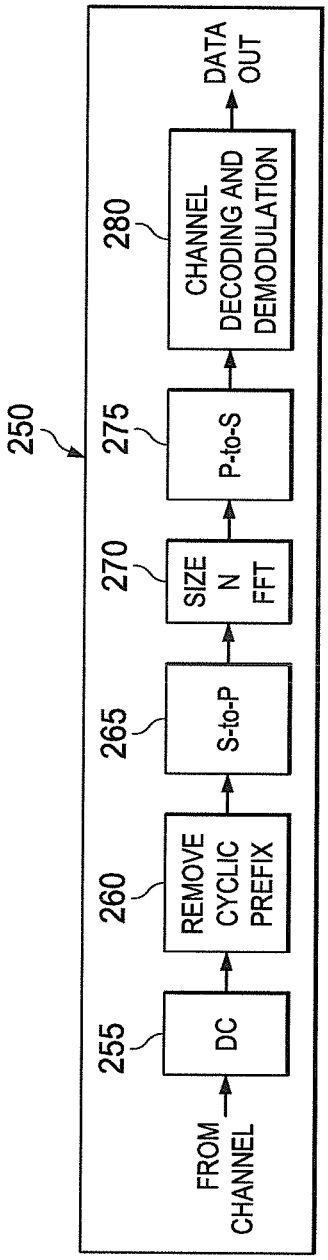
250
255
DC
260
REMOVE CYCLIC PREFIX
265
S-to-P
270
SIZE N FFT
275
P-to-S
280
CHANNEL DECODING AND DEMODULATION
FROM CHANNEL
DATA OUT

FIG. 2B

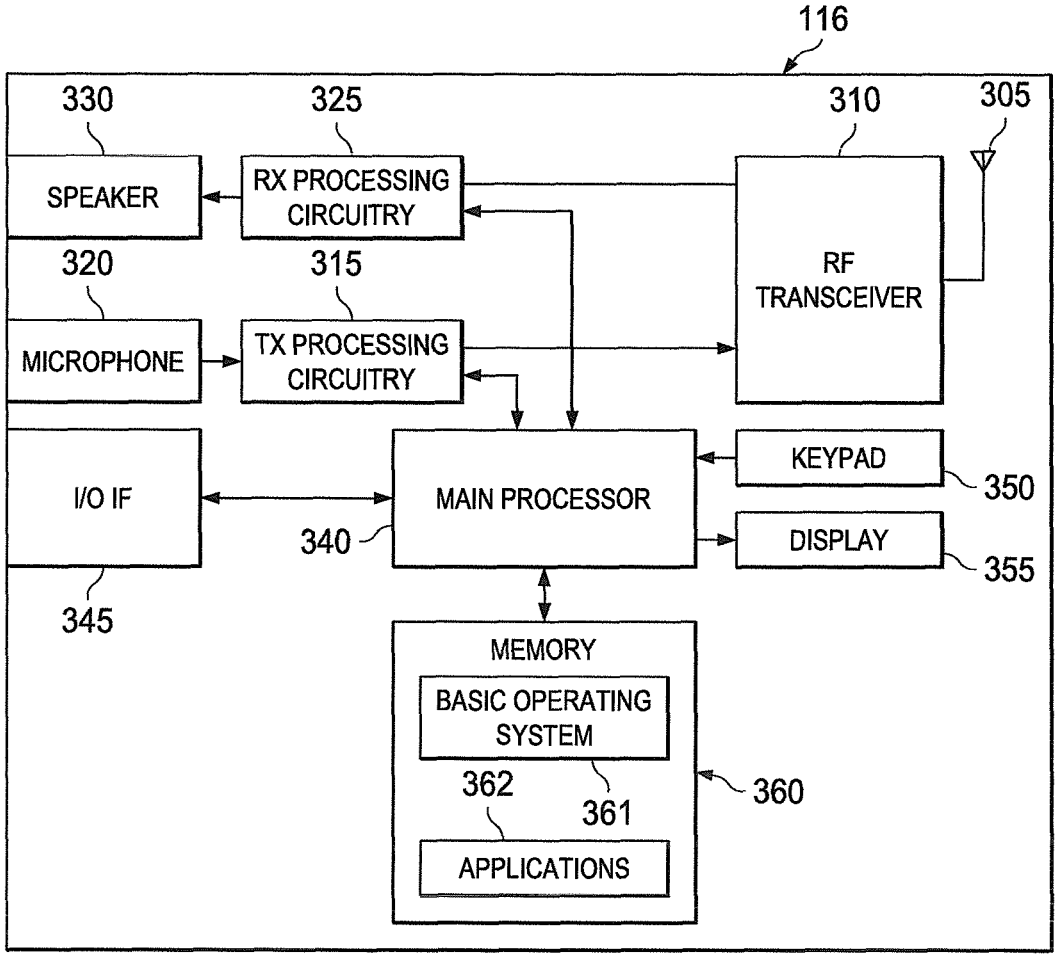
116
330
325
310
305
SPEAKER
RX PROCESSING CIRCUITRY
RF TRANSCEIVER
320
315
MICROPHONE
TX PROCESSING CIRCUITRY
I/O IF
MAIN PROCESSOR
KEYPAD
350
DISPLAY
355
340
345
MEMORY
BASIC OPERATING SYSTEM
362
361
360
APPLICATIONS

FIG. 3

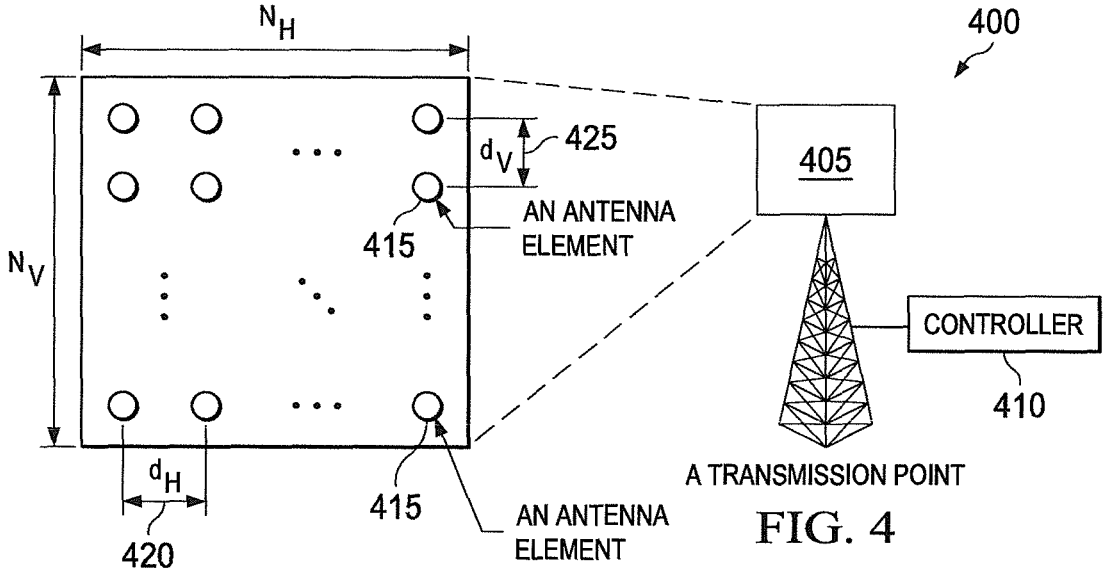
N_H
400
425
d_V
405
AN ANTENNA ELEMENT
415
N_V
CONTROLLER
410
A TRANSMISSION POINT
d_H
420
415
AN ANTENNA ELEMENT

FIG. 4

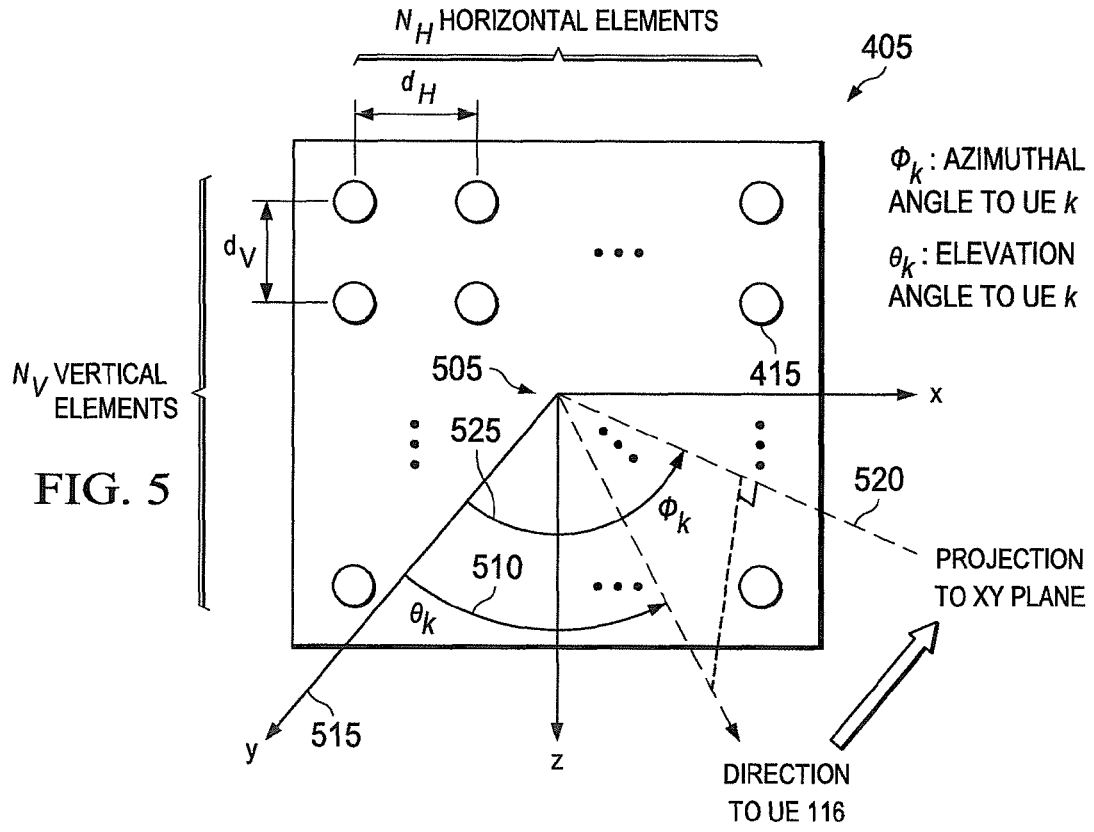
N_H HORIZONTAL ELEMENTS
405
d_H
d_V
N_V VERTICAL ELEMENTS
Φ_k : AZIMUTHAL ANGLE TO UE k
θ_k : ELEVATION ANGLE TO UE k
505
415
x
525
520
Φ_k
510
θ_k
PROJECTION TO XY PLANE
y
515
z
DIRECTION TO UE 116

FIG. 5

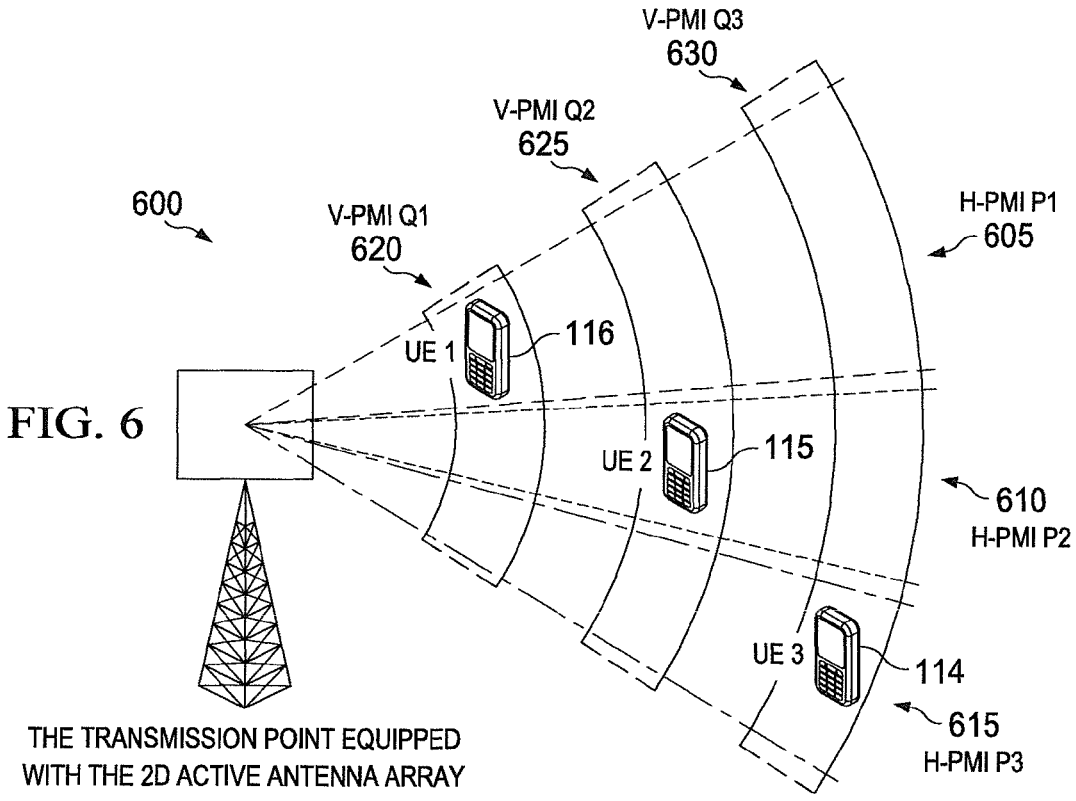
V-PMI Q3
630
V-PMI Q2
625
600
V-PMI Q1
620
H-PMI P1
605
UE 1
116
UE 2
115
610
H-PMI P2
UE 3
114
615
H-PMI P3
THE TRANSMISSION POINT EQUIPPED WITH THE 2D ACTIVE ANTENNA ARRAY

FIG. 6

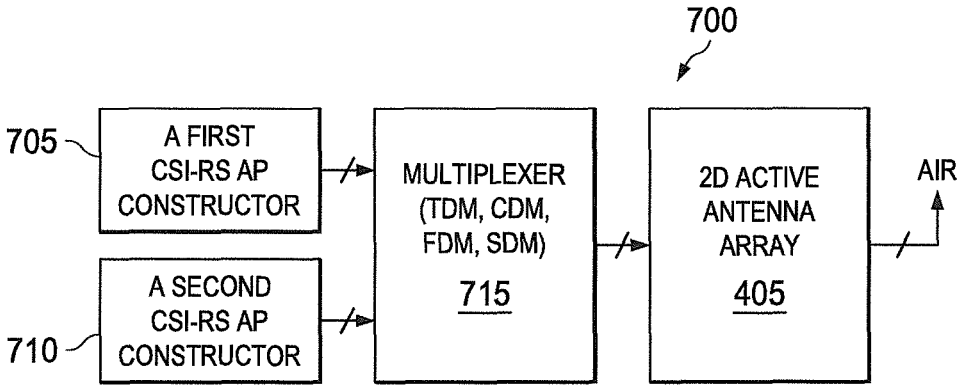
700
705
A FIRST CSI-RS AP CONSTRUCTOR
710
A SECOND CSI-RS AP CONSTRUCTOR
MULTIPLEXER (TDM, CDM, FDM, SDM)
715
2D ACTIVE ANTENNA ARRAY
405
AIR

FIG. 7

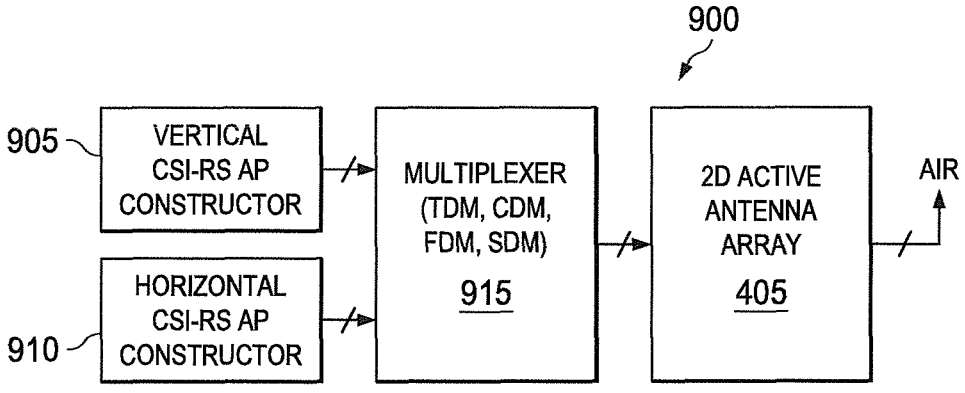
900
905
VERTICAL CSI-RS AP CONSTRUCTOR
910
HORIZONTAL CSI-RS AP CONSTRUCTOR
MULTIPLEXER (TDM, CDM, FDM, SDM)
915
2D ACTIVE ANTENNA ARRAY
405
AIR

FIG. 9

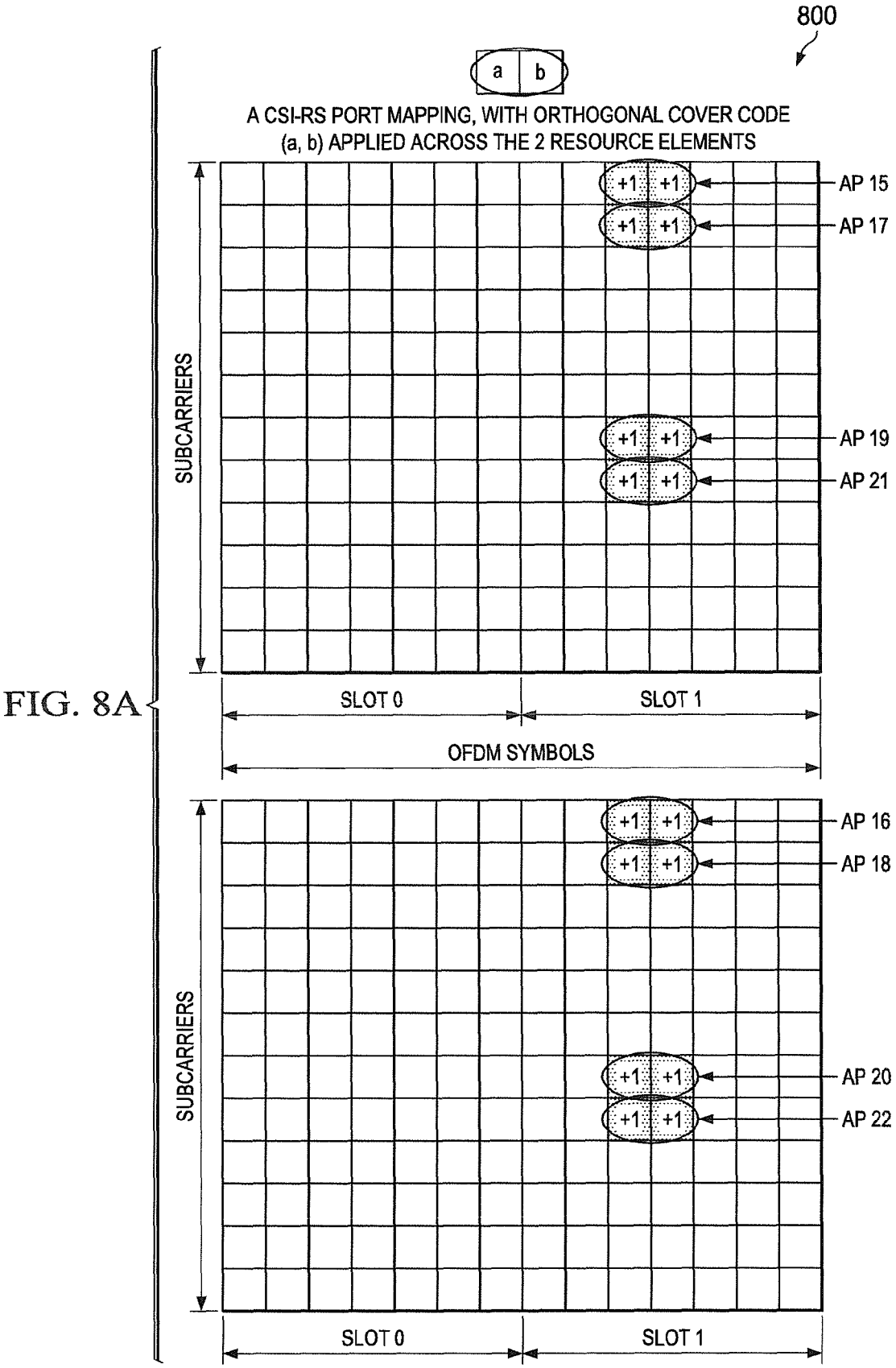
800
a
b
A CSI-RS PORT MAPPING, WITH ORTHOGONAL COVER CODE
(a, b) APPLIED ACROSS THE 2 RESOURCE ELEMENTS
+1 +1
AP 15
AP 17
AP 19
AP 21
SUBCARRIERS
SLOT 0
SLOT 1
OFDM SYMBOLS
AP 16
AP 18
AP 20
AP 22

FIG. 8A

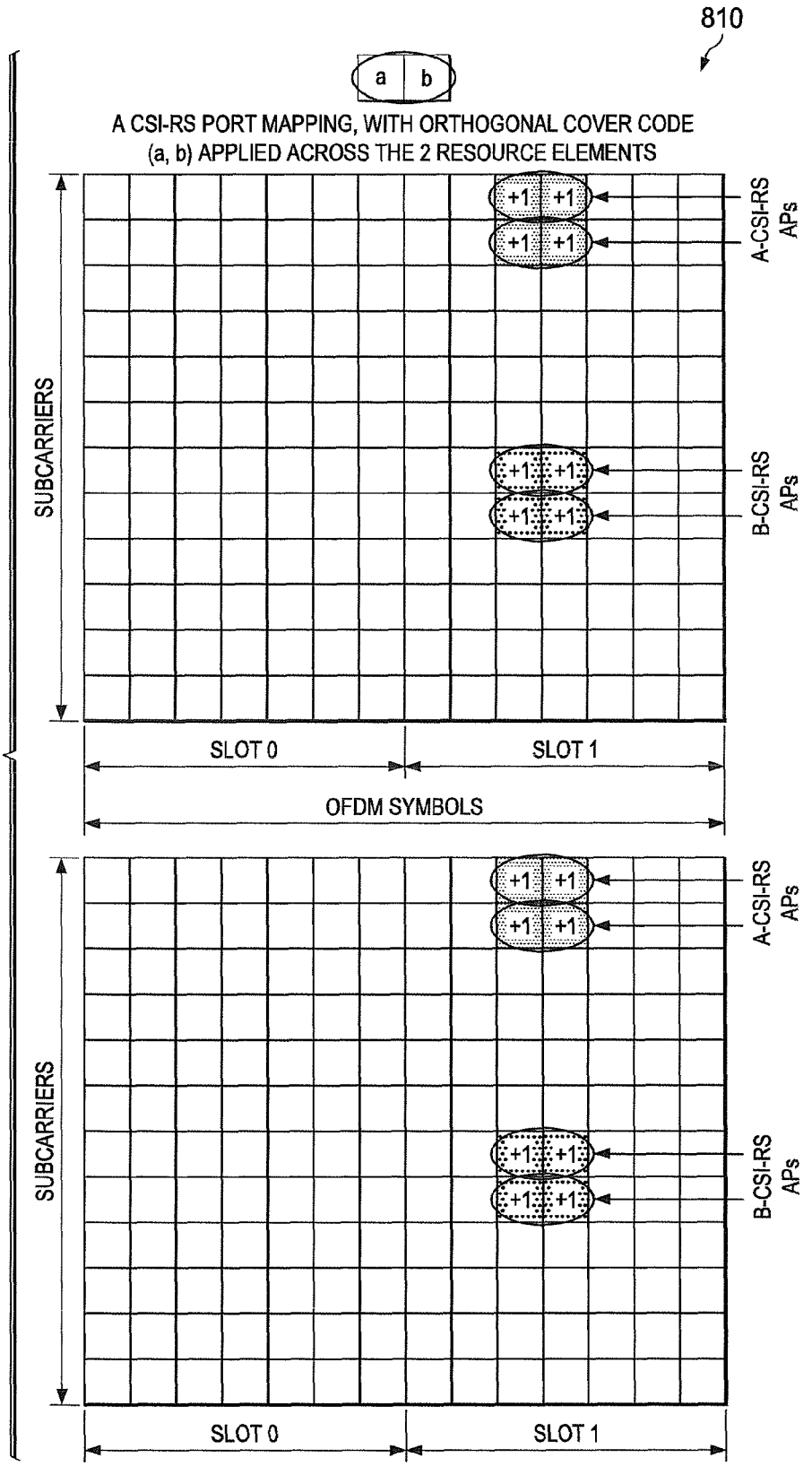
810
a
b
A CSI-RS PORT MAPPING, WITH ORTHOGONAL COVER CODE
(a, b) APPLIED ACROSS THE 2 RESOURCE ELEMENTS
+1
A-CSI-RS APs
B-CSI-RS APs
SUBCARRIERS
SLOT 0
SLOT 1
OFDM SYMBOLS

FIG. 8B

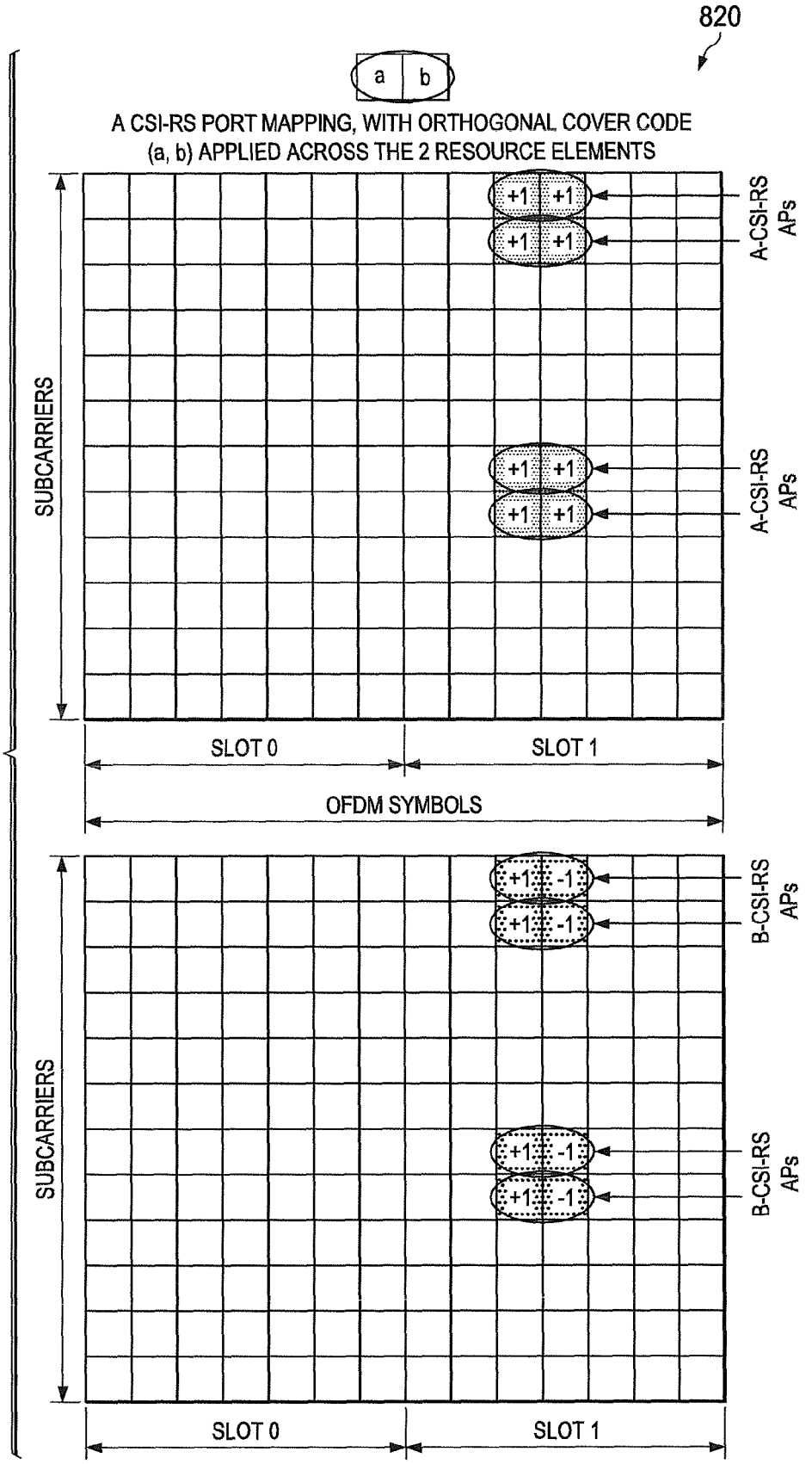
820
a
b
A CSI-RS PORT MAPPING, WITH ORTHOGONAL COVER CODE
(a, b) APPLIED ACROSS THE 2 RESOURCE ELEMENTS
+1 +1
+1 +1
A-CSI-RS APs
+1 +1
+1 +1
A-CSI-RS APs
SUBCARRIERS
SLOT 0
SLOT 1
OFDM SYMBOLS
+1 -1
+1 -1
B-CSI-RS APs
+1 -1
+1 -1
B-CSI-RS APs
SUBCARRIERS
SLOT 0
SLOT 1

FIG. 8C

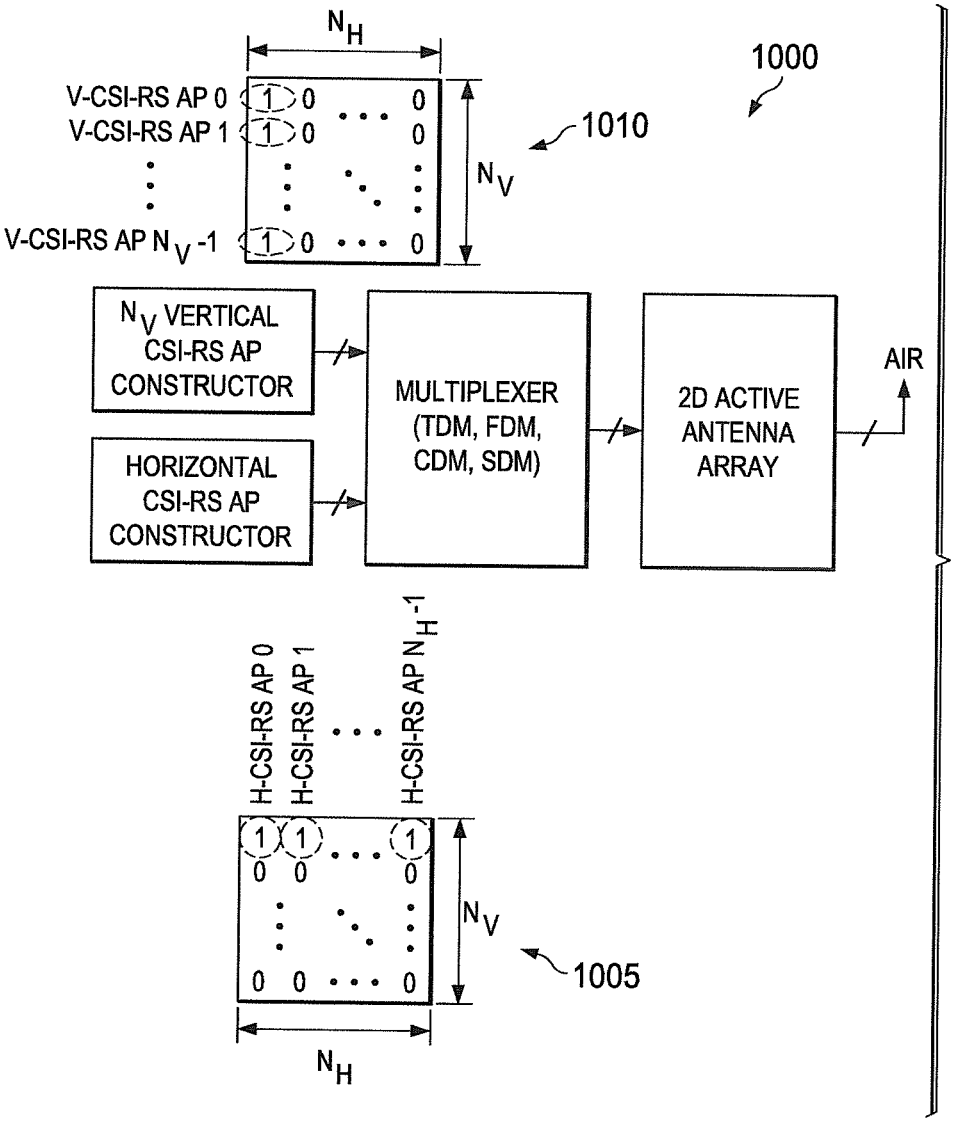
N_H
1000
V-CSI-RS AP 0
V-CSI-RS AP 1
V-CSI-RS AP N_V -1
1010
N_V
N_V VERTICAL CSI-RS AP CONSTRUCTOR
HORIZONTAL CSI-RS AP CONSTRUCTOR
MULTIPLEXER (TDM, FDM, CDM, SDM)
2D ACTIVE ANTENNA ARRAY
AIR
H-CSI-RS AP 0
H-CSI-RS AP 1
H-CSI-RS AP N_H -1
N_V
1005
N_H

FIG. 10

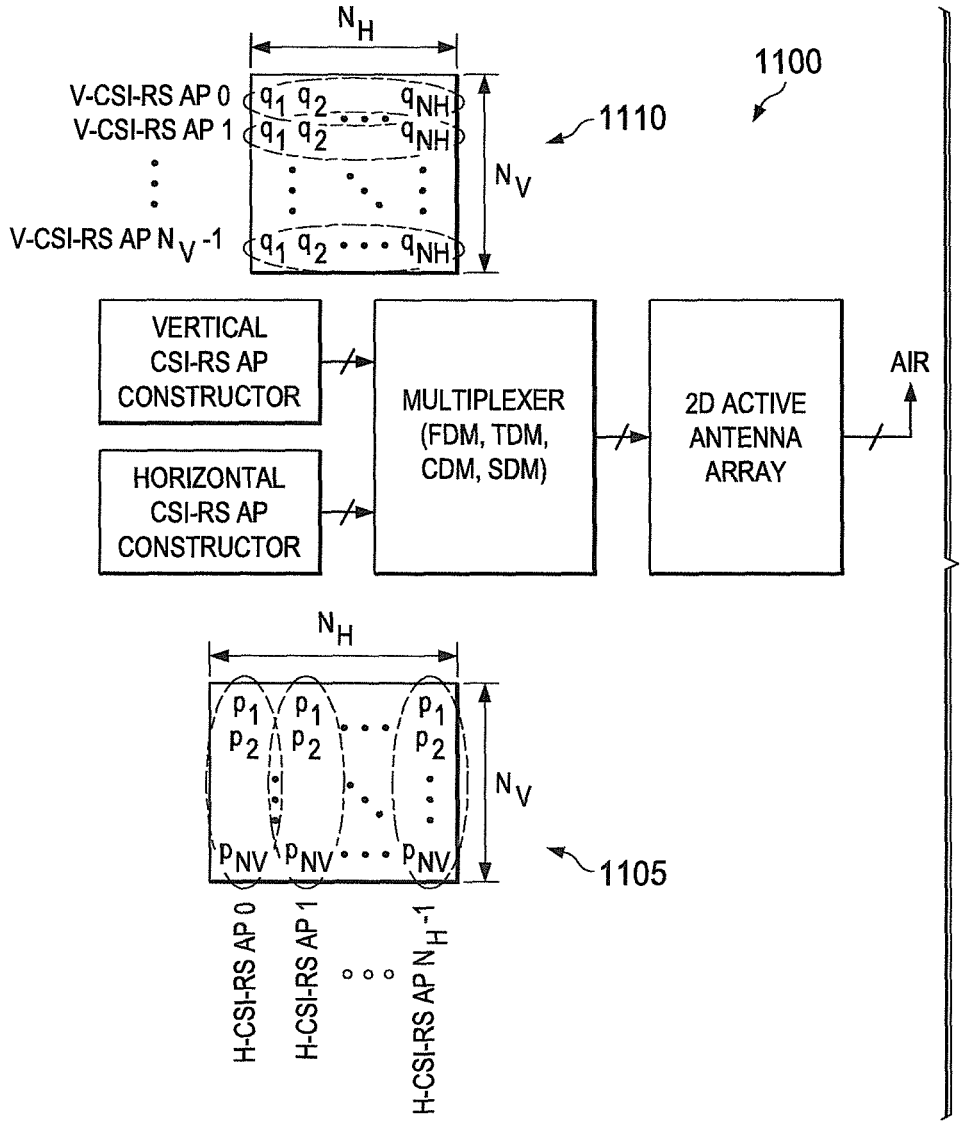
N_H
1100
V-CSI-RS AP 0
V-CSI-RS AP 1
V-CSI-RS AP N_V-1
q_1 q_2 ... q_NH
1110
N_V
VERTICAL CSI-RS AP CONSTRUCTOR
HORIZONTAL CSI-RS AP CONSTRUCTOR
MULTIPLEXER (FDM, TDM, CDM, SDM)
2D ACTIVE ANTENNA ARRAY
AIR
p_1 p_2 ... p_NV
1105
H-CSI-RS AP 0
H-CSI-RS AP 1
H-CSI-RS AP N_H-1

FIG. 11

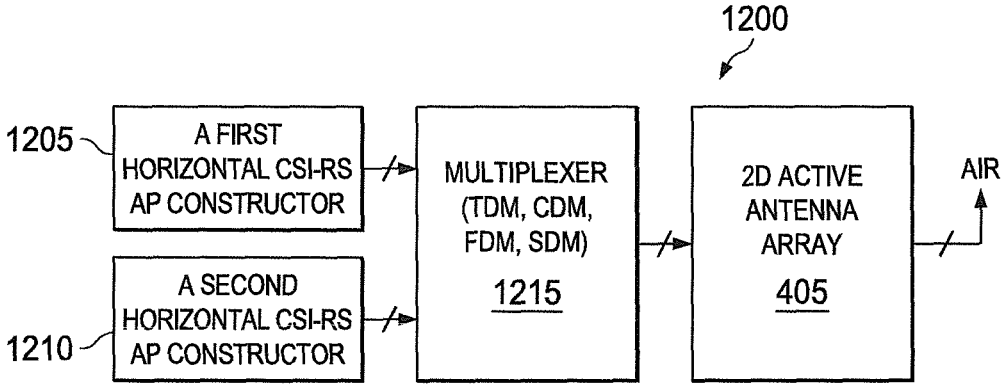
1200
1205
A FIRST HORIZONTAL CSI-RS AP CONSTRUCTOR
1210
A SECOND HORIZONTAL CSI-RS AP CONSTRUCTOR
MULTIPLEXER (TDM, CDM, FDM, SDM)
1215
2D ACTIVE ANTENNA ARRAY
405
AIR

FIG. 12

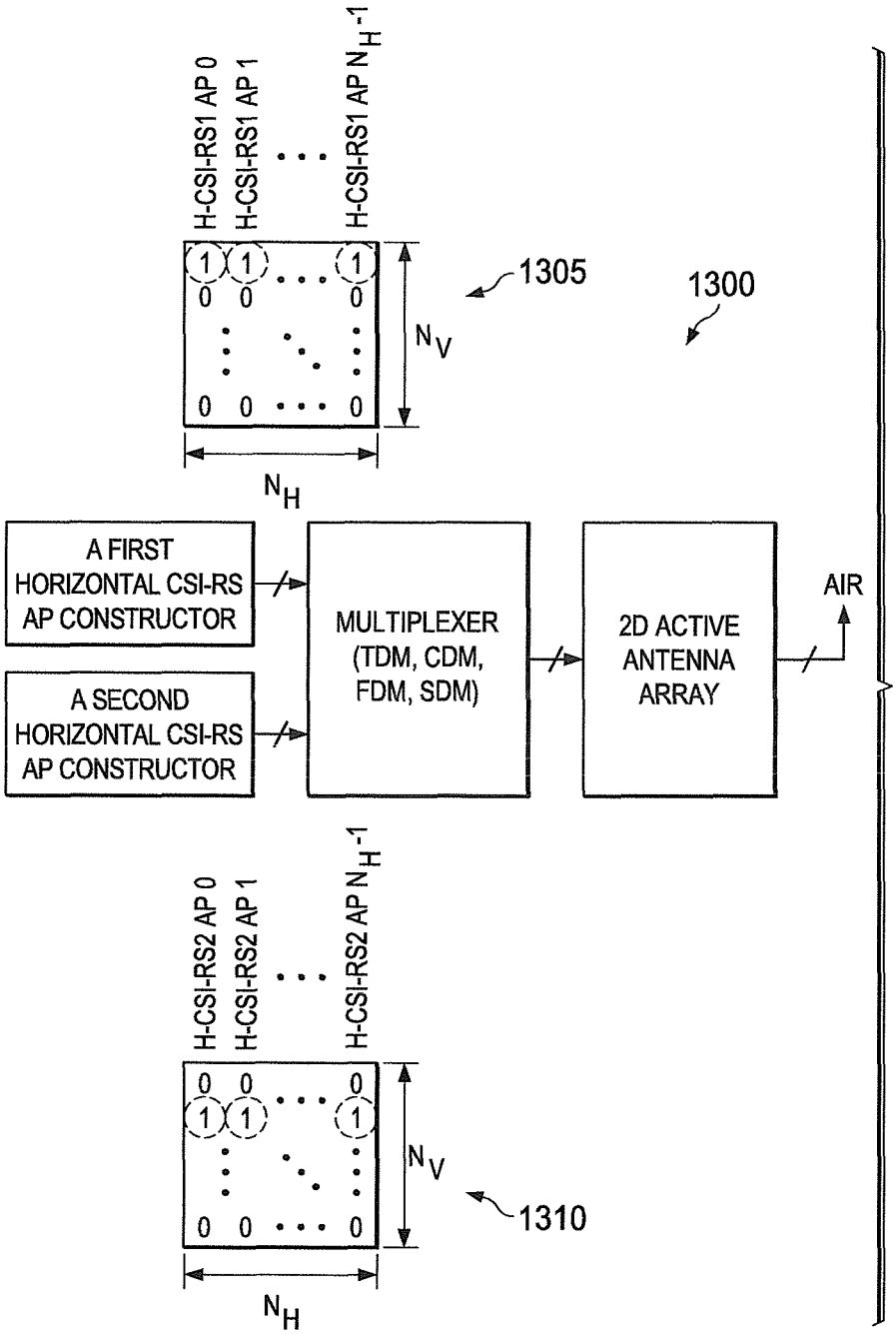
H-CSI-RS1 AP 0
H-CSI-RS1 AP 1
H-CSI-RS1 AP N_H-1
1305
1300
N_V
N_H
A FIRST HORIZONTAL CSI-RS AP CONSTRUCTOR
A SECOND HORIZONTAL CSI-RS AP CONSTRUCTOR
MULTIPLEXER (TDM, CDM, FDM, SDM)
2D ACTIVE ANTENNA ARRAY
AIR
H-CSI-RS2 AP 0
H-CSI-RS2 AP 1
H-CSI-RS2 AP N_H-1
1310
N_V
N_H

FIG. 13

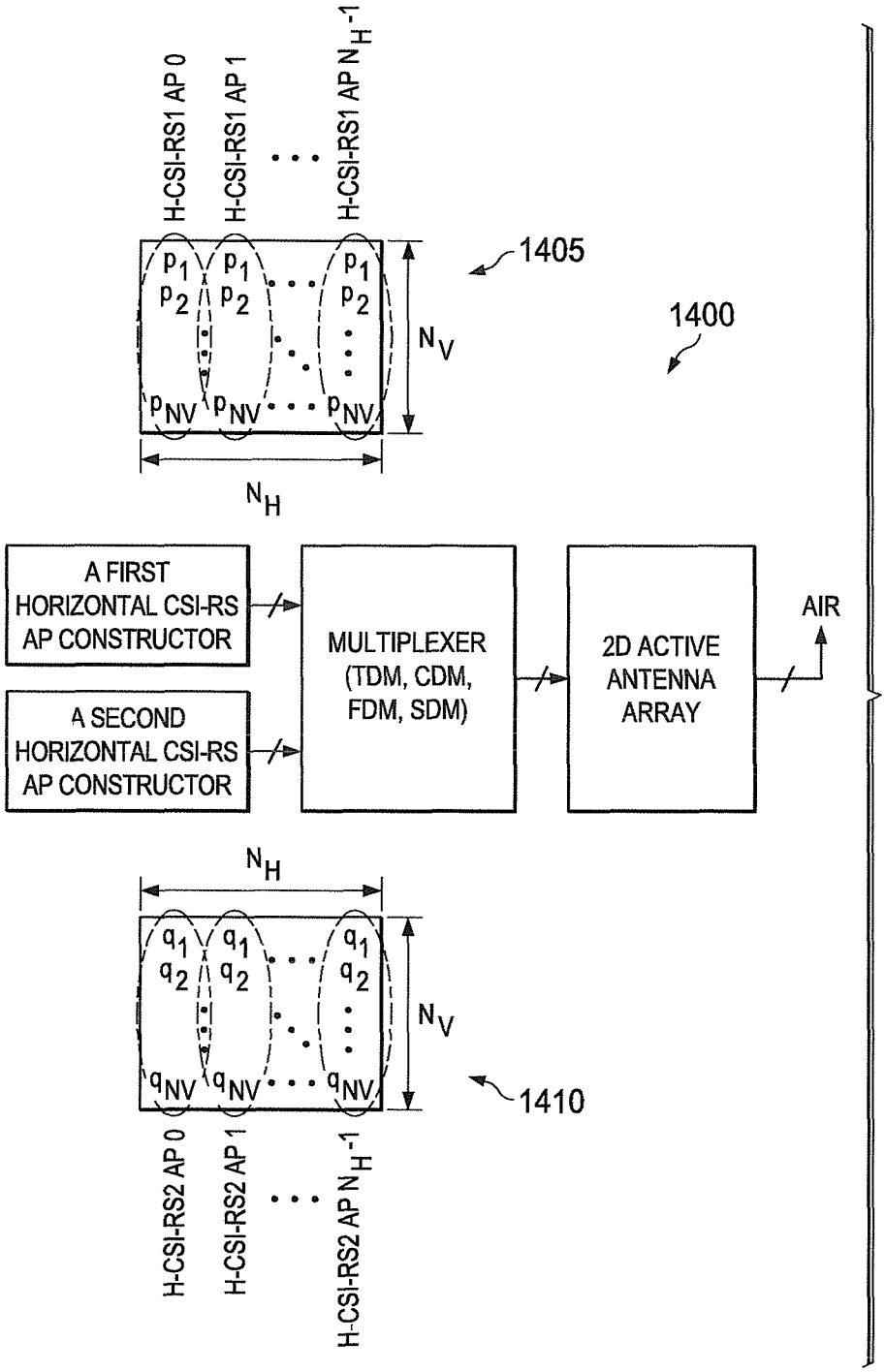
H-CSI-RS1 AP 0
H-CSI-RS1 AP 1
H-CSI-RS1 AP N_H-1
1405
1400
N_V
N_H
A FIRST HORIZONTAL CSI-RS AP CONSTRUCTOR
A SECOND HORIZONTAL CSI-RS AP CONSTRUCTOR
MULTIPLEXER (TDM, CDM, FDM, SDM)
2D ACTIVE ANTENNA ARRAY
AIR
N_H
N_V
1410
H-CSI-RS2 AP 0
H-CSI-RS2 AP 1
H-CSI-RS2 AP N_H-1

FIG. 14

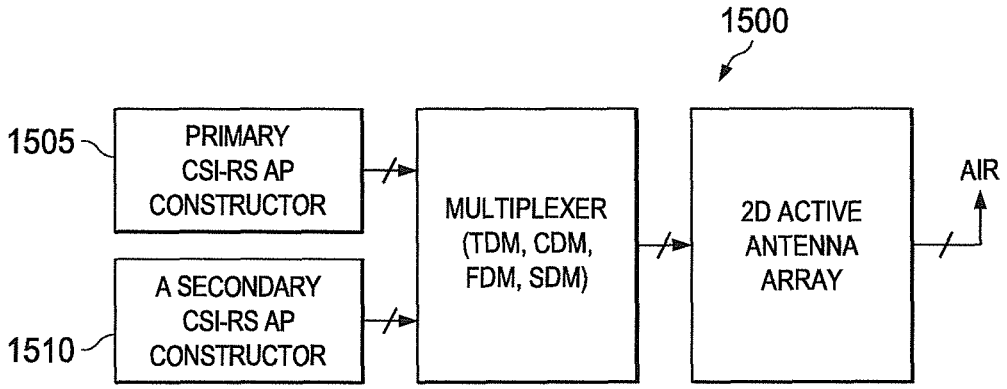
1500
1505
PRIMARY CSI-RS AP CONSTRUCTOR
1510
A SECONDARY CSI-RS AP CONSTRUCTOR
MULTIPLEXER (TDM, CDM, FDM, SDM)
2D ACTIVE ANTENNA ARRAY
AIR

FIG. 15

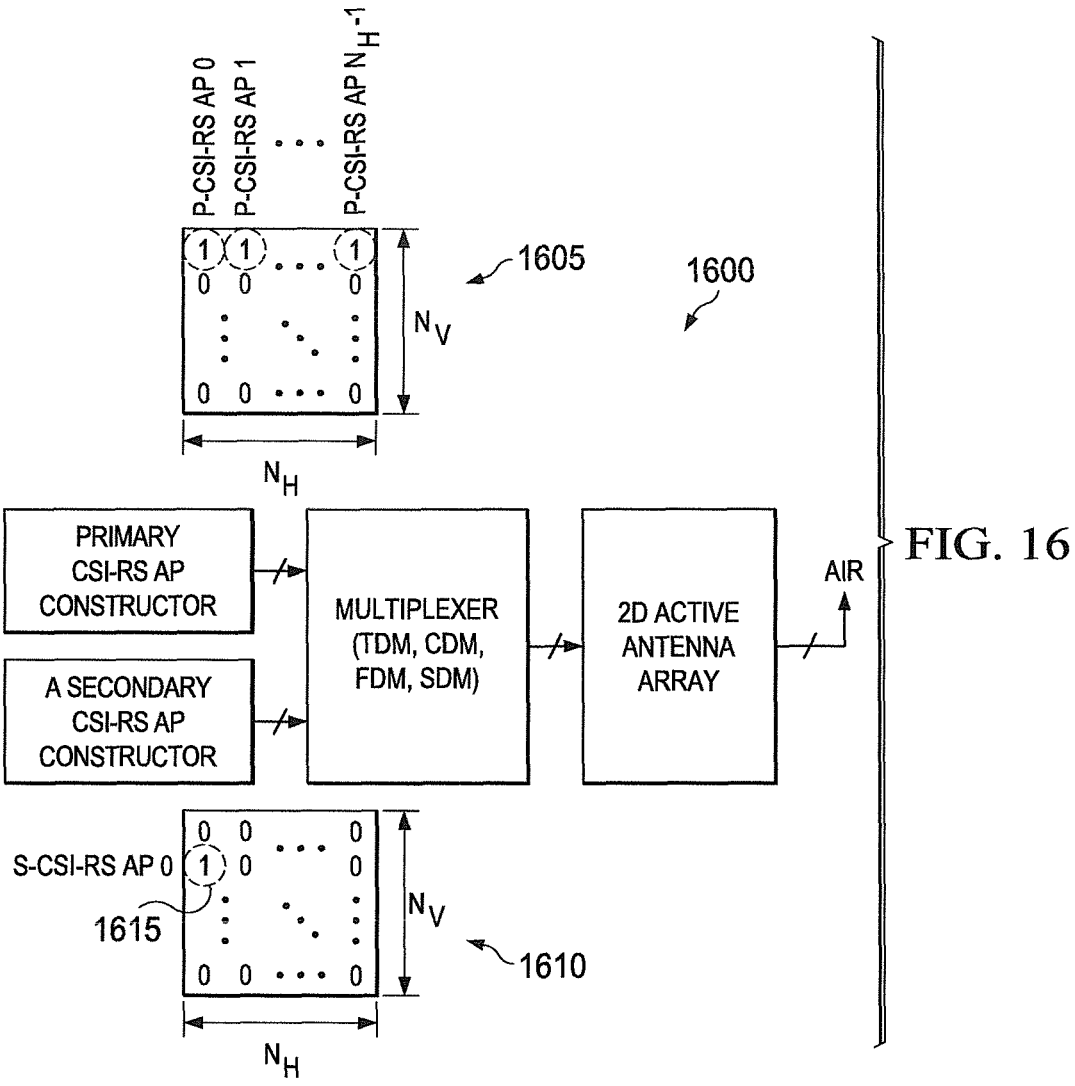
P-CSI-RS AP 0
P-CSI-RS AP 1
P-CSI-RS AP N_H-1
1605
1600
N_V
N_H
PRIMARY CSI-RS AP CONSTRUCTOR
A SECONDARY CSI-RS AP CONSTRUCTOR
MULTIPLEXER (TDM, CDM, FDM, SDM)
2D ACTIVE ANTENNA ARRAY
AIR
S-CSI-RS AP 0
1615
1610
N_V
N_H

FIG. 16

APPARATUS AND METHOD FOR CHANNEL-STATE-INFORMATION PILOT DESIGN FOR AN ADVANCED WIRELESS NETWORK

Matter enclosed in heavy brackets [ ] appears in the original patent but forms no part of this reissue specification; matter printed in italics indicates the additions made by reissue; a claim printed with strikethrough indicates that the claim was canceled, disclaimed, or held invalid by a prior post-patent action or proceeding.

CROSS-REFERENCE TO RELATED APPLICATION(S) AND CLAIM OF PRIORITY

The present application *is an application for reissue of U.S. Pat. No. 9,119,209 issued Aug. 25, 2015 on U.S. Non-Provisional patent application Ser. No. 13/828,530 filed Mar. 14, 2013, and which* claims priority to U.S. Provisional Patent Application [Ser.] No. 61/618,213, filed Mar. 30, 2012, entitled "CHANNEL-STATE-INFORMATION PILOT DESIGN FOR ADVANCED WIRELESS COMMUNICATIONS SYSTEM" and U.S. Provisional Patent Application [Ser.] No. 61/635,152, filed Apr. 18, 2012, entitled "CHANNEL-STATE-INFORMATION PILOT DESIGN FOR ADVANCED WIRELESS COMMUNICATIONS SYSTEM". The content of the above-identified patent documents is incorporated herein by reference.

TECHNICAL FIELD

The present application relates generally to wireless communication systems and, more specifically, to a channel-state-information pilot design for advanced wireless communications system.

BACKGROUND

3GPP Long Term Evolution (LTE) and Long Term Evolution Advanced (LTE-A) systems may operates in a Frequency Division Duplex (FDD) mode or a Time Division Duplex (TDD) mode. In the FDD mode, two different frequencies are used for uplink and downlink transmission, and the base station and user equipment may send and receive data at the same time. In the TDD mode, the same frequency is used for uplink and downlink transmission, and the base station and user equipment cannot send and receive data at the same time. Therefore, in the TDD mode, the LTE system has configurations specifying subframes for either uplink or downlink.

SUMMARY

A base station is provided. The base station includes a two dimensional (2D) antenna array comprising a number N of antenna elements configured in a 2D grid $N_H \times N_V$. The 2D antenna array is configured to communicate with at least one subscriber station. The base station also includes a controller configured to transmit N channel-state-information reference-signal (CSI-RS) antenna ports (APs) associated with each of the N antenna elements.

A subscriber station is provided. The subscriber station includes an antenna array configured to communicate with at least one base station. The subscriber station also includes processing circuitry configured receives physical downlink shared channels (PDSCHs) from a 2D active antenna array at the at least one base station. The 2D active antenna array includes a number N antenna elements. The processing circuitry further configured to estimate a horizontal and vertical CSI associated with the N antenna elements.

A method is provided. The method includes transmitting, from a two dimensional (2D) antenna array, N channel-state-information reference-signal (CSI-RS) antenna ports (APs). The 2D antenna array includes a number N of antenna elements configured in a 2D grid $N_H \times N_V$. The CSI-RS APs is associated with each of the N antenna elements.

Before undertaking the DETAILED DESCRIPTION below, it may be advantageous to set forth definitions of certain words and phrases used throughout this patent document: the terms "include" and "comprise," as well as derivatives thereof, mean inclusion without limitation; the term "or," is inclusive, meaning and/or; the phrases "associated with" and "associated therewith," as well as derivatives thereof, may mean to include, be included within, interconnect with, contain, be contained within, connect to or with, couple to or with, be communicable with, cooperate with, interleave, juxtapose, be proximate to, be bound to or with, have, have a property of, or the like; and the term "controller" means any device, system or part thereof that controls at least one operation, such a device may be implemented in hardware, firmware or software, or some combination of at least two of the same. It should be noted that the functionality associated with any particular controller may be centralized or distributed, whether locally or remotely. Definitions for certain words and phrases are provided throughout this patent document, those of ordinary skill in the art should understand that in many, if not most instances, such definitions apply to prior, as well as future uses of such defined words and phrases.

BRIEF DESCRIPTION OF THE DRAWINGS

For a more complete understanding of the present disclosure and its advantages, reference is now made to the following description taken in conjunction with the accompanying drawings, in which like reference numerals represent like parts:

FIG. **1** illustrates a wireless network according to embodiments of the present disclosure;

FIG. **2**A illustrates a high-level diagram of a wireless transmit path according to embodiments of the present disclosure;

FIG. **2**B illustrates a high-level diagram of a wireless receive path according to embodiments of the present disclosure;

FIG. **3** illustrates a subscriber station according to embodiments of the present disclosure;

FIG. **4** illustrates a transmission point equipped with 2D active antenna array according to embodiments of the present disclosure;

FIG. **5** illustrates azimuth and elevation angles to a mobile station from the 2D active antenna array according to embodiments of the present disclosure;

FIG. **6** illustrates H-PMI and V-PMI according to embodiments of the present disclosure;

FIG. **7** illustrates a first and a second CSI-RS APs according to embodiments of the present disclosure;

FIGS. **8**A through **8**C illustrates joint configuration of A- and B-CSI-RS according to embodiments of the present disclosure;

FIG. **9** illustrates Vertical CSI-RS APs and horizontal CSI-RS APs according to embodiments of the present disclosure;

FIGS. **10** and **11** illustrate construction of the horizontal and the vertical CSI-RS APs according to embodiments of the present disclosure;

FIG. **12** illustrates first and second sets of horizontal CSI-RS APs according to embodiments of the present disclosure;

FIGS. **13** and **14** illustrate construction of two sets of H-CSI-RS APs according to embodiments of the present disclosure;

FIG. **15** illustrates primary and secondary CSI-RS APs according to embodiments of the present disclosure; and

FIG. **16** illustrates construction of the primary and the secondary CSI-RS according to embodiments of the present disclosure.

DETAILED DESCRIPTION

FIGS. **1** through **16**, discussed below, and the various embodiments used to describe the principles of the present disclosure in this patent document are by way of illustration only and should not be construed in any way to limit the scope of the disclosure. Those skilled in the art will understand that the principles of the present disclosure may be implemented in any suitably arranged wireless communication system.

The following documents and standards descriptions are hereby incorporated into the present disclosure as if fully set forth herein: 3GPP TS 36.211 v10.1.0, "E-UTRA, Physical channels and modulation" (REF1); 3GPP TS 36.212 v10.1.0, "E-UTRA, Multiplexing and Channel coding" (REF2); 3GPP TS 36.213 v10.1.0, "E-UTRA, Physical Layer Procedures" (REF 3); and 3GPP TS 36.331 V10.1.0 (REF4).

FIG. **1** illustrates a wireless network **100** according to one embodiment of the present disclosure. The embodiment of wireless network **100** illustrated in FIG. **1** is for illustration only. Other embodiments of wireless network **100** could be used without departing from the scope of this disclosure.

The wireless network **100** includes a base sta eNodeB (eNB) **101**, eNB **102**, and eNB **103**. The eNB **101** communicates with eNB **102** and eNB **103**. The eNB **101** also communicates with Internet protocol (IP) network **130**, such as the Internet, a proprietary IP network, or other data network.

Depending on the network type, other well-known terms may be used instead of "eNodeB," such as "base station" or "access point". For the sake of convenience, the term "eNodeB" shall be used herein to refer to the network infrastructure components that provide wireless access to remote terminals. In addition, the term "user equipment" or "UE" is used herein to designate any remote wireless equipment that wirelessly accesses an eNB and that can be used by a consumer to access services via the wireless communications network, whether the UE is a mobile device (e.g., cell phone) or is normally considered a stationary device (e.g., desktop personal computer, vending machine, etc.). Other well know terms for the remote terminals include "mobile stations" (MS) and "subscriber stations" (SS), "remote terminal" (RT), "wireless terminal" (WT), and the like.

The eNB **102** provides wireless broadband access to network **130** to a first plurality of user equipments (UEs) within coverage area **120** of eNB **102**. The first plurality of UEs includes UE **111**, which may be located in a small business; UE **112**, which may be located in an enterprise; UE **113**, which may be located in a WiFi hotspot; UE **114**, which may be located in a first residence; UE **115**, which may be located in a second residence; and UE **116**, which may be a mobile device, such as a cell phone, a wireless laptop, a wireless PDA, or the like. UEs **111-116** may be any wireless communication device, such as, but not limited to, a mobile phone, mobile PDA and any mobile station (MS).

The eNB **103** provides wireless broadband access to a second plurality of UEs within coverage area **125** of eNB **103**. The second plurality of UEs includes UE **115** and UE **116**. In some embodiments, one or more of eNBs **101-103** may communicate with each other and with UEs **111-116** using 5G, LTE, LTE-A, or WiMAX techniques including techniques for using a new channel-state-information pilot design as described in embodiments of the present disclosure.

Dotted lines show the approximate extents of coverage areas **120** and **125**, which are shown as approximately circular for the purposes of illustration and explanation only. It should be clearly understood that the coverage areas associated with base stations, for example, coverage areas **120** and **125**, may have other shapes, including irregular shapes, depending upon the configuration of the base stations and variations in the radio environment associated with natural and man-made obstructions.

Although FIG. **1** depicts one example of a wireless network **100**, various changes may be made to FIG. **1**. For example, another type of data network, such as a wired network, may be substituted for wireless network **100**. In a wired network, network terminals may replace eNBs **101-103** and UEs **111-116**. Wired connections may replace the wireless connections depicted in FIG. **1**.

FIG. **2**A is a high-level diagram of a wireless transmit path. FIG. **2**B is a high-level diagram of a wireless receive path. In FIGS. **2**A and **2**B, the transmit path **200** may be implemented, e.g., in eNB **102** and the receive path **250** may be implemented, e.g., in a UE, such as UE **116** of FIG. **1**. It will be understood, however, that the receive path **250** could be implemented in an eNB (e.g. eNB **102** of FIG. **1**) and the transmit path **200** could be implemented in a UE. In certain embodiments, transmit path **200** and receive path **250** are configured to perform methods for communication using a new channel-state-information pilot design as described in embodiments of the present disclosure.

Transmit path **200** comprises channel coding and modulation block **205**, serial-to-parallel (S-to-P) block **210**, Size N Inverse Fast Fourier Transform (IFFT) block **215**, parallel-to-serial (P-to-S) block **220**, add cyclic prefix block **225**, up-converter (UC) **230**. Receive path **250** comprises down-converter (DC) **255**, remove cyclic prefix block **260**, serial-to-parallel (S-to-P) block **265**, Size N Fast Fourier Transform (FFT) block **270**, parallel-to-serial (P-to-S) block **275**, channel decoding and demodulation block **280**.

At least some of the components in FIGS. **2**A and **2**B may be implemented in software while other components may be implemented by configurable hardware (e.g., a processor) or a mixture of software and configurable hardware. In particular, it is noted that the FFT blocks and the IFFT blocks described in this disclosure document may be implemented as configurable software algorithms, where the value of Size N may be modified according to the implementation.

Furthermore, although this disclosure is directed to an embodiment that implements the Fast Fourier Transform and the Inverse Fast Fourier Transform, this is by way of illustration only and should not be construed to limit the scope of the disclosure. It will be appreciated that in an alternate embodiment of the disclosure, the Fast Fourier Transform functions and the Inverse Fast Fourier Transform functions may easily be replaced by Discrete Fourier Trans-

form (DFT) functions and Inverse Discrete Fourier Transform (IDFT) functions, respectively. It will be appreciated that for DFT and IDFT functions, the value of the N variable may be any integer number (i.e., 1, 2, 3, 4, etc.), while for FFT and IFFT functions, the value of the N variable may be any integer number that is a power of two (i.e., 1, 2, 4, 8, 16, etc.).

In transmit path **200**, channel coding and modulation block **205** receives a set of information bits, applies coding (e.g., LDPC coding) and modulates (e.g., Quadrature Phase Shift Keying (QPSK) or Quadrature Amplitude Modulation (QAM)) the input bits to produce a sequence of frequency-domain modulation symbols. Serial-to-parallel block **210** converts (i.e., de-multiplexes) the serial modulated symbols to parallel data to produce N parallel symbol streams where N is the IFFT/FFT size used in eNB **102** and UE **116**. Size N IFFT block **215** then performs an IFFT operation on the N parallel symbol streams to produce time-domain output signals. Parallel-to-serial block **220** converts (i.e., multiplexes) the parallel time-domain output symbols from Size N IFFT block **215** to produce a serial time-domain signal. Add cyclic prefix block **225** then inserts a cyclic prefix to the time-domain signal. Finally, up-converter **230** modulates (i.e., up-converts) the output of add cyclic prefix block **225** to RF frequency for transmission via a wireless channel. The signal may also be filtered at baseband before conversion to RF frequency.

The transmitted RF signal arrives at UE **116** after passing through the wireless channel and reverse operations to those at eNB **102** are performed. Down-converter **255** down-converts the received signal to baseband frequency and remove cyclic prefix block **260** removes the cyclic prefix to produce the serial time-domain baseband signal. Serial-to-parallel block **265** converts the time-domain baseband signal to parallel time domain signals. Size N FFT block **270** then performs an FFT algorithm to produce N parallel frequency-domain signals. Parallel-to-serial block **275** converts the parallel frequency-domain signals to a sequence of modulated data symbols. Channel decoding and demodulation block **280** demodulates and then decodes the modulated symbols to recover the original input data stream.

Each of eNBs **101-103** may implement a transmit path that is analogous to transmitting in the downlink to UEs **111-116** and may implement a receive path that is analogous to receiving in the uplink from UEs **111-116**. Similarly, each one of UEs **111-116** may implement a transmit path corresponding to the architecture for transmitting in the uplink to eNBs **101-103** and may implement a receive path corresponding to the architecture for receiving in the downlink from eNBs **101-103**.

FIG. **3** illustrates a subscriber station according to embodiments of the present disclosure. The embodiment of subscribe station, such as UE **116**, illustrated in FIG. **3** is for illustration only. Other embodiments of the wireless subscriber station could be used without departing from the scope of this disclosure.

UE **116** comprises antenna **305**, radio frequency (RF) transceiver **310**, transmit (TX) processing circuitry **315**, microphone **320**, and receive (RX) processing circuitry **325**. Although shown as a single antenna, antenna **305** can include multiple antennas. SS **116** also comprises speaker **330**, main processor **340**, input/output (I/O) interface (IF) **345**, keypad **350**, display **355**, and memory **360**. Memory **360** further comprises basic operating system (OS) program **361** and a plurality of applications **362**. The plurality of applications can include one or more of resource mapping tables (Tables 1-10 described in further detail herein below).

Radio frequency (RF) transceiver **310** receives from antenna **305** an incoming RF signal transmitted by a base station of wireless network **100**. Radio frequency (RF) transceiver **310** down-converts the incoming RF signal to produce an intermediate frequency (IF) or a baseband signal. The IF or baseband signal is sent to receiver (RX) processing circuitry **325** that produces a processed baseband signal by filtering, decoding, and/or digitizing the baseband or IF signal. Receiver (RX) processing circuitry **325** transmits the processed baseband signal to speaker **330** (i.e., voice data) or to main processor **340** for further processing (e.g., web browsing).

Transmitter (TX) processing circuitry **315** receives analog or digital voice data from microphone **320** or other outgoing baseband data (e.g., web data, e-mail, interactive video game data) from main processor **340**. Transmitter (TX) processing circuitry **315** encodes, multiplexes, and/or digitizes the outgoing baseband data to produce a processed baseband or IF signal. Radio frequency (RF) transceiver **310** receives the outgoing processed baseband or IF signal from transmitter (TX) processing circuitry **315**. Radio frequency (RF) transceiver **310** up-converts the baseband or IF signal to a radio frequency (RF) signal that is transmitted via antenna **305**.

In certain embodiments, main processor **340** is a microprocessor or microcontroller. Memory **360** is coupled to main processor **340**. According to some embodiments of the present disclosure, part of memory **360** comprises a random access memory (RAM) and another part of memory **360** comprises a Flash memory, which acts as a read-only memory (ROM).

Main processor **340** executes basic operating system (OS) program **361** stored in memory **360** in order to control the overall operation of wireless subscriber station **116**. In one such operation, main processor **340** controls the reception of forward channel signals and the transmission of reverse channel signals by radio frequency (RF) transceiver **310**, receiver (RX) processing circuitry **325**, and transmitter (TX) processing circuitry **315**, in accordance with well-known principles.

Main processor **340** is capable of executing other processes and programs resident in memory **360**, such as operations for performing communications including a new channel-state-information pilot design as described in embodiments of the present disclosure. Main processor **340** can move data into or out of memory **360**, as required by an executing process. In some embodiments, the main processor **340** is configured to execute a plurality of applications **362**, such as applications for CoMP communications and MU-MIMO communications. The main processor **340** can operate the plurality of applications **362** based on OS program **361** or in response to a signal received from BS **102**. Main processor **340** is also coupled to I/O interface **345**. I/O interface **345** provides subscriber station **116** with the ability to connect to other devices such as laptop computers and handheld computers. I/O interface **345** is the communication path between these accessories and main controller **340**.

Main processor **340** is also coupled to keypad **350** and display unit **355**. The operator of subscriber station **116** uses keypad **350** to enter data into subscriber station **116**. Display **355** may be a liquid crystal display capable of rendering text and/or at least limited graphics from web sites. Alternate embodiments may use other types of displays.

Embodiments of the present disclosure provide methods and apparatus to for a channel-state-information (CSI) pilot design for advanced wireless communications system. In REF4, the following configuration is defined for channel-state-information reference signal (CSI-RS). A information element (IE) CSI-RS configuration (CSI-RS-Config) is used to specify the CSI-RS configuration as shown in here:

CSI-RS-Config information elements

```
-- ASN1START
CSI-RS-Config-r10 ::=     SEQUENCE {
    csi-RS-r10            CHOICE {
        release                       NULL,
        setup                         SEQUENCE {
            antennaPortsCount-r10         ENUMERATED {an1, an2, an4, an8},
            resourceConfig-r10            INTEGER (0..31),
            subframeConfig-r10                    INTEGER (0..154),
            p-C-r10                       INTEGER (−8..15)
        }
    }                                                 OPTIONAL,  -- Need ON
    zeroTxPowerCSI-RS-r10         CHOICE {
        release                       NULL,
        setup                         SEQUENCE {
            zeroTxPowerResourceConfigList-r10   BIT STRING (SIZE (16)),
            zeroTxPowerSubframeConfig-r10       INTEGER (0..154)
        }
    }                                                 OPTIONAL   -- Need ON
}
-- ASN1STOP
```

the CSI-RS-Config field descriptions as follows:

CSI-RS-Config field descriptions

antennaPortsCount
Parameter represents the number of antenna ports used for transmission of CSI reference signals where an1 corresponds to 1, an2 to 2 antenna ports etc. see TS 36.211 [21, 6.10.5].
p-C
Parameter: P_c, see TS 36.213 [23, 7.2.5].
resourceConfig
Parameter: CSI reference signal configuration, see TS 36.211 [21, table 6.10.5.2-1 and 6.10.5.2-2].
subframeConfig
Parameter: $I_{CSI\text{-}RS}$, see TS 36.211 [21, table 6.10.5.3-1].
zeroTxPowerResourceConfigList
Parameter: ZeroPowerCSI-RS, see TS 36.211 [21, 6.10.5.2].
zeroTxPowerSubframeConfig
Parameter: $I_{CSI\text{-}RS}$, see TS 36.211 [21, table 6.10.5.3-1].

Also, according to section 6.10.5.2 Mapping to resource elements in REF1, CSI-RS mapping to resource elements are described as—In subframes configured for CSI reference signal transmission, the reference signal sequence $r_{l,n_s}(m)$ is mapped to complex-valued modulation symbols $a_{k,l}^{(p)}$ used as reference symbols on antenna port p according to Equation 1:

$$a_{k,l}^{(p)} = w_{l''} \cdot r_{l,n_s}(m') \quad (1)$$

where

$$k = k' + 12m + \begin{cases} -0 \text{ for } p \in \{15, 16\}, \text{ normal cyclic prefix} \\ -6 \text{ for } p \in \{17, 18\}, \text{ normal cyclic prefix} \\ -1 \text{ for } p \in \{19, 20\}, \text{ normal cyclic prefix} \\ -7 \text{ for } p \in \{21, 22\}, \text{ normal cyclic prefix} \\ -0 \text{ for } p \in \{15, 16\}, \text{ extended cyclic prefix} \\ -3 \text{ for } p \in \{17, 18\}, \text{ extended cyclic prefix} \\ -6 \text{ for } p \in \{19, 20\}, \text{ extended cyclic prefix} \\ -9 \text{ for } p \in \{21, 22\}, \text{ extended cyclic prefix} \end{cases}$$

-continued

$$l = l' + \begin{cases} l'' & \text{CSI reference signal configurations 0-19, normal cyclic prefix} \\ 21'' & \text{CSI reference signal configurations 20-31, normal cyclic prefix} \\ l'' & \text{CSI reference signal configurations 0-27, extended cyclic prefix} \end{cases}$$

$$w_{l''} = \begin{cases} 1 & p \in \{15, 17, 19, 21\} \\ (-1)^{l''} & p \in \{16, 18, 20, 22\} \end{cases}$$

$l'' = 0, 1$

$m = 0, 1, \ldots, N_{RB}^{DL} - 1$

$$m' = m + \left\lfloor \frac{N_{RB}^{max,DL} - N_{RB}^{DL}}{2} \right\rfloor$$

The quantity (k',l') and the necessary conditions on n_s are given by TABLE 1 for normal cyclic prefix.

TABLE 1

Mapping from CSI reference signal configuration to (k', l') for normal cyclic prefix

CSI reference signal Configuration		Number of CSI reference signals configured: 1 or 2		4		8	
(resourceConfig)		(k', l')	n_s mod 2	(k', l')	n_s mod 2	(k', l')	n_s mod 2
Frame structure type 1 and 2	0	(9, 5)	0	(9, 5)	0	(9, 5)	0
	1	(11, 2)	1	(11, 2)	1	(11, 2)	1
	2	(9, 2)	1	(9, 2)	1	(9, 2)	1
	3	(7, 2)	1	(7, 2)	1	(7, 2)	1
	4	(9, 5)	1	(9, 5)	1	(9, 5)	1
	5	(8, 5)	0	(8, 5)	0		
	6	(10, 2)	1	(10, 2)	1		
	7	(8, 2)	1	(8, 2)	1		
	8	(6, 2)	1	(6, 2)	1		
	9	(8, 5)	1	(8, 5)	1		
	10	(3, 5)	0				
	11	(2, 5)	0				
	12	(5, 2)	1				
	13	(4, 2)	1				
	14	(3, 2)	1				

TABLE 1-continued

Mapping from CSI reference signal configuration to (k', l') for normal cyclic prefix							
CSI reference signal Configuration		Number of CSI reference signals configured					
		1 or 2		4		8	
(resourceConfig)		(k', l')	n_s mod 2	(k', l')	n_s mod 2	(k', l')	n_s mod 2
	15	(2, 2)	1				
	16	(1, 2)	1				
	17	(0, 2)	1				
	18	(3, 5)	1				
	19	(2, 5)	1				
Frame	20	(11, 1)	1	(11, 1)	1	(11, 1)	1
structure	21	(9, 1)	1	(9, 1)	1	(9, 1)	1
type	22	(7, 1)	1	(7, 1)	1	(7, 1)	1
2 only	23	(10, 1)	1	(10, 1)	1		
	24	(8, 1)	1	(8, 1)	1		
	25	(6, 1)	1	(6, 1)	1		
	26	(5, 1)	1				
	27	(4, 1)	1				
	28	(3, 1)	1				
	29	(2, 1)	1				
	30	(1, 1)	1				
	31	(0, 1)	1				

According to section 6.10.5.3—CSI reference signal subframe configuration, the cell-specific subframe configuration period $T_{CSI\text{-}RS}$ and the cell-specific subframe offset $\Delta_{CSI\text{-}RS}$ for the occurrence of CSI reference signals are listed in TABLE 2. The parameter $I_{CSI\text{-}RS}$ can be configured separately for CSI reference signals for which UE **116** assume non-zero and zero transmission power. Subframes containing CSI reference signals shall satisfy Equation 2:

$$(10n_f+\lfloor n_s/2\rfloor-\Delta_{CSI\text{-}RS})\bmod T_{CSI\text{-}RS}=0. \quad (2)$$

TABLE 2

CSI reference signal subframe configuration		
CSI-RS-SubframeConfig $I_{CSI\text{-}RS}$	CSI-RS periodicity $T_{CSI\text{-}RS}$ (subframes)	CSI-RS subframe offset $\Delta_{CSI\text{-}RS}$ (subframes)
0-4	5	$I_{CSI\text{-}RS}$
5-14	10	$I_{CSI\text{-}RS}$-5
15-34	20	$I_{CSI\text{-}RS}$-15
35-74	40	$I_{CSI\text{-}RS}$-35
75-154	80	$I_{CSI\text{-}RS}$-75

In REF1, CSI-RS sequence generation is explained as in the following section 6.10.5.1-Sequence generation: The reference-signal sequence $r_{l,n_s}(m)$ is defined by Equation 3:

$$r_{l,n_s}(m)=\frac{1}{\sqrt{2}}(1-2\cdot c(2m))+j\frac{1}{\sqrt{2}}(1-2\cdot c(2m+1)), \quad (3)$$
$$m=0,1,\ldots,N_{RB}^{max,DL}-1$$

where n_s is the slot number within a radio frame and l is the OFDM symbol number within the slot. The pseudo-random sequence c(i) is defined in Section 7.2. The pseudo-random sequence generator is initialized with

$$c_{init}=2^{10}\cdot(7\cdot(n_s+1)+l+1)\cdot(2\cdot N_{ID}^{cell}+1)+2\cdot N_{ID}^{cell}+N_{CP} \quad (4)$$

at the start of each OFDM symbol.

Further, for CSI-RS configuration for CoMP: Configuration of multiple non-zero-power CSI-RS resources includes at least:

antennaPortsCount, resourceConfig

Independently configured among CSI-RS resources

subframeConfig

Whether common or independent among CSI-RS resources is FFS

Configurable parameter to derive the pseudo-random sequence generator initialisation (c_{init})

c_{init} is independently configured among CSI-RS resources,

$$C_{init}=2^{10}\cdot(7\cdot(n_s+1)+1+1)\cdot(2\cdot X+1)+2\cdot X+N_{CP} \quad (5)$$

where X is configurable in a UE-specific manner and may take on any value in the range of 0 to 503,

FFS whether Rel-10 formula can be used without a change

FFS whether beyond 503 are supported

FFS whether CSI-RS ports always have the same scrambling or can have different scrambling within a CSI-RS resource

P_c

Details of signaling is FFS.

Additional Parameters May be Considered

Quasi Co-location: Two antenna ports are said to be quasi co-located if the large-scale properties of the channel over which a symbol on one antenna port is conveyed can be inferred from the channel over which a symbol on the other antenna port is conveyed. The large-scale properties include one or more of delay spread, Doppler spread, Doppler shift, average gain, and average delay.

CSI Process: UE **116** in transmission mode **10** can be configured with one or more CSI processes per serving cell by higher layers. Each CSI process is associated with a CSI-RS resource (defined in Section 7.2.5) and a CSI-interference measurement (CSI-IM) resource (defined in Section 7.2.6). A CSI reported by UE **116** corresponds to a CSI process configured by higher layers. Each CSI process can be configured with or without PMI/RI reporting by higher layer signalling.

For UE **116** in transmission mode **10**, UE **116** derives the interference measurements for computing the CQI value reported in uplink subframe n and corresponding to a CSI process, based on only the zero power CSI-RS (defined in REF3) within the configured CSI-IM resource associated with the CSI process. If UE **116** in transmission mode **10** is configured by higher layers for CSI subframe sets $C_{CSI,0}$ and $C_{CSI,1}$, the configured CSI-IM resource within the subframe subset belonging to the CSI reference resource is used to derive the interference measurement.

CSI-Process: the IE CSI-Process is the CSI process configuration that E-UTRAN can configure on a serving frequency.

CSI-Process information elements

```
CSI-Process-r11 ::=   SEQUENCE {
    csi-ProcessIdentity-r11          CSI-ProcessIdentity-r11,
    csi-RS-IdentityNZP-r11           CSI-RS-IdentityNZP-r11,
    csi-IM-Identity-r11              CSI-IM-Identity-r11,
    p-C-AndAntennaInfoDedList-r11 SEQUENCE (SIZE (1..2)) OF P-C-AndAntennaInfoDed-r11,
    cqi-ReportBothPS-r11             CQI-ReportBothPS-r11          OPTIONAL, -- Need OR
    cqi-ReportPeriodicId-r11 INTEGER (0..maxCQI-Ext-r11)           OPTIONAL, -- Need OR
    cqi-ReportAperiodicPS-r11        CQI-ReportAperiodicPS-r11     OPTIONAL, -- Need OR
    ...
}
P-C-r11 ::=          INTEGER (-8..15)
P-C-AndAntennaInfoDed-r11::= SEQUENCE {
    p-C-r11                                P-C-r11,
    antennaInfoDedConfigId-r11             AntennaInfoConfigDedId-r11
}
```

CSI-Process field descriptions

antennaInfoDedConfigId
Refers to a dedicated antenna info configuration that is configured for the same frequency as the CSI process.
csi-IM-Identity
Refers to a CSI-IM configuration that is configured for the same frequency as the CSI process.
csi-RS-IdentityNZP
Refers to a CSI RS configuration that is configured for the same frequency as the CSI process.
cqi-ReportBothPS
Includes CQI configuration parameters applicable for both aperiodic and periodic CSI reporting, for which CSI process specific values may be configured. E-URAN configures the field if and only if cqi-ReportPeriodicId is included and/or if cqi-ReportAperiodicPS is included and set to setup.
cqi-ReportPeriodicId
Refers to a periodic CQI reporting configuration that is configured for the same frequency as the CSI process. Value 0 refers to the set of parameters defined by the REL-10 CQI reporting configuration fields, while the other values refer to the additional configurations E-UTRAN assigns by CQI-ReportPeriodicExt-r11 (and as covered by CQI-ReportPeriodicExtId).
p-C
Parameter: P_c, see TS 36.213 [23, 7.2.5].
p-C-AndAntennaInfoDedList
A p-C-AndAntennaInfoDedList including 2 entries indicates that the subframe patterns configured for CSI (CQI/PMI/PTI/RI) reporting (i.e. as defined by field csi-MeasSubframeSet1 and csi-MeasSubframeSet2) are to be used for this CSI process, while a single entry indicates that the subframe patterns are not to be used for this CSI process. E-UTRAN does not include 2 entries in p-C-AndAntennaInfoDedList for CSI processes concerning a secondary frequency. E-UTRAN includes 2 entries in p-C-AndAntennaInfoDedList when configuring both cqi-pmi-ConfigIndex and cqi-pmi-ConfigIndex2.

CSI-ProcessIdentity: the IE CSI-ProcessIdentity is used to identify a CSI process that is configured by the IE CSI-Process. The identity is unique within the scope of a carrier frequency.

CSI-ProcessIdentity Information Elements

CSI-ProcessIdentity-r11::=INTEGER (1 . . . maxCSI-Proc-r11)

CSI-RS-ConfigNZP: the IE CSI-RS-ConfigNZP is the CSI-RS resource configuration using non-zero power transmission that E-UTRAN may configure on a serving frequency.

CSI-RS-ConfigNZP information elements

```
CSI-RS-ConfigNZP-r11 ::=   SEQUENCE {
    csi-RS-IdentityNZP-r11          CSI-RS-IdentityNZP-r11,
    antennaPortsCount-r11       ENUMERATED {an1, an2, an4, an8},
    resourceConfig-r11          INTEGER (0..31),
    subframeConfig-r11              INTEGER (0..154),
    scramblingIdentity-r11      INTEGER (0..503),
```

-continued

CSI-RS-ConfigNZP information elements

```
    qcl-CRS-Info-r11                SEQUENCE {
        qcl-ScramblingIdentity-r11  INTEGER (0..503),
        crs-PortsCount-r11          ENUMERATED {n1, n2, n4, spare1},
        mbsfn-SubframeConfig-r11    MBSFN-SubframeConfig  OPTIONAL,-- Need OR
    }                                                     OPTIONAL,-- Need OR
    ...
}
```

CSI-RS-ConfigZP: the IE CSI-RS-ConfigZP is the CSI-RS resource configuration, for which UE **116** assumes zero transmission power, that E-UTRAN can configure on a serving frequency.

CSI-RS-ConfigZP information elements

```
    CSI-RS-ConfigZP-r11 ::=         SEQUENCE {
        csi-RS-IdentityZP-r11       CSI-RS-IdentityZP-r11,
        resourceConfigList-r11      BIT STRING (SIZE (16)),
        subframeConfig-r11              INTEGER (0..154)
    }
```

CSI-RS-ConfigZP field descriptions

resourceConfigList

Parameter: CSI reference signal configuration, see TS 36.211 [21, table 6.10.5.2-1 and 6.10.5.2-2].

subframeConfig

Parameter: $I_{CSI\text{-}RS}$, see TS 36.211 [21, table 6.10.5.3-1].

CSI-RS-IdentityNZP: the IE CSI-RS-IdentityNZP is used to identify a CSI-RS resource configuration using non-zero transmission power, as configured by the IE CSI-RS-ConfigNZP. The identity is unique within the scope of a carrier frequency.

CSI-RS-IdentityNZP Information Elements

CSI-RS-IdentityNZP-r11::=INTEGER (1 . . . maxCSI-RS-NZP-r11)

CSI-RS-IdentityZP: the IE CSI-RS-IdentityZP is used to identify a CSI-RS resource configuration for which UE assumes zero transmission power, as configured by the IE CSI-RS-ConfigZP. The identity is unique within the scope of a carrier frequency.

CSI-RS-IdentityZP Information Elements

CSI-RS-IdentityZP-r11::=INTEGER (1 . . . maxCSI-RS-ZP-r11)

RRC Multiplicity and Type Constraint Values:

Multiplicity and Type Constraint Definitions

```
maxCSI-IM-r11       INTEGER ::= 3   -- Maximum number of CSI-IM configurations
                                    -- (per frequency)
maxCSI-Proc-r11     INTEGER ::= 4   -- Maximum number of CSI RS processes (per frequency)
maxCSI-RS-NZP-r11   INTEGER ::= 3   -- Maximum number of CSI RS resource
                                    -- configurations using non-zero Tx power
                                    -- (per frequency)
maxCSI-RS-ZP-r11    INTEGER ::= 4   -- Maximum number of CSI RS resource
                                    -- configurations using zero Tx power(per frequency)
maxCQI-Ext-r11      INTEGER ::= 3   -- Maximum number of additional periodic CQI
                                    -- configurations (per frequency)
```

CSI-IM-CONFIG: the IE CSI-IM-Config is the CSI-IM configuration that E-UTRAN may configure on a serving frequency.

CSI-IM-Config information elements

```
    CSI-IM-Config-r11 ::=   SEQUENCE {
        csi-im-Identity-r11         CSI-IM-Identity-r11,
        resourceConfig-r11          INTEGER (0..15),
        subframeConfig-r11              INTEGER (0..154),
        ...
    }
```

CSI-IM-Config field descriptions

resourceConfig
Parameter: CSI-IM configuration, see TS 36.211 [21, table 6.10.5.2-1 and 6.10.5.2-2] for 4 REs.
subframeConfig
Parameter: $I_{CSI\text{-}RS}$, see TS 36.211 [21, table 6.10.5.3-1].

CSI-IM-Identity: the IE CSI-IM-Identity is used to identify a CSI-IM configuration that is configured by the IE CSI-IM-Config. The identity is unique within the scope of a carrier frequency.

CSI-IM-Identity Information Elements

CSI-IM-Identity-r11::=INTEGER (1 . . . maxCSI-IM-r11)

Various embodiments of the present disclosure consider pilot transmissions from transmission points equipped with 2-dimensional (2D) active antenna array depicted in FIG. **4**. Here, transmission points (TPs) are a network node can

transmit downlink signals and receive uplink signals in a cellular network, examples of which include base stations, NodeBs, enhanced NodeBs (eNBs) remote radio heads (RRHs), and so forth. Alternatively, an entity controlling at least one TP is called the controller, the network or eNB. Each active antenna array may have separate base band, which could dynamically control the antenna weights in frequency selective manner.

FIG. **4** illustrates a transmission point equipped with 2D active antenna array according to embodiments of the present disclosure. The embodiment of the transmission point **400** shown in FIG. **4** is for illustration only. Other embodiments could be used without departing from the scope of this disclosure.

The transmission point **400** includes an antenna array **405** and a controller **410**. The Antenna array **405** that includes N (=$N_H \times N_V$) 2D active antenna elements **415**, and the N antenna, elements are placed in 2D grid of $N_H \times N_V$. The horizontal spacing between any two closest antenna elements is denoted by d_H **420**, and the vertical spacing between any two closest antenna elements is denoted by d_V **425**.

FIG. **5** illustrates azimuth and elevation angles to a mobile station from the 2D active antenna array according to embodiments of the present disclosure. The embodiment of the 2D active antenna array **405** shown in FIG. **5** is for illustration only. Other embodiments could be used without departing from the scope of this disclosure.

A transmission vector between the transmission point **400** equipped with 2D antenna array and UE **116** is transmitted at azimuth and elevation angles. In the example placement shown in FIG. **5**, antenna elements **415** are placed in a rectangle on XZ plane in an orthogonal XYZ coordinate system. The origin **505** of the coordinate system is placed at the center of the rectangle. The azimuth (horizontal) angle θ_k **510** for UE **116** is defined as the angle between Y axis **515** and the projection vector **520** of a straight line between the TP and UE **116** to the XY plane. Alternatively, the elevation (vertical) angle θ_k **525** is defined as the angle between Y axis and the projection vector of the straight line to the YZ plane.

In the cellular networks, the network utilizes UEs' channel state information (CSI) to schedule time-frequency resources, to select precoders and modulation and coding schemes (MCS) for each individual UE. To facilitate the UEs' CSI estimation, the network can configure and transmit CSI reference signals (CSI-RS). At the same time, each UE can be configured to feed back estimated precoding matrix information (PMI), channel quality information (CQI) and rank information (RI), by receiving and processing the CSI-RS. Traditionally, the UEs' CSI feedback is designed with mainly targeting horizontal CSI associated with the azimuth angles. For example, PMI/CQI feedback for downlink beamforming in LTE informs the eNB the horizontal direction (or the azimuth angle) along which the UE receives the strongest signal and the associated channel strength. When active antenna array elements are introduced in the vertical domain as well, the necessity of vertical CSI feedback emerges. To facilitate the vertical CSI feedback, the corresponding CSI-RS design is crucial.

Embodiments of the present disclosure illustrate CSI-RS designs and associated configuration methods to be used in the wireless communication networks (e.g., cellular networks) having TPs equipped with 2D active antenna array. It is noted that unless otherwise specified, the CSI-RS disclosed herein refers to NZP CSI-RS.

A new transmission mode (TM), referenced hereinafter as TM X, is defined for helping UEs' reception from the 2D active antenna array **405**. When UE **116** is configured with TM X, UE **116** receives PDSCHs from the 2D active antenna array **405**, and is configured with a newly designed CSI-RS. The MIMO transmission from the 2D active antenna array **405** is also referenced as full-dimensional MIMO or FD-MIMO.

In one method (method 1), TP **400** is capable of transmitting all the N CSI-RS antenna ports (APs) associated with each of the N antenna elements **415**, and the network is capable of configuring all the N CSI-RS APs to each UE using a UE-specific RRC configuration or a broadcast signaling, so that UE **116** can estimate the full CSI associated with the N antenna elements **415**.

In another method (method 2), TP **400** is capable of transmitting at least two sets of CSI-RS APs, and the network is capable of configuring the at least two sets of CSI-RS APs to each UE, wherein UE **116** derives and feeds back horizontal CSI (H-CSI) and vertical CSI (V-CSI) estimated by receiving and processing the at least two sets of CSI-RS. Here the total number of CSI-RS APs can be less than N, and hence the CSI-RS transmission overhead is reduced as compared to method 1.

For Horizontal CSI and vertical CSI: the H-CSI of a UE is horizontal CSI estimated at UE **116**, which are channel characteristics mainly associated with horizontally placed antenna elements **415** at TP **400**. The horizontal CSI includes horizontal CQI (H-CQI), horizontal PMI (H-PMI) and horizontal RI (H-RI). For example, the H-CSI can be the same as the CSI (PMI, CQI and RI) in another LTE system, because the certain LTE systems CSI feedback contents and mechanism are designed considering horizontal antenna array.

The V-CSI of a UE is vertical CSI estimated at UE **116**, which are channel characteristics mainly associated with vertically placed antenna elements at TP **400**. The vertical CSI includes vertical CQI (V-CQI), vertical PMI (V-PMI) and vertical RI (V-RI).

FIG. **6** illustrates H-PMI and V-PMI according to embodiments of the present disclosure. The embodiment of the H-PMI and V-PMI **600** shown in FIG. **6** is for illustration only. Other embodiments could be used without departing from the scope of this disclosure.

In certain embodiments, UE 1 **116**, UE 2 **115** and UE 3 **114** receives the strongest signal when the (H-PMI, V-PMI) pairs are (P1,Q1), (P2,Q2) and (P3,Q3), respectively, according to their respective horizontal directions (or azimuth angles) and vertical directions (or elevation angles). When configured to feed back H-PMIs, UE 1 **116**, UE 2 **115** and UE 3 **114** report H-PMIs P1 **605**, P2 **610** and P3 **615**, respectively. When configured to feed back V-PMIs, UE 1 **116**, UE 2 **115** and UE 3 **114** report V-PMIs Q1 **620**, Q2 **625** and Q3 **630**, respectively.

As for CQI, two feedback methods can be considered: 1) H-CQI and V-CQI are separately derived and are independently fed back to the network; and 2) One joint CQI is derived and is fed back to the network for the N antenna channel. In one design, UE **116** constructs a desired precoding matrix for the N-Tx antenna channel using H-PMI and V-PMI, and calculates a received power under the assumption that the TP transmits signals using the precoding matrix. From the received power, UE **116** derives CQI, where the CQI can be a desired MCS. In one example, the desired precoding matrix is found by taking Kronecker product of H-PMI=$[p_1, p_2, \ldots, P_{NH}]^t \in C^{NH\times 1}$ and V-PMI=$[q_1, q_2, \ldots, q_{NH}]^t \in CN^{NV\times 1}$. In this case, when N_H=2, N_V=2, H-RI=1 and V-RI=1, the Kronecker product would be calculated as in the Equations 5 and 6:

$$H-PMI \otimes V-PMI = \begin{bmatrix} p_1 \\ p_2 \end{bmatrix} \otimes \begin{bmatrix} q_1 \\ q_2 \end{bmatrix} = \begin{bmatrix} p_1 q_1 \\ p_1 q_2 \\ p_2 q_1 \\ p_2 q_2 \end{bmatrix}, \quad (5)$$

$$V-PMI \otimes H-PMI = \begin{bmatrix} q_1 \\ q_2 \end{bmatrix} \otimes \begin{bmatrix} p_1 \\ p_2 \end{bmatrix} = \begin{bmatrix} q_1 p_1 \\ q_1 p_2 \\ q_2 p_1 \\ q_2 p_2 \end{bmatrix}. \quad (6)$$

Joint RI is the rank information about the MIMO channels between the N-Tx antenna and a number of receive antennas at the UE.

For ease of illustration, the example shown in FIG. **6** illustrates only line-of-sight channels. However, the non-line-of-sight channels, the V-CSI and H-CSI can be described and defined in a similar way. The example shown in FIG. **6** is for illustration only and it does not prevent other similar constructions and definitions of V-CSI and H-CSI.

FIG. **7** illustrates a first and a second CSI-RS APs according to embodiments of the present disclosure. The embodiment of the transmitter chain **700** including the first and second CSI-RS APs shown in FIG. **7** is for illustration only. Other embodiments could be used without departing from the scope of the present disclosure.

The transmitter chain **700** is configured for multiplexing a first set of CSI-RS **705** (denoted by A-CSI-RS APs) and a second set of CSI-RS APs **710** (denoted by B-CSI-RS APs) for the at least two sets of CSI-RS APs. Here, the multiplexer operation **715** for A-CSI-RS APs **705** and B-CSI-RS APs **710** can be time-domain multiplexing (TDM), CDM (code-domain multiplexing), FDM (frequency-domain multiplexing) and SDM (spatial-domain multiplexing) and any combination of TDM, FDM, CDM and SDM. When TDM multiplexing is applied, A-CSI-RS APs **705** and B-CSI-RS APs **710** transmit their CSI-RS at two different time location, e.g., in two different time slots, or in two different subframes, or in two different sets of OFDM symbols. When FDM multiplexing is applied, A-CSI-RS APs **705** and B-CSI-RS APs **710** transmit their CSI-RS at two different frequency (or subcarrier) location. When CDM multiplexing is applied, A-CSI-RS APs **705** and B-CSI-RS APs **710** transmit their CSI-RS using two different orthogonal codes (e.g., Walsh code, CAZAC code) in the same time-frequency location. When SDM is applied, A-CSI-RS APs **705** and B-CSI-RS APs **710** transmit their CSI-RS in two different spatial beams, and they can be differently scrambled using two different scrambling initializations. Some example combinations of TDM, CDM, FDM and SDM are described below. When FDM/TDM multiplexing is applied, A-CSI-RS APs **705** and B-CSI-RS APs **710** transmit their CSI-RS at two different time-frequency location. Two sets of CSI-RS APs are (quasi) co-located if large-scale propagation properties of the channel over which a symbol on the first antenna port is conveyed can be inferred from the channel over which another symbol on the other antenna port is conveyed.

In certain embodiments, for deriving at least one of joint CQI, joint PMI and joint RI for the $N=N_H \times N_V$ antenna channels utilizing the two sets of CSI-RS, UE **116** can assume that the two sets of CSI-RS APs are (quasi) co-located. In certain embodiments, the network can indicate whether UE **116** can assume that the two sets of CSI-RS APs are (quasi) co-located or not for deriving joint CQI, joint PMI and joint RI.

In certain embodiments, (A-CSI-RS, B-CSI-RS) can be (H-CSI-RS, V-CSI-RS), (a first H-CSI-RS, a second H-CSI-RS), (a primary CSI-RS, a secondary CSI-RS), as illustrated in later embodiments.

In certain embodiments, the CSI-RS configurations defined in Rel-10 LTE or Rel-11 LTE is reused for configuring each of A-CSI-RS and B-CSI-RS. When Rel-10 LTE CSI-RS configuration is used, some of the following parameters in the Table 3 are separately configured for each of A-CSI-RS and B-CSI-RS.

TABLE 3

CSI-RS-Config field descriptions
AntennaPortsCount Parameter represents the number of antenna ports used for transmission of CSI reference signals where an1 corresponds to 1, an2 to 2 antenna ports etc. see TS 36.211 [21, 6.10.5]. p-C Parameter: P_c, see TS 36.213 [23, 7.2.5]. resourceConfig Parameter: CSI reference signal configuration, see TS 36.211 [21, table 6.10.5.2-1 and 6.10.5.2-2]. subframeConfig Parameter: I_{CSI-RS}, see TS 36.211 [21, table 6.10.5.3-1].

When Rel-11 LTE NZP CSI-RS configuration is used, some of the parameters defining a CSI-RS-ConfigNZP-r11 (whose fields are copied below and in the background section) are separately configured for each of A-CSI-RS and B-CSI-RS.

```
CSI-RS-ConfigNZP-r11 ::=  SEQUENCE {
    csi-RS-IdentityNZP-r11          CSI-RS-IdentityNZP-r11,
    antennaPortsCount-r11       ENUMERATED {an1, an2, an4, an8},
    resourceConfig-r11          INTEGER (0..31),
    subframeConfig-r11              INTEGER (0..154),
    scramblingIdentity-r11      INTEGER (0..503),
    qcl-CRS-Info-r11            SEQUENCE {
        qcl-ScramblingIdentity-r11  INTEGER (0..503),
        crs-PortsCount-r11          ENUMERATED {n1, n2, n4, spare1},
        mbsfn-SubframeConfig-r11    MBSFN-SubframeConfig  OPTIONAL,-- Need OR
    }                                                     OPTIONAL,-- Need OR
    ...
}
```

The resource configurations (resourceConfig) and AntennaPortsCount for A-CSI-RS and B-CSI-RS can be independently or jointly configured.

In one example of independent configuration, (A-resourceConfig, A-AntennaPortsCount) and (B-resourceConfig, B-AntennaPortCount) are configured for A-CSI-RS and B-CSI-RS. When these are configured to UE, UE **116** derives each of A-CSI-RS pattern B-CSI-RS pattern with

replacing (resourceConfig,AntennaPortCount) by each of (A-resource-Config,A-AntennaPortCount) and (B-resource-Config, B-AntennaPortCount) according to TABLE 1.

In one example of joint configuration, (resourceConfig, AntennaPortCount) is configured for both A-CSI-RS and B-CSI-RS. When (resourceConfig,AntennaPortCount) is configured to UE **116**, UE **116** first derives a CSI-RS pattern according to TABLE 1 with the configured (resourceConfig, AntennaPortCount). Then, the time frequency locations for N_1 A-CSI-RS APs and N_2 B-CSI-RS APs are determined according to a pre-defined way, where AntennaPortCount=N_1+N_2. Note that N_1 and N_2 can be RRC configured or be constants in the standard specification. Some examples of joint configuration are described in FIG. **8** and below.

In a first example (Example 1) When AntennaPortCount=8, N_1=4 and N_2=4, APs 15-18 are assigned for A-CSI-RS, and APs 19-22 are assigned for B-CSI-RS. In other words, A-CSI-RS and B-CSI-RS are FDM-multiplexed; and multiple CSI-RS ports in each of A-CSI-RS and B-CSI-RS are CDM multiplexed.

In a second example (Example 2) When AntennaPortCount=8, N_1=4 and N_2=4, APs (15, 17, 19, 21) are assigned for A-CSI-RS, and APs (16, 18, 20, 22) are assigned for B-CSI-RS. In other words, the 8 CSI-RS are multiplexed in 4 CDM groups of 2 REs each, wherein a first CDM code, e.g., [+1, +1] is assigned for A-CSI-RS; and a second CDM code, e.g., [+1, −1] is assigned for B-CSI-RS.

The resource configurations (resourceConfig) and AntennaPortsCount for A-CSI-RS and B-CSI-RS can be independently or jointly configured.

In one example of independent configuration, (A-resourceConfig, A-AntennaPortsCount) and (B-resourceConfig, B-AntennaPortCount) are configured for A-CSI-RS and B-CSI-RS. When these are configured to UE **116**, UE **116** derives each of A-CSI-RS pattern B-CSI-RS pattern with replacing (resourceConfig,AntennaPortCount) by each of (A-resourceConfig,A-AntennaPortCount) and (B-resource-Config, B-AntennaPortCount) according to TABLE 1.

In one example of joint configuration, (resourceConfig, AntennaPortCount) is configured for both A-CSI-RS and B-CSI-RS. When (resourceConfig,AntennaPortCount) is configured to UE **116**, UE **116** first derives a CSI-RS pattern according to TABLE 1 with the configured (resourceConfig, AntennaPortCount). Then, the time frequency locations for N_1 A-CSI-RS APs and N_2 B-CSI-RS APs are determined according to a pre-defined way, where AntennaPortCount=N_1+N_2. Note that N_1 and N_2 can be RRC configured or be constants in the standard specification. Some examples of joint configuration are described in FIGS. **8** and below.

In a first example, (Example 1) When AntennaPortCount=8, N_1=4 and N_2=4, APs 15-18 are assigned for A-CSI-RS, and APs **19-22** are assigned for B-CSI-RS. In other words, A-CSI-RS and B-CSI-RS are FDM-multiplexed; and multiple CSI-RS ports in each of A-CSI-RS and B-CSI-RS are CDM multiplexed.

In a second example (Example 2) When AntennaPortCount=8, N_1=4 and N_2=4, APs (15, 17, 19, 21) are assigned for A-CSI-RS, and APs (16, 18, 20, 22) are assigned for B-CSI-RS. In other words, the 8 CSI-RS are multiplexed in 4 CDM groups of 2 REs each, wherein a first CDM code, e.g., [+1, +1] is assigned for A-CSI-RS; and a second CDM code, e.g., [+1, −1] is assigned for B-CSI-RS.

FIGS. **8**A through **8**C illustrates joint configuration of A- and B-CSI-RS according to embodiments of the present disclosure. The embodiments of the joint configuration **800**, **810**, **820** shown in FIGS. **8**A through **8**C are for illustration only. Other embodiments could be used without departing from the scope of this disclosure.

In certain embodiments, a common AntennaPortCount is configured for both A-CSI-RS and B-CSI-RS, and at the same time, A-resourceConfig and B-resourceConfig are separately configured for UE **116**. In this case, UE **116** derives A-CSI-RS pattern and B-CSI-RS pattern with (A-resourceConfig, AntennaPortCount) and (B-resourceConfig, AntennaPortCount), respectively.

In addition, the total N number of antenna ports at TP **400** can be additionally signaled from A-AntennaPortCount and B-AntennaPortCount.

The subframe configurations (subframeConfig) for A-CSI-RS and B-CSI-RS can be independently or jointly configured.

In one example of independent configuration, for each of A-CSI-RS and B-CSI-RS, the subframe period and the subframe offset for the occurrence are configured as in the same way as the Rel-10 CSI-RS are configured. In this case, two parameters are configured to UE **116**, i.e., A-CSI-RS-SubframeConfig and B-CSI-RS-SubframeConfig and UE **116** derives the subframe period and the subframe offset for the occurrence of each of B-CSI-RS and A-CSI-RS according to TABLE 2, with replacing CSI-RS-SubframeConfig by each of A-CSI-RS-SubframeConfig and B-CSI-RS-SubframeConfig.

In one example of joint configuration, for both A-CSI-RS and B-CSI-RS, the subframe configuration period and the subframe offset for the occurrence are configured as in the same way as the Rel-10 CSI-RS are configured. In this case, one parameter is configured to UE **116** as in Rel-10, i.e., CSI-RS-SubframeConfig and UE **116** derives the subframe period and the subframe offset for the occurrence of both B-CSI-RS and A-CSI-RS according to TABLE 2 with the configured CSI-RS-SubframeConfig.

It is noted that (A-CSI-RS, B-CSI-RS) can be (H-CSI-RS, V-CSI-RS), (a first H-CSI-RS, a second H-CSI-RS), (a primary CSI-RS, a secondary CSI-RS), as illustrated in later embodiments.

For configuration of CSI-RS transmission and CSI feedback for UE **116** configured with TM X, a new CSI process, referenced hereafter as CSI-Process-r12, is defined. To facilitate joint CQI transmission, the new CSI process is associated with two CSI resources, i.e., A-CSI-RS and B-CSI-RS, rather than one CSI-RS and one CSI-IM.

One illustration example construction of CSI-process-r12 is described below, where a common Pc (p-C-AndAntennaInfoDedList-r12) is configured for A-CSI-RS and B-CSI-RS.

```
CSI-Process-r12 ::=  SEQUENCE {
    csi-ProcessIdentity-r12              CSI-ProcessIdentity-r12,
    a-csi-RS-IdentityNZP-r12        CSI-RS-IdentityNZP-r12,
    b-csi-RS-IdentityNZP-r12        CSI-RS-IdentityNZP-r12,
    p-C-AndAntennaInfoDedList-r12    SEQUENCE (SIZE (1..2)) OF P-C-
AndAntennaInfoDed-r12,
```

-continued

```
cqi-ReportBothPS-r12          CQI-ReportBothPS-r12
OPTIONAL,  -- Need OR
cqi-ReportPeriodidd-r12       INTEGER (0..maxCQI-Ext-r12)
OPTIONAL,  -- Need OR
cqi-ReportAperiodicPS-r12     CQI-ReportAperiodicPS-r12     OPTIONAL,
-- Need OR
...}
```

In certain embodiments, when configuring a set of CSI-RS, a CSI-RS type is signaled in addition to other CSI-RS configuration parameters, e.g., CSI-RS pattern, subframe period, subframe offset, and power. The signaling can be either UE-specific or cell-specific. Depending on the configured CSI-RS type information, UE **116** derives CSI differently with estimating channels using the configured CSI-RS, e.g., based on different PMI codebooks.

In one example, a first CSI-RS type is associated with a first PMI codebook, and a second CSI-RS type is associated with a second PMI codebook.

The first and the second PMI codebooks can be a horizontal PMI codebook and a vertical PMI codebook, respectively. Here, the horizontal PMI codebook can be the same as one of Rel-8 and Rel-10 downlink 2-Tx, 4-Tx and 8-Tx PMI codebooks defined in the LTE specifications; and the vertical PMI codebook can be differently designed from the Rel-8 and Rel-10 downlink 2-Tx, 4-Tx and 8-Tx codebooks.

The first and the second PMI codebooks can have different sizes. That is, the first and the second PMI codebooks are composed of M_1 number of PMI matrices and M_2 number of PMI matrices respectively, wherein M_1 and M_2 can be different.

In one example, the first PMI codebook is a 4-bit codebook, composed of M_1=16 matrices; and the second PMI codebook is a 2-bit codebook, composed of M_2=4 matrices.

In certain embodiments, UE **116** is configured with a first set of CSI-RS of a first CSI-RS type and a second set of CSI-RS of a second CSI-RS type. UE **116** derives a first PMI according to the first PMI codebook with estimating channels using the first set of CSI-RS. UE **116** also derives a second PMI according to the second PMI codebook with estimating channels using the second set of CSI-RS.

The feedback reporting of the first PMI and the second PMI is configured either jointly or independently.

When the feedback reporting is independently (or individually) configured, the first PMI and the second PMI are reported to the eNB **102** according to the respective configurations.

When the feedback reporting is jointly configured, both the first PMI and the second PMI are reported in a single uplink physical channel transmitted in a subframe, e.g., on a PUSCH or a PUCCH.

Similarly, when configuring a set of CSI-RS, a PMI codebook information is signaled in addition to the other CSI-RS configuration parameters. According to the configured PMI codebook, UE **116** derives PMI with estimating channels using the configured CSI-RS. For example, when UE **116** is configured with a first set of CSI-RS and the first PMI codebook; and a second set of CSI-RS and the second PMI codebook, then, UE **116** derives a first PMI according to the first PMI codebook with estimating channels using the first set of CSI-RS. In addition, UE **116** derives a second PMI according to the second PMI codebook with estimating channels using the second set of CSI-RS. In one example, the first PMI codebook and the second PMI codebook are a horizontal PMI codebook and a vertical PMI codebook, respectively.

In certain embodiments, when CSI-process-r12 is newly defined as above, a CSI-RS configuration is implicitly associated with a PMI codebook. In one example, PMI estimated with A-CSI-RS (a-csi-RS-IdentityNZP-r12) is selected from the first codebook; and PMI estimated with B-CSI-RS (a-csi-RS-IdentityNZP-r12) is selected from the second codebook.

FIG. **9** illustrates Vertical CSI-RS APs and horizontal CSI-RS APs according to embodiments of the present disclosure. The embodiment of the transmitter chain **900** including the Vertical CSI-RS APs and horizontal CSI-RS APs shown in FIG. **9** is for illustration only. Other embodiments could be used without departing from the scope of the present disclosure.

Configuration of Vertical and Horizontal CSI-RS APs:

In certain embodiments, two sets of CSI-RS APs **905**, **910** out of the at least two sets of CSI-RS APs are separately constructed: one set consists of N_V vertical CSI-RS (V-CSI-RS) APs **905**, and the other set consists of N_H horizontal CSI-RS (H-CSI-RS) APs **910**. Here, the horizontal CSI-RS APs **910** are used for UEs' horizontal CSI (H-CSI) estimation, and the vertical CSI-RS APs **905** is used for UEs' vertical CSI (V-CSI) estimation.

When UE **116** is configured with N_V V-CSI-RS APs **905** and N_H H-CSI-RS APs **910**, UE **116** can assume that the total number of antenna ports at the TP **400** is $N=N_H \times N_V$ for deriving at least one of joint CQI and joint PMI for the N antenna channels. In another design the total number of antenna ports at the TP is separately signaled to UE **116**.

In certain embodiments, H-CSI-RS is associated with H-PMI codebook and V-CSI-RS is associated with V-PMI codebook. In certain embodiments, H-PMI codebook and V-CSI-RS codebook can be identical.

In one alternative, 3GPP LTE Rel-8 and Rel-10 2-Tx, 4-Tx and 8-Tx DL codebooks are reused for both H-PMI and V-PMI. In certain embodiments, UE **116** derives H-CSI using H-CSI-RS by applying the same procedure used for deriving Rel-10 CQI/PMI/RI based on Rel-10 CSI-RS. In certain embodiments, UE **116** derives V-CSI using V-CSI-RS by applying the same procedure used for deriving Rel-10 CQI/PMI/RI based on Rel-10 CSI-RS.

In another alternative, 3GPP LTE Rel-8 and Rel-10 2-Tx, 4-Tx, and 8-Tx DL codebooks are reused for H-PMI codebook only and V-PMI codebook is newly designed; or both the H-PMI and the V-PMI codebooks are newly designed.

Then, the CSI-RS configuration can include a CSI-RS type field, to indicate whether the configured CSI-RS is H-CSI-RS or V-CSI-RS. When UE **116** is configured with H-CSI-RS, UE **116** derives a PMI (H-PMI) using the H-PMI codebook with estimating channels using H-CSI-RS. Alternatively, when UE **116** is configured with V-CSI-RS, UE **116** derives a PMI (V-PMI) using the V-PMI codebook with estimating channels using V-CSI-RS.

Similarly, the CSI-RS configuration can include a PMI codebook information field, to indicate which PMI codebook should be used for deriving PMI using the configured CSI-RS. When UE **116** receives a configuration signaling of a CSI-RS and a H-PMI codebook, UE **116** derives a PMI (H-PMI) using the H-PMI codebook with estimating channels using the configured CSI-RS; on the other hand when UE **116** receives a configuration signaling of a CSI-RS and a V-PMI codebook, UE **116** derives a PMI (V-PMI) using the V-PMI codebook with estimating channels using the configured CSI-RS.

In another alternative, a PMI codebook information can be separately signaled from the CSI-RS configuration. Then, UE **116** derives H-PMI and V-PMI using either a first PMI codebook or a second PMI codebook, depending on the configured PMI codebook information. In certain embodiments, the first PMI codebook can be 3GPP LTE Rel-8 and Rel-10 2-Tx, 4-Tx, and 8-Tx DL codebooks; and the second PMI codebook can be a newly designed codebook.

In certain embodiments, the codebook sizes of the H-PMI codebook and the V-PMI codebook are different. In one example, for assigning better beam resolution of horizontal beams more than that of vertical beams, a larger size codebook is used for H-PMI than for V-PMI. In one example, for assigning better beam resolution of vertical beams more than that of horizontal beams, a larger size codebook is used for V-PMI than for H-PMI.

FIG. **10** illustrates construction of the horizontal and the vertical CSI-RS APs according to embodiments of the present disclosure. The embodiment of the construction **1000** shown in FIG. **10** is for illustration only. Other embodiments could be used without departing from the scope of this disclosure.

In certain embodiments, in the construction **1000** of the horizontal and the vertical CSI-RS APs (Construction Example 1) includes the N_H horizontal CSI-RS APs (say, H-APs 0, . . . , N_H−1) are transmitted from a row **1005** of the active antenna array, while the N_V vertical CSI-RS APs (say, V-APs 0, . . . , N−1) are transmitted from a column **1010** of the active antenna array. In the example shown in FIG. **10**, the horizontal CSI-RS APs are transmitted from the first row **1005** of the antenna array, while the vertical CSI-RS APs are transmitted from the first column **1010** of the antenna array.

When the H-CSI-RS and V-CSI-RS are transmitted in the same subframe, one CSI-RS AP can be shared between the two sets of the CSI-RS APs. For example, only a single CSI-RS signal mapped onto single-port CSI-RS REs is transmitted for H-AP 0 and V-AP 0. Alternatively, the H-CSI-RS and V-CSI-RS can also be orthogonally and independently mapped in the time-frequency grid, even if the two CSI-RS APs are scheduled in the same subframe.

FIG. **11** illustrates construction of the horizontal and the vertical CSI-RS APs according to embodiments of the present disclosure. The embodiment of the construction **1100** shown in FIG. **11** is for illustration only. Other embodiments could be used without departing from the scope of this disclosure.

In certain embodiments, in the construction **1100** of the horizontal and the vertical CSI-RS APs (Construction Example 2), each of the N_H horizontal CSI-RS for the N_H H-CSI-RS APs (say, H-APs 0, . . . , N_H−1) are transmitted from a column **1105** of the active antenna array. Each H-CSI-RS signal is precoded with a precoding vector of $[p_1\ p_2\ \ldots\ p_{NV}]^t$, where the precoding is applied across the antenna elements in each column of the active antenna array.

Alternatively, each of the N_V vertical CSI-RS for the N_V APs (say, V-APs 0, . . . , N_V−1) are transmitted from a row **1110** of the active antenna array. Each H-CSI-RS signal is precoded with a precoding vector of $[q_1\ q_2\ \ldots\ q_{NH}]$, where the precoding is applied across the antenna elements in each row of the active antenna array.

The precoding to generate a CSI-RS signal also is referenced as antenna virtualization precoding. As shown in FIG. **11**, the construction **1100** can be easily extended to a construction in which different precoding vectors are applied across different rows (or columns) corresponding to the different V-CSI-RS (or H-CSI-RS).

FIG. **12** illustrates first and second sets of horizontal CSI-RS APs according to embodiments of the present disclosure. The embodiment of the transmitter chain **1200** including the first and second sets of horizontal CSI-RS APs shown in FIG. **12** is for illustration only. Other embodiments could be used without departing from the scope of the present disclosure.

Configuration of a First and a Second Horizontal CSI-RS APs:

In certain embodiments, two sets of CSI-RS APs **1205**, **1210** out of the at least two sets of CSI-RS APs are separately constructed: each of the two sets consists of N_H H-CSI-RS APs corresponding to a row of antenna elements in the 2D active antenna array **405**. Here, the two sets of H-CSI-RS APs **1205**, **1210** are used for UEs' horizontal and vertical CSI estimation.

In this case, the total number of antenna ports at the TP N is separately RRC configured from the configurations for the two sets of CSI-RS **1205**, **1210**. The total number of antenna ports $N=N_H \times N_V$ is used for deriving at least one of joint CQI and joint PMI for the N antenna channels

FIG. **13** illustrates construction of two sets of H-CSI-RS APs according to embodiments of the present disclosure. The embodiment of the construction **1300** shown in FIG. **13** is for illustration only. Other embodiments could be used without departing from the scope of this disclosure.

In certain embodiments, in the construction **1300** of the two sets of H-CSI-RS APs (Set Construction Example 1), the two rows of antenna elements corresponding to the two sets of H-CSI-RS APs are the first two rows **1305** in the 2D active antenna array **405**. In this case, UE **116** determines the vertical CSI for the entire $N_H \times N_V$ antennas in the 2D active antenna array **405** by estimating the phase difference between the two rows, as well as the horizontal CSI by relying on the traditional methods of estimating horizontal CSI. The two rows are configurable by the network, in which case, the network is configured to indicate to each UE at least one of the following: The indices of the two rows corresponding to the two H-CSI-RS APs. For example, when the first two rows **1305**, **1310** are corresponding to the two H-CSI-RS APs as in the example shown in FIG. **13**, the network configures to each UE two row indices, row index 0 **1305** and row index 1 **1310**.

In certain embodiments, eNB **102** signals to UE **116** the difference of the two indices of the two rows corresponding to the two H-CSI-RS APs. For example, when the first two rows are corresponding to the two H-CSI-RS APs as in the example shown in FIG. **13**, the network configures to each UE the difference of the two row indices, i.e., (1−0)=1.

The example shown in FIG. **13** is for illustration only. The same idea can be used for constructing N_V sets of H-CSI-RS APs corresponding to the N_V rows of the 2D antenna array.

In one alternative, CSI-RS configuration includes a CSI-RS type field to indicate whether the configured CSI-RS is the first H-CSI-RS or the second H-CSI-RS.

FIG. **14** illustrates Construction of two sets of H-CSI-RS APs according to embodiments of the present disclosure.

The embodiment of the construction **1400** shown in FIG. **14** is for illustration only. Other embodiments could be used without departing from the scope of this disclosure.

In certain embodiments, in the construction **1400** of the two sets of H-CSI-RS APs (Set Construction Example 2), two different virtualization precoding vectors are applied to the two sets of H-CSI-RS APs **1405**, **1410**. Each H-CSI-RS signal in the first set **1405** is precoded with a precoding vector of $[p_1\ p_2 \ldots p_{NV}]^t$, and each H-CSI-RS in the second set is precoded with a precoding vector of $[q_1\ q_2 \ldots q_{NV}]^t$, where the precoding vector is applied across the antenna elements in each column of the active antenna array in each set of H-CSI-RS APs. UE **116** determines the vertical CSI for the entire $N_H \times N_V$ antennas in the 2D active antenna array **405** by estimating the phase difference between the two sets of H-CSI-RS APs **1405**, **1410**, as well as the horizontal CSI by relying on the traditional methods of estimating horizontal CSI. The two virtualization precoding vectors can be indicated by the network to each UE.

FIG. **15** illustrates primary and secondary CSI-RS APs according to embodiments of the present disclosure. The embodiment of the transmitter chain **1500** including the primary and secondary CSI-RS APs shown in FIG. **15** is for illustration only. Other embodiments could be used without departing from the scope of the present disclosure.

In one alternative, CSI-RS configuration includes a CSI-RS type field, to indicate whether the configured CSI-RS is the primary CSI-RS or the secondary CSI-RS.

Configuration of a First and a Second Horizontal CSI-RS APs:

In certain embodiments, two sets of CSI-RS APs out of the at least two sets of CSI-RS APs are separately constructed and configured (period as well): a set of primary CSI-RS APs **1505** and a set of secondary CSI-RS APs **1510**.

Primary CSI-RS APs **1505**: in certain embodiments, UE **116** utilizes the set of primary CSI-RS APs **1505** to derive either H-CSI or V-CSI, depending on whether the primary CSI-RS **1505** are corresponding to the (N_H) horizontally placed antenna elements or (N_V) vertically placed antenna elements. Whether UE **116** can derive H-CSI or V-CSI out of the primary CSI-RS **1505** is indicated by the network, or fixed in the standard specification (e.g., pre-stored in memory **360**).

Secondary CSI-RS APs **1510**: in certain embodiments, UE **116** combines the primary CSI-RS APs **1505** and the secondary CSI-RS APs **1510** to determine either V-CSI-RS or H-CSI-RS. In one example, when the primary CSI-RS APs **1505** correspond to the horizontally placed antenna elements and are used for estimating H-CSI-RS, the secondary CSI-RS APs **1510**, together with the primary CSI-RS APs **1505**, can be used for estimating the V-CSI-RS. In another example, when the primary CSI-RS APs **1505** correspond to the vertically placed antenna elements and are used for estimating V-CSI-RS, the secondary CSI-RS APs **1510** together with the primary CSI-RS APs **1505** can be used for estimating the H-CSI-RS. The number of secondary APs can be less than the number of the primary APs, and can be separately configured from the number of the primary CSI-RS APs **1505**.

In this case, the total number of antenna ports at TP N is separately RRC configured from the configurations for the two sets of CSI-RS. The total number of antenna ports $N=N_H \times N_V$ is used for deriving at least one of joint CQI and joint PMI for the N antenna channels.

FIG. **16** illustrates construction of the primary and the secondary CSI-RS according to embodiments of the present disclosure. The embodiment of the construction **1600** shown in FIG. **16** is for illustration only. Other embodiments could be used without departing from the scope of this disclosure.

In the example construction of the primary and the secondary CSI-RS shown in FIG. **16**, the primary CSI-RS **1605** are H-CSI-RS, while only one AP is provided for the secondary CSI-RS **1610**, which is the first antenna element **1615** of the second row of the 2D active antenna array **405**. When UE **116** is configured with these primary and secondary CSI-RS, UE **116** derives H-CSI utilizing the primary CSI-RS, and UE **116** derives V-CSI utilizing the primary and the secondary CSI-RS, such as, by estimating the phase difference between the two types of CSI-RS. The relative location of the secondary CSI-RS with respect to the primary CSI-RS can be configured by the network.

In another method (method 3), the network is capable of configuring and transmitting at least two sets of CSI-RS APs. A first set of CSI-RS APs is used for horizontal CSI estimation at a first group of UEs, and a second set of CSI-RS APs is used for horizontal CSI estimation at a second group of UEs.

Each of the at least two sets of CSI-RS APs can be targeted to be best received in a certain distance from the TP (or a certain range of elevation angles). For example, a first set of CSI-RS is best received at distance of 0 m to 200 m, while the second set of CSI-RS is best received at distance of 200 m to 400 m. For this operation, the network can tailor antenna virtualization precoding method of each set of CSI-RS accordingly. That is, the first set of CSI-RS is virtualized with a first virtualization precoding so that it is best received at a first range of distances, and the second set of CSI-RS is virtualized with a second virtualization precoding so that it is best received at a second range of distances.

UE **116** can be configured for one set out of the at least two sets of CSI-RS APs by an RRC configuration. Then, UE **116** estimates horizontal CSI based on the configured set of CSI-RS APs.

UE **116** can be re-configured to estimate horizontal CSI based on a first set of CSI-RS APs from a second set of CSI-RS APs, by an RRC configuration.

UE **116** can be configured for the at least two sets of CSI-RS APs. UE **116** can estimate and report RSRPs for the at least two sets of CSI-RS APs, e.g., depending on a configured triggering condition.

Although the present disclosure has been described with an exemplary embodiment, various changes and modifications may be suggested to one skilled in the art. It is intended that the present disclosure encompass such changes and modifications as fall within the scope of the appended claims.

What is claimed is:

1. For use in a wireless communication network, a base station comprising:

a two dimensional (2D) antenna array comprising a number N of antenna elements configured in a 2D grid $N_H \times N_v$, the 2D antenna array configured to communicate with at least one subscriber station; and

a controller configured to transmit N channel-state-information reference-signal (CSI-RS) antenna ports (APs) associated with each of the N antenna elements, wherein the controller is configured to transmit at least two sets of CSI-RS APs and the at least one subscriber station derives and feeds back horizontal CSI (H-CSI) and vertical CSI (V-CSI) estimated by the at least one subscriber station receiving and processing the at least two sets of CSI-RS APs, and wherein a total number of CSI-RS APs is less than N.

2. The base station as set forth in claim 1, wherein the H-CSI comprises channel characteristics mainly associated with horizontally placed antenna elements estimated at the at least one subscriber station and includes horizontal channel quality indicator (CQI) (H-CQI), horizontal precoding matrix index (PMI) (H-PMI) and horizontal rank indicator (RI) (H-RI).

3. The base station as set forth in claim 1, wherein the V-CSI comprises channel characteristics mainly associated with vertically placed antenna elements estimated at the at least one subscriber station and includes vertical CQI (V-CQI), vertical PMI (V-PMI) and vertical RI (V-RI).

4. The base station as set forth in claim 1, wherein the controller is configured to multiplex a first set of CSI-RS APs and a second set of CSI-RS APs for the at least two sets of CSI-RS APs.

5. The base station as set forth in claim 4, wherein the multiplexer operation comprises one or more of: a time-domain multiplexing (TDM), code-domain multiplexing (CDM), frequency-domain multiplexing (FDM) and spatial-domain multiplexing (SDM) and wherein:

when TDM multiplexing is applied, the controller is configured to transmit the CSI-RS corresponding to the at least two sets of CSI-RS APs at two different time locations comprising at least one of: in two different time slots, in two different subframes, in two different sets of OFDM symbols;

when FDM multiplexing is applied, the controller is configured to transmit the CSI-RS corresponding to the at least two sets of CSI-RS APs at two different frequency or subcarrier locations;

when CDM multiplexing is applied, the controller is configured to transmit the CSI-RS APs corresponding to the at least two sets of CSI-RS APs using two different orthogonal codes in the same time-frequency location;

when SDM is applied, the controller is configured to transmit the CSI-RS APs corresponding to the at least two sets of CSI-RS APs in two different spatial beams and wherein the at least two sets of CSI-RS APs are differently scrambled using two different scrambling initializations; and

when FDM/TDM multiplexing is applied, the controller is configured to transmit the CSI-RS APs corresponding to the at least two sets of CSI-RS APs at two different time-frequency location.

6. The base station as set forth in claim 1, wherein the at least two sets of CSI-RS APs comprise one of:

A-CSI-RS AP and B-CSI-RS AP;

a vertical CSI-RS AP and a horizontal CSI-RS AP;

two horizontal CSI-RS APs; and

a primary CSI-RS AP and a secondary CSI-RS AP.

7. A subscriber station configured to communicate with at least one base station using a multiple input multiple output (MIMO) communication, the subscriber station comprising:

an antenna array configured to communicate with at least one base station; and

processing circuitry configured to receive physical downlink shared channels (PDSCHs) from a two dimensional (2D) active antenna array at the at least one base station, the 2D active antenna array comprising a number N antenna elements; the processing circuitry further configured to estimate a horizontal channel state information (CSI) and vertical CSI associated with the N antenna elements, wherein the processing circuitry is configured to receive and process at least two sets of CSI-RS antenna ports (APs), and derive and feedback horizontal CSI (H-CSI) and vertical CSI (V-CSI) from the at least two sets of CSI-RS APs, wherein a total number of CSI-RS APs is less than N.

8. The subscriber station as set forth in claim 7, wherein the H-CSI comprises channel characteristics mainly associated with horizontally placed antenna elements estimated at the at least one subscriber station and includes horizontal channel quality indicator (CQI) (H-CQI), horizontal precoding matrix index (PMI) (H-PMI) and horizontal rank indicator (RI) (H-RI).

9. The subscriber station as set forth in claim 7, wherein the V-CSI comprises channel characteristics mainly associated with vertically placed antenna elements estimated at the at least one subscriber station and includes vertical CQI (V-CQI), vertical PMI (V-PMI) and vertical RI (V-RI).

10. The subscriber station as set forth in claim 7, *wherein* a first set of CSI-RS and a second set of CSI-RS APs for the at least two sets of CSI-RS APs are multiplexed.

11. The subscriber station as set forth in claim 10, wherein the multiplexer operation comprises one or more of: a time-domain multiplexing (TDM), code-domain multiplexing (CDM), frequency-domain multiplexing (FDM) and spatial-domain multiplexing (SDM) and wherein:

when TDM multiplexing is applied, the [controller] *processing circuitry* is configured to transmit the CSI-RS corresponding to the at least two sets of CSI-RS APs at two different time locations comprising at least one of: in two different time slots, in two different subframes, in two different sets of OFDM symbols;

when FDM multiplexing is applied, the [controller] *processing circuitry* is configured to transmit the CSI-RS APs corresponding to the at least two sets of CSI-RS APs at two different frequency or subcarrier locations;

when CDM multiplexing is applied, the [controller] *processing circuitry* is configured to transmit the CSI-RS APs corresponding to the at least two sets of CSI-RS APs using two different orthogonal codes in the same time-frequency location;

when SDM is applied, the [controller] *processing circuitry* is configured to transmit the CSI-RS corresponding to the at least two sets of CSI-RS APs in two different spatial beams and wherein the at least two sets of CSI-RS APs are differently scrambled using two different scrambling initializations; and

when FDM/TDM multiplexing is applied, the [controller] *processing circuitry* is configured to transmit the CSI-RS APs corresponding to the at least two sets of CSI-RS APs at two different time-frequency location.

12. The subscriber station as set forth in claim 7, wherein the at least two sets of CSI-RS APs comprise one of:

A-CSI-RS AP and B-CSI-RS AP;

a vertical CSI-RS AP and a horizontal CSI-RS AP;

two horizontal CSI-RS APs; and

a primary CSI-RS AP and a secondary CSI-RS AP.

13. For use in a wireless communication network, a method comprising:

transmitting, from a two dimensional (2D) antenna array, N channel-state-information reference-signal (CSI-RS) antenna ports (APs), the 2D antenna array comprising a number N of antenna elements configured in a 2D grid $N_H \times N_v$, the CSI-RS APs associated with each of the N antenna elements, wherein transmitting comprises transmitting at least two sets of CSI-RS APs; and

receiving a feedback signal from the at least one subscriber station, the feedback signal comprising horizontal CSI (H-CSI) and vertical CSI (V-CSI) estimated by the at least one subscriber station receiving and

processing the at least two sets of CSI-RS APs, and wherein a total number of CSI-RS APs is less than N.

14. The method as set forth in claim **13**, wherein the H-CSI comprises channel characteristics mainly associated with horizontally placed antenna elements estimated at the at least one subscriber station and includes horizontal CQI (H-CQI), horizontal PMI (H-PMI) and horizontal RI (H-RI).

15. The method as set forth in claim **13**, wherein the V-CSI comprises channel characteristics mainly associated with vertically placed antenna elements estimated at the at least one subscriber station and includes vertical CQI (V-CQI), vertical PMI (V-PMI) and vertical RI (V-RI).

16. The method as set forth in claim **13**, wherein transmitting comprises multiplexing a first set of CSI-RS and a second set of CSI-RS for the at least two sets of CSI-RS.

17. The method as set forth in claim **16**, wherein multiplexing comprises one or more of: a time-domain multiplexing (TDM), code-domain multiplexing (CDM), frequency-domain multiplexing (FDM) and spatial-domain multiplexing (SDM) and wherein:

when TDM multiplexing is applied, the controller is configured to transmit the CSI-RS corresponding to the at least two sets of CSI-RS APs at two different time locations comprising at least one of: in two different time slots, in two different subframes, in two different sets of OFDM symbols;

when FDM multiplexing is applied, the controller is configured to transmit the CSI-RS corresponding to the at least two sets of CSI-RS APs at two different frequency or subcarrier locations;

when CDM multiplexing is applied, the controller is configured to transmit the CSI-RS corresponding to the at least two sets of CSI-RS APs using two different orthogonal codes in the same time-frequency location;

when SDM is applied, the controller is configured to transmit the CSI-RS corresponding to the at least two sets of CSI-RS APs in two different spatial beams and wherein the at least two sets of CSI-RS APs are differently scrambled using two different scrambling initializations; and

when FDM/TDM multiplexing is applied, the controller is configured to transmit the CSI-RS corresponding to the at least two sets of CSI-RS APs at two different time-frequency location.

18. The method as set forth in claim **13**, wherein the at least two sets of CSI-RS APs comprise one of:

A-CSI-RS and B-CSI-RS;

a vertical CSI-RS AP and a horizontal CSI-RS AP;

two horizontal CSI-RS APs; and

a primary CSI-RS AP and a secondary CSI-RS AP.

19. An apparatus in a base station for transmitting channel state information reference signal (CSI-RS), the apparatus comprising:

a controller configured to:

identify a same number of antenna ports associated with aggregation of each of at least two CSI-RS configurations, the at least two CSI-RS configurations including a first CSI-RS configuration and a second CSI-RS configuration; and

a transceiver configured to:

transmit information on the same number of antenna ports,

transmit information on the at least two CSI-RS configurations, and

transmit a first CSI-RS corresponding to the same number of antenna ports and the first CSI-RS configuration and a second CSI-RS corresponding to the same number of antenna ports and the second CSI-RS configuration.

20. The apparatus of claim 19, wherein one subframe configuration is set for the at least two CSI-RS configurations, the at least two CSI-RS configurations are aggregated in a subframe.

21. The apparatus of claim 19, wherein a resource configuration for each of the at least two CSI-RS configurations is set separately.

22. The apparatus of claim 19, wherein the same number of antenna ports is 8.

23. The base station of claim 1, wherein the antenna array is further configured to:

transmit information indicating a codebook for the at least two CSI-RS configurations.

24. An apparatus in a mobile station for receiving channel state information reference signal (CSI-RS), the apparatus comprising:

a transceiver configured to:

receive information on a same number of antenna ports, and

receive information on at least two CSI-RS configurations, wherein the same number of antenna ports is associated with aggregation of the at least two CSI-RS configurations and the at least two CSI-RS configurations include a first CSI-RS configuration and a second CSI-RS configuration; and

a controller configured to identify the same number of antenna ports associated with the aggregation of the at least two CSI-RS configurations,

wherein the transceiver is configured to receive a first CSI-RS corresponding to the same number of antenna ports and the first CSI-RS configuration and a second CSI-RS corresponding to the same number of antenna ports and the second CSI-RS configurations.

25. The apparatus of claim 24, wherein one subframe configuration is set for the at least two CSI-RS configurations, the at least two CSI-RS configurations are aggregated in a subframe.

26. The apparatus of claim 24, wherein a resource configuration for each of the at least two CSI-RS configurations is set separately.

27. The apparatus of claim 24, wherein the same number of antenna ports is 8.

28. The apparatus of claim 24, wherein the transceiver is further configured to:

receive information indicating a codebook for the at least two CSI-RS configurations.

29. A method for transmitting channel state information reference signal (CSI-RS) by a base station, the method comprising:

identifying a same number of antenna ports associated with aggregation of each of at least two CSI-RS configurations, the at least two CSI-RS configurations including a first CSI-RS configuration and a second CSI-RS configuration;

transmitting information on the same number of antenna ports;

transmitting information on the at least two CSI-RS configurations; and

transmitting a first CSI-RS corresponding to the same number of antenna ports and the first CSI-RS configuration and a second CSI-RS corresponding to the same number of antenna ports and the second CSI-RS configurations.

30. The method of claim 29, wherein one subframe configuration is set for the at least two CSI-RS configurations, the at least two CSI-RS configurations are aggregated in a subframe.

31. The method of claim 29, wherein a resource configuration for each of the at least two CSI-RS configurations is set separately.

32. The method of claim 29, wherein the same number of antenna ports is 8.

33. The method of claim 29, further comprising:

transmitting information indicating a codebook for the at least two CSI-RS configurations.

34. A method for receiving channel state information reference signal (CSI-RS), comprising:

receiving information on a same number of antenna ports;

receiving information on at least two CSI-RS configurations, wherein the same number of antenna ports is associated with aggregation of the at least two CSI-RS configurations and the at least two CSI-RS configurations include a first CSI-RS configuration and a second CSI-RS configuration;

identifying the same number of antenna ports associated with the aggregation of the at least two CSI-RS configurations; and

receiving a first CSI-RS corresponding to the same number of antenna ports and the first CSI-RS configuration and a second CSI-RS corresponding to the same number of antenna ports and the second CSI-RS configurations.

35. The method of claim 34, wherein one subframe configuration is set for the at least two CSI-RS configurations, and the at least two CSI-RS configurations are aggregated in a subframe.

36. The method of claim 34, wherein a resource configuration for each of the at least two CSI-RS configurations is set separately.

37. The method of claim 34, wherein the same number of antenna ports is 8.

38. The method of claim 34, further comprising:

receiving information indicating a codebook for the at least two CSI-RS configurations.

39. An apparatus in a base station for transmitting channel state information reference signal (CSI-RS), the apparatus comprising:

a controller configured to:

identify a total number of antenna ports associated with aggregation of at least two CSI-RS configurations; and

a transceiver configured to:

transmit information on the at least two CSI-RS configurations, and

transmit CSI-RSs corresponding to the total number of antenna ports and the at least two CSI-RS configurations,

wherein the antenna ports associated with aggregation of at least two CSI-RS configurations comprise, for a two dimensional (2D) antenna array, channel state information reference signal (CSI-RS) antenna ports (APs) corresponding to two rows of antenna elements including a first row of N antenna elements and a second row of N antenna elements for a total of 2N antenna elements, and wherein the CSI-RS APs are each mapped 1:1 with one of the 2N antenna elements.

40. An apparatus in a mobile station for receiving channel state information reference signal (CSI-RS), the apparatus comprising:

a transceiver configured to:

receive information on at least two CSI-RS configurations, and

receive CSI-RSs corresponding to a total number of antenna ports and the at least two CSI-RS configurations; and

a controller configured to:

identify the total number of antenna ports associated with aggregation of the at least two CSI-RS configurations,

wherein the antenna ports associated with aggregation of at least two CSI-RS configurations comprise, for a two dimensional (2D) antenna array, channel state information reference signal (CSI-RS) antenna ports (APs) corresponding to two rows of antenna elements including a first row of N antenna elements and a second row of N antenna elements for a total of 2N antenna elements, and wherein the CSI-RS APs are each mapped 1:1 with one of the 2N antenna elements.

41. A method for transmitting channel state information reference signal (CSI-RS) by a base station, the method comprising:

identifying a total number of antenna ports associated with aggregation of at least two CSI-RS configurations; and

transmitting information on the at least two CSI-RS configurations;

transmitting CSI-RSs corresponding to the total number of antenna ports and the at least two CSI-RS configurations,

wherein the antenna ports associated with aggregation of at least two CSI-RS configurations comprise, for a two dimensional (2D) antenna array, channel state information reference signal (CSI-RS) antenna ports (APs) corresponding to two rows of antenna elements including a first row of N antenna elements and a second row of N antenna elements for a total of 2N antenna elements, and wherein the CSI-RS APs are each mapped 1:1 with one of the 2N antenna elements.

42. A method for receiving channel state information reference signal (CSI-RS), comprising:

receiving information on at least two CSI-RS configurations;

identifying a total number of antenna ports associated with aggregation of the at least two CSI-RS configurations;

receiving CSI-RSs corresponding to the total number of antenna ports and the at least two CSI-RS configurations,

wherein the antenna ports associated with aggregation of at least two CSI-RS configurations comprise, for a two dimensional (2D) antenna array, channel state information reference signal (CSI-RS) antenna ports (APs) corresponding to two rows of antenna elements including a first row of N antenna elements and a second row of N antenna elements for a total of 2N antenna elements, and wherein the CSI-RS APs are each mapped 1:1 with one of the 2N antenna elements.

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