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CONFIRMATION NO. 9427

FILING RECEIPT



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96817

Samsung Research America, Inc. (SRA)
665 Clyde Ave.
Mountain View, CA 94043

Date Mailed: 09/06/2016

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Title

HYBRID CSI REPORTING FOR MIMO WIRELESS COMMUNICATION SYSTEMS

Statement under 37 CFR 1.55 or 1.78 for AIA (First Inventor to File) Transition Applications: No

page 1 of 3

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Signature		Date	1/21/2014
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Title and Company	Vice President, Samsung Electronics Co., Ltd.		

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Electronic Patent Application Fee Transmittal				
Application Number:				
Filing Date:				
Title of Invention:		HYBRID CSI REPORTING FOR MIMO WIRELESS COMMUNICATION SYSTEMS		
First Named Inventor/Applicant Name:		Md Saifur Rahman		
Filer:		Ravindranath V. Kanamangala/Michelle R. Mizerak		
Attorney Docket Number:		2016.06.013.SR0		
Filed as Large Entity				
Filing Fees for Provisional				
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Provisional Application Filing	1005	1	260	260
Pages:				
Claims:				
Miscellaneous-Filing:				
Petition:				
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				

Description	Fee Code	Quantity	Amount	Sub-Total in USD(\$)
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Application Number:	62378578
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Deposit Account	505271
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File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Specification	201606013SR0_PROV_Update2.pdf	750996	no	38
			c9bdc30f8f91db78b214fea5ef5ec79ccdca5b07		
Warnings:					
Information:					
2	Application Data Sheet	201606013SR0_ADS.pdf	110062	no	8
			8f7a541ec71e9365c85d2e8bda03543f5da4e856		
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3	Miscellaneous Incoming Letter	201606013SR0_PoA_Transmittal.pdf	114389	no	2
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Warnings:					
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4	Power of Attorney	GeneralPoA-executed-Farooq.pdf	1681937	no	1
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5	Fee Worksheet (SB06)	fee-info.pdf	30318	no	2
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Hybrid CSI reporting for MIMO wireless communication systems

The following documents and standards descriptions are hereby incorporated into the present disclosure as if fully set forth herein:

- [1] 3GPP TS 36.211 v13.0.0, "E-UTRA, Physical channels and modulation."
- [2] 3GPP TS 36.212 v13.0.0, "E-UTRA, Multiplexing and Channel coding."
- [3] 3GPP TS 36.213 v13.0.0, "E-UTRA, Physical Layer Procedures."
- [4] 3GPP TS 36.321 v13.0.0, "E-UTRA, Medium Access Control (MAC) protocol specification."
- [5] 3GPP TS 36.331 v13.0.0, "E-UTRA, Radio Resource Control (RRC) Protocol Specification."
- [6] RP-160623, "New WID Proposal: Enhancements on Full-Dimension (FD) MIMO for LTE," Samsung

A description of example embodiments is provided on the follow pages.

The text and figures are provided solely as examples to aid the reader in understanding the invention. They are not intended and are not to be construed as limiting the scope of this invention in any manner. Although certain embodiments and examples have been provided, it will be apparent to those skilled in the art based on the disclosures herein that changes in the embodiments and examples shown may be made without departing from the scope of this invention.

Abbreviations:

2D	Two-dimensional
AoA	Angle of arrival
AoD	Angle of departure
ACK	Acknowledgement
ARQ	Automatic Repeat Request
BI	Beam Index
BW	Bandwidth
CE	Coverage Enhancement
C-RNTI	Cell RNTI
CRS	Common Reference Signal
CRI	CSI-RS Resource Index
CSI	Channel State Information
CSI-RS	Channel State Information Reference Signal
CQI	Channel Quality Indicator
DCI	Downlink Control Information
dB	decibel
DL	Downlink
DL-SCH	DL Shared Channel
DMRS	Demodulation Reference Signal
FDD	Frequency Division Duplexing
HARQ	Hybrid ARQ
LC	Linear Combination
LC-UE	Low Cost User Equipment
LTE	Long-term evolution
MIMO	Multi-input multi-output
MTC	Machine Type Communications
MU-MIMO	Multi-user MIMO

NACK	Negative ACKnowledgement
PDCCH	Physical Downlink Control Channel
PDSCH	Physical Downlink Shared Channel
PRB	Physical Resource Block
PMI	Precoding Matrix Indicator
PUCCH	Physical Uplink Control Channel
PUSCH	Physical Uplink Shared Channel
RB	Resource Block
RE	Resource Element
RI	Rank Indicator
RRC	Radio Resource Control
RS	Reference Signals
SINR	Signal to Interference and Noise Ratio
SPS	Semi-Persistent Scheduling
SRS	Sounding RS
SF	Subframe
SU-MIMO	Single-user MIMO
TB	Transport Block
TDD	Time Division Duplexing
UCI	Uplink Control Information
UE	User Equipment
UL	Uplink
UL-SCH	UL Shared Channel

The present invention relates generally to wireless communication systems and, more specifically, to *the details about the different hybrid CSI reporting alternatives*.

A communication system includes a DownLink (DL) that conveys signals from transmission points such as Base Stations (BSs) or NodeBs to User Equipments (UEs) and an UpLink (UL) that conveys signals from UEs to reception points such as NodeBs. A UE, also commonly referred to as a terminal or a mobile station, may be fixed or mobile and may be a cellular phone, a personal computer device, or an automated device. An eNodeB, which is generally a fixed station, may also be referred to as an access point or other equivalent terminology. For LTE systems, an eNodeB is often referred to as an eNodeB.

In a communication system, such as LTE, DL signals can include data signals conveying information content, control signals conveying DL Control Information (DCI), and Reference Signals (RS) that are also known as pilot signals. An eNodeB transmits data information through a Physical DL Shared CHannel (PDSCH). An eNodeB transmits DCI through a Physical DL Control CHannel (PDCCH) or an Enhanced PDCCH (EPDCCH) – see also REF 3. An eNodeB transmits acknowledgement information in response to data Transport Block (TB) transmission from a UE in a Physical Hybrid ARQ Indicator CHannel (PHICH). An eNodeB transmits one or more of multiple types of RS including a UE-Common RS (CRS), a Channel State Information RS (CSI-RS), or a DeModulation RS (DMRS). A CRS is transmitted over a DL system BandWidth (BW) and can be used by UEs to obtain a channel estimate to demodulate data or control information or to perform measurements. To reduce CRS overhead, an eNodeB may transmit a CSI-RS with a smaller density in the time and/or frequency domain than a CRS. DMRS can be transmitted only in the BW of a respective PDSCH or EPDCCH and a UE can use the DMRS to demodulate data or control information in a PDSCH or an EPDCCH, respectively. A transmission time interval for DL channels is referred to as a subframe and can have, for example, duration of 1 millisecond.

DL signals also include transmission of a logical channel that carries system control information. A BCCH is mapped to either a transport channel referred to as a Broadcast CHannel (BCH) when it conveys a Master Information Block (MIB) or to a DL Shared CHannel (DL-SCH) when it conveys a System Information Block (SIB) – see also REF3 and REF 5. Most system information is included in different SIBs that are transmitted using DL-

SCH. A presence of system information on a DL-SCH in a subframe can be indicated by a transmission of a corresponding PDCCH conveying a codeword with a CRC scrambled with a special System Information RNTI (SI-RNTI). Alternatively, scheduling information for a SIB transmission can be provided in an earlier SIB and scheduling information for the first SIB (SIB-1) can be provided by the MIB.

Figure 1 illustrates an example structure for a DL subframe according to this invention. The embodiment of the DL subframe structure shown in **Figure 1** is for illustration only. Other embodiments could be used without departing from the scope of the present invention.

A DL SF 110 includes two slots 120 and a total of $N_{\text{syb}}^{\text{DL}}$ symbols for transmitting of data information and DCI. The first $M_{\text{syb}}^{\text{DL}}$ SF symbols are used to transmit PDCCHs and other control channels (not shown) 130. The remaining $N_{\text{syb}}^{\text{DL}} - M_{\text{syb}}^{\text{DL}}$ SF symbols are primarily used to transmit PDSCHs 140, 142, 144, 146, and 148 or EPDCCHs 150, 152, 154, and 156. A transmission BW consists of frequency resource units referred to as Resource Blocks (RBs). Each RB consists of $N_{\text{sc}}^{\text{RB}}$ sub-carriers, or Resource Elements (REs), such as 12 REs. A unit of one RB over one subframe is referred to as a Physical RB (PRB). A UE can be allocated M_{PDSCH} RBs for a total of $M_{\text{sc}}^{\text{PDSCH}} = M_{\text{PDSCH}} \cdot N_{\text{sc}}^{\text{RB}}$ REs for the PDSCH transmission BW. An EPDCCH transmission can be in one RB or in multiple of RBs.

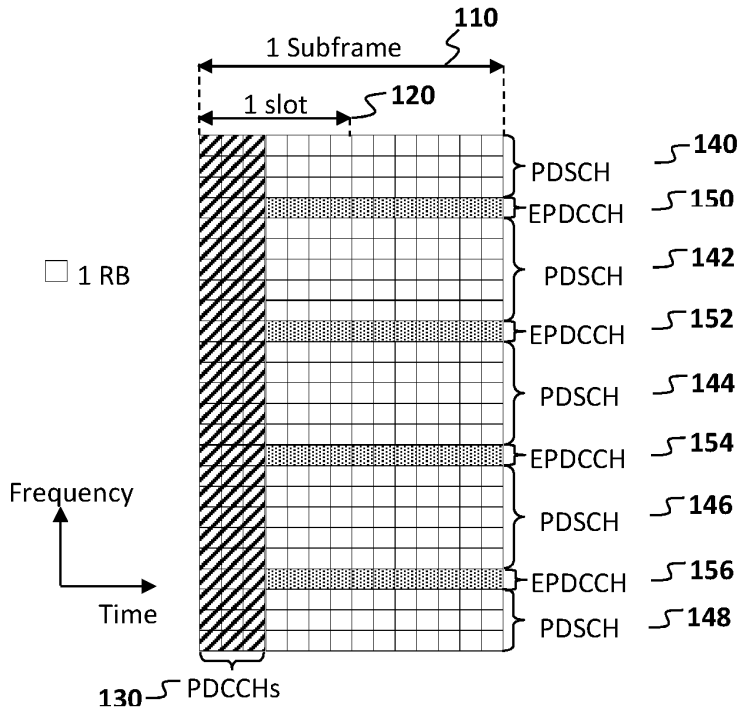


Figure 1

UL signals can include data signals conveying data information, control signals conveying UL Control Information (UCI), and UL RS. UL RS includes DMRS and Sounding RS (SRS). A UE transmits DMRS only in a

BW of a respective PUSCH or PUCCH. An eNodeB can use a DMRS to demodulate data signals or UCI signals. A UE transmits SRS to provide an eNodeB with an UL CSI. A UE transmits data information or UCI through a respective Physical UL Shared CHannel (PUSCH) or a Physical UL Control CHannel (PUCCH). If a UE needs to transmit data information and UCI in a same UL subframe, it may multiplex both in a PUSCH. UCI includes Hybrid Automatic Repeat reQuest ACKnowledgement (HARQ-ACK) information, indicating correct (ACK) or incorrect (NACK) detection for a data TB in a PDSCH or absence of a PDCCH detection (DTX), Scheduling Request (SR) indicating whether a UE has data in its buffer, Rank Indicator (RI), and Channel State Information (CSI) enabling an eNodeB to perform link adaptation for PDSCH transmissions to a UE. HARQ-ACK information is also transmitted by a UE in response to a detection of a PDCCH/EPDCCH indicating a release of semi-persistently scheduled PDSCH (see also REF 3); for brevity, this is not explicitly mentioned in the following descriptions.

Figure 2 illustrates a transmission structure for a PUSCH or a PUCCH over an UL subframe. The embodiment of the transmission structure for a PUSCH or a PUCCH over an UL subframe shown in **Figure 2** is for illustration only. Other embodiments could be used without departing from the scope of the present invention.

An UL subframe 210 includes two slots. Each slot 220 includes $N_{\text{symb}}^{\text{UL}}$ symbols 230 for transmitting data information, UCI, DMRS, or SRS. A frequency resource unit of an UL system BW is a RB. A UE is allocated N_{RB} RBs 240 for a total of $N_{\text{RB}} \cdot N_{\text{sc}}^{\text{RB}}$ REs for a transmission BW. For a PUCCH, $N_{\text{RB}} = 1$. A last subframe symbol can be used to multiplex SRS transmissions 250 from one or more UEs. A number of subframe symbols that are available for data/UCI/DMRS transmission is $N_{\text{symb}} = 2 \cdot (N_{\text{symb}}^{\text{UL}} - 1) - N_{\text{SRS}}$, where $N_{\text{SRS}} = 1$ if a last subframe symbol is used to transmit SRS and $N_{\text{SRS}} = 0$ otherwise.

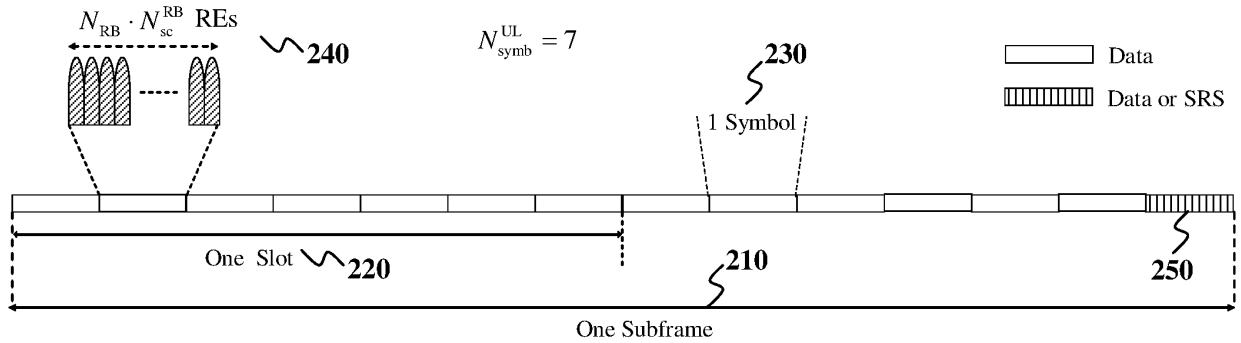


Figure 2

Figure 3 illustrates a transmitter block diagram for a PDSCH in a subframe. The embodiment of the PDSCH transmitter block diagram shown in **Figure 3** is for illustration only. Other embodiments could be used without departing from the scope of the present invention.

Information bits 310 are encoded by encoder 320, such as a turbo encoder, and modulated by modulator 330, for example using Quadrature Phase Shift Keying (QPSK) modulation. A Serial to Parallel (S/P) converter 340 generates M modulation symbols that are subsequently provided to a mapper 350 to be mapped to REs selected by a transmission BW selection unit 355 for an assigned PDSCH transmission BW, unit 360 applies an Inverse Fast Fourier Transform (IFFT), the output is then serialized by a Parallel to Serial (P/S) converter 370 to create a time domain signal, filtering is applied by filter 380, and a signal transmitted 390. Additional functionalities, such as data

scrambling, cyclic prefix insertion, time windowing, interleaving, and others are well known in the art and are not shown for brevity.

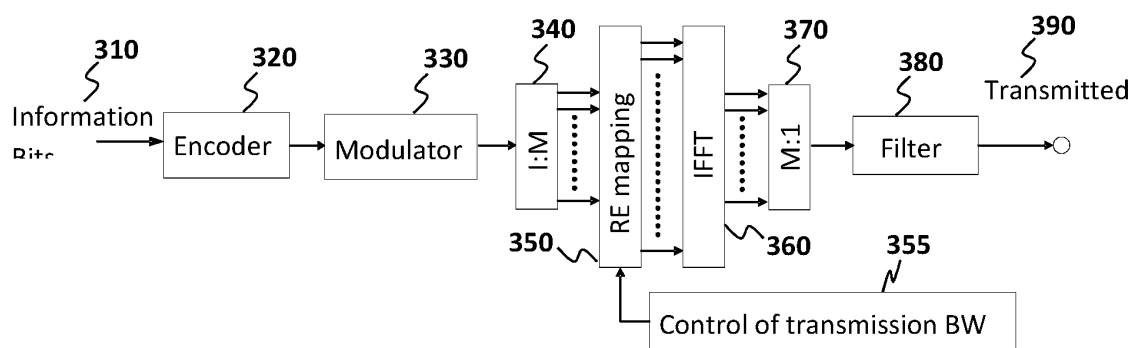


Figure 3

Figure 4 illustrates a receiver block diagram for a PDSCH in a subframe. The embodiment of the PDSCH receiver block diagram shown in **Figure 4** is for illustration only. Other embodiments could be used without departing from the scope of the present invention.

A received signal 410 is filtered by filter 420, REs 430 for an assigned reception BW are selected by BW selector 435, unit 440 applies a Fast Fourier Transform (FFT), and an output is serialized by a parallel-to-serial converter 450. Subsequently, a demodulator 460 coherently demodulates data symbols by applying a channel estimate obtained from a DMRS or a CRS (not shown), and a decoder 470, such as a turbo decoder, decodes the demodulated data to provide an estimate of the information data bits 480. Additional functionalities such as time-windowing, cyclic prefix removal, de-scrambling, channel estimation, and de-interleaving are not shown for brevity.

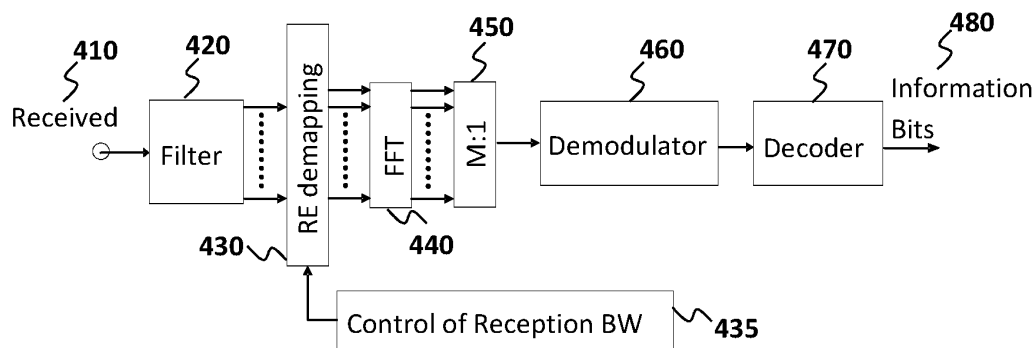


Figure 4

Figure 5 illustrates a transmitter block diagram for a PUSCH in a subframe. The embodiment of the PUSCH transmitter block diagram shown in **Figure 5** is for illustration only. Other embodiments could be used without departing from the scope of the present invention.

Information data bits 510 are encoded by encoder 520, such as a turbo encoder, and modulated by modulator 530. A Discrete Fourier Transform (DFT) unit 540 applies a DFT on the modulated data bits, REs 550

corresponding to an assigned PUSCH transmission BW are selected by transmission BW selection unit 555, unit 560 applies an IFFT and, after a cyclic prefix insertion (not shown), filtering is applied by filter 570 and a signal transmitted 580.

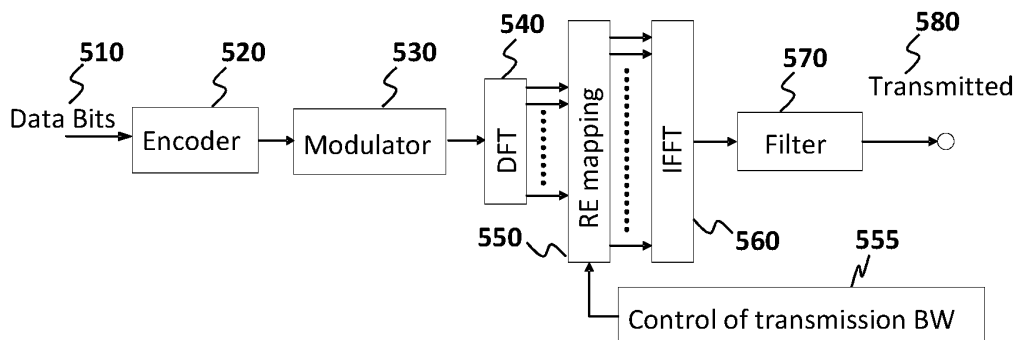


Figure 5

Figure 6 illustrates a receiver block diagram for a PUSCH in a subframe. The embodiment of the PUSCH receiver block diagram shown in **Figure 6** is for illustration only. Other embodiments could be used without departing from the scope of the present invention.

A received signal 610 is filtered by filter 620. Subsequently, after a cyclic prefix is removed (not shown), unit 630 applies a FFT, REs 640 corresponding to an assigned PUSCH reception BW are selected by a reception BW selector 645, unit 650 applies an Inverse DFT (IDFT), a demodulator 660 coherently demodulates data symbols by applying a channel estimate obtained from a DMRS (not shown), a decoder 670, such as a turbo decoder, decodes the demodulated data to provide an estimate of the information data bits 680.

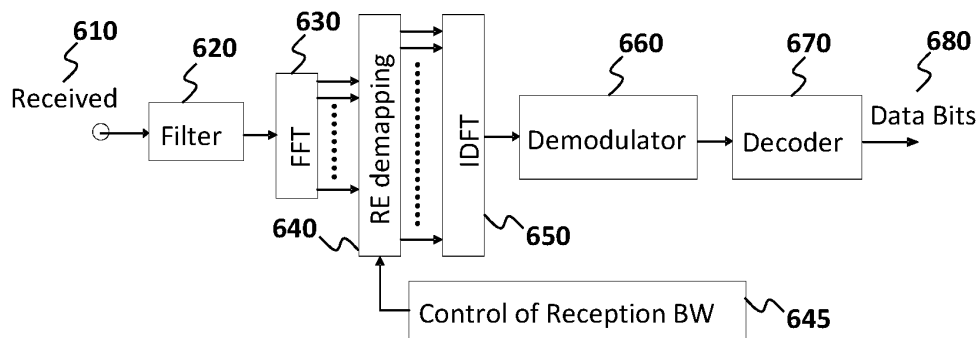


Figure 6

Figure 7 depicts an exemplary 2D antenna array which is constructed from 16 dual-polarized antenna elements arranged in a 4x4 rectangular format. In this illustration, each labelled antenna element is logically mapped onto a single antenna port. Two alternative labelling conventions are depicted for illustrative purposes: horizontal first in 700 and vertical first in 710. In general, one antenna port can correspond to multiple antenna elements (physical antennas) combined via a virtualization. This 4x4 dual polarized array can then be viewed as 16x2 = 32-element array of elements. The vertical dimension (consisting of 4 rows) facilitates elevation beamforming in addition to the

azimuthal beamforming across the horizontal dimension (consisting of 4 columns of dual polarized antennas). MIMO precoding in Rel.12 LTE standardization (per TS36.211 section 6.3.4.2, 6.3.4.4, and TS36.213 section 7.2.4) was largely designed to offer precoding gain for one-dimensional antenna array. While fixed beamforming (i.e. antenna virtualization) can be implemented across the elevation dimension, it is unable to reap the potential gain offered by the spatial and frequency selective nature of the channel.

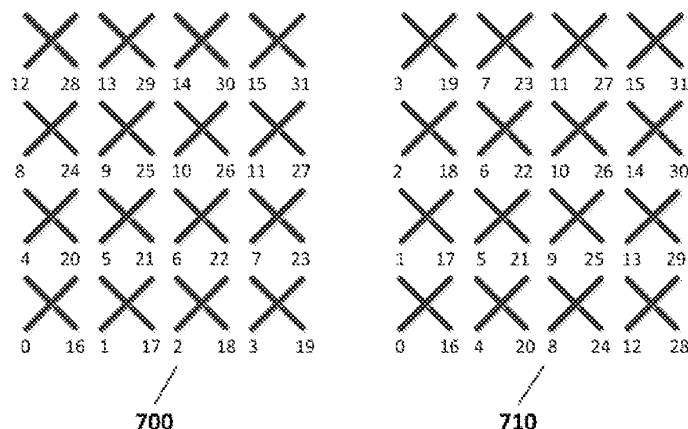


Figure 7

In Rel.13 3GPP LTE, MIMO precoding (for beamforming or spatial multiplexing) can be facilitated via PMI (i.e. precoding codebook index) reporting as a component of CSI (channel state information) reporting. PMI report is derived from one of the following sets of standardized codebooks:

- Two antenna ports: single-stage {TS36.211 table 6.3.4.2.3-1} [1]
- Four antenna ports: single-stage {TS36.211 table 6.3.4.2.3-2} [1] or dual-stage {TS36.213 table 7.2.4-0A, B, C, and D} [3]
- Eight antenna ports: dual-stage {TS36.213 table 7.2.4-1, 2, 3, 4, 5, 6, 7, and 8} [3]
- Configurable dual-stage eMIMO-Type of 'CLASS A' codebook for eight, twelve, or sixteen antenna ports: {TS36.213 table 7.2.4-10, 11, 12, 13, 14, 15, 16, and 17} [3], also known as 'nonPrecoded' in {TS36.331} [5]
- Single-stage eMIMO-Type of 'CLASS B' codebook for two, four, or eight antenna ports: {TS36.213 table 7.2.4-18, 19, and 20} [3], also known as 'beamformed' in {TS36.331} [5]

If an eNodeB follows a PMI recommendation from a UE, the eNodeB is expected to precode its transmitted signal according to a recommended precoding vector or matrix for a given subframe and RB. Regardless whether the eNodeB follows this recommendation, the UE is configured to report a PMI according to a configured precoding codebook. Here a PMI, which may consist of a single index or a pair of indices, is associated with a precoding matrix $\mathbf{W}$ in an associated codebook.

When dual-stage class A codebook is configured, a resulting precoding matrix can be described in (1). That is, the first stage precoder can be described as a Kronecker product of a first and a second precoding vector (or matrix), which can be associated with a first and a second dimension, respectively. This type is termed partial Kronecker Product (partial KP) codebook. The subscripts m and n in $\mathbf{W}_{m,n}(i_{m,n})$ denote precoding stage (first or second stage) and dimension (first or second dimension), respectively. Each of the precoding matrices $\mathbf{W}_{m,n}$ can be described as a function of an index which serves as a PMI component. As a result, the precoding matrix $\mathbf{W}$ can be described as a function of 3 PMI components. The first stage pertains to a long-term component. Therefore it is associated with long-term channel statistics such as the aforementioned AoD profile and AoD spread. On the other hand, the second stage pertains to a short-term component which performs selection, co-phasing, or any linear operation to the first

component precoder $\mathbf{W}_{1,1}(i_{1,1}) \otimes \mathbf{W}_{1,2}(i_{1,2})$. The precoder $\mathbf{W}_2(i_2)$, therefore, performs a linear transformation of the long-term component such as a linear combination of a set of basis functions or vectors associated with the column vectors of $\mathbf{W}_{1,1}(i_{1,1}) \otimes \mathbf{W}_{1,2}(i_{1,2})$.

$$\mathbf{W}(i_{1,1}, i_{1,2}, i_2) = \underbrace{(\mathbf{W}_{1,1}(i_{1,1}) \otimes \mathbf{W}_{1,2}(i_{1,2}))}_{\mathbf{W}_1(i_{1,1}, i_{1,2})} \mathbf{W}_2(i_2) \quad (1)$$

The above discussion assumes that the serving eNB transmits and a served UE measures non-precoded CSI-RS (NP CSI-RS). That is, a cell-specific one-to-one mapping between CSI-RS port and TXRU is utilized. Here, different CSI-RS ports have the same wide beam width and direction and hence generally cell wide coverage. This use case can be realized when the eNB configures the UE with 'CLASS A' *eMIMO-Type* which corresponds to NP CSI-RS. Other than CQI and RI, CSI reports associated with 'CLASS A' or 'nonPrecoded' *eMIMO-Type* include a three-component PMI $\{i_{1,1}, i_{1,2}, i_2\}$.

Another type of CSI-RS applicable to FD-MIMO is beamformed CSI-RS (BF CSI-RS). In this case, beamforming operation, either cell-specific (with $K > 1$ CSI-RS resources) or UE-specific (with $K = 1$ CSI-RS resource), is applied on a non-zero-power (NZP) CSI-RS resource (consisting of multiple ports). Here, (at least at a given time/frequency) CSI-RS ports have narrow beam widths and hence not cell wide coverage, and (at least from the eNB perspective) at least some CSI-RS port-resource combinations have different beam directions. This beamforming operation is intended to increase CSI-RS coverage. In addition, when UE-specific beamforming is applied to CSI-RS resource (termed the UE-specific or UE-specifically beamformed CSI-RS), CSI-RS overhead reduction is possible. UE complexity reduction is also evident since the configured number of ports tends to be much smaller than its NP CSI-RS counterpart. When a UE is configured to receive BF CSI-RS from a serving eNB, the UE can be configured to report PMI parameter(s) associated with a second-stage precoder without the associated first-stage precoder or, in general, associated with a single-stage precoder/codebook. This use case can be realized when the eNB configures the UE with 'CLASS B' *eMIMO-Type* which corresponds to BF CSI-RS. Other than CQI and RI, CSI reports associated with 'CLASS B' or 'beamformed' *eMIMO-Type* (with one CSI-RS resource and alternative codebook) include a one-component PMI n . Although a single PMI defined with respect to a distinct codebook, this PMI can be associated with the second-stage PMI component of 'CLASS A'/'nonPrecoded' codebooks i_2 .

Therefore, given a precoding codebook (a set of precoding matrices), a UE measures a CSI-RS in a subframe designated to carry CSI-RS, calculates/determines a CSI (including PMI, RI, and CQI where each of these three CSI parameters can consist of multiple components) based on the measurement, and reports the calculated CSI to a serving eNB. In particular, this PMI is an index of a recommended precoding matrix in the precoding codebook. Similar to that for the first type, different precoding codebooks can be used for different values of RI. The measured CSI-RS can be one of the two types: non-precoded (NP) CSI-RS and beamformed (BF) CSI-RS. As mentioned, in Rel.13, the support of these two types of CSI-RS is given in terms of two *eMIMO-Types*: 'CLASS A' (with one CSI-RS resource) and 'CLASS B' (with one or a plurality of CSI-RS resources), respectively.

In scenarios where DL long-term channel statistics can be measured through UL signals at a serving eNB, UE-specific BF CSI-RS can be readily used. This is typically feasible when UL-DL duplex distance is sufficiently small. When this condition does not hold, however, some UE feedback is necessary for the eNB to obtain an estimate of DL long-term channel statistics (or any of its representation thereof). To facilitate such a procedure, a first BF CSI-RS transmitted with periodicity T_1 (ms) and a second NP CSI-RS transmitted with periodicity T_2 (ms), where $T_1 \leq T_2$. This approach is termed hybrid CSI-RS. The implementation of hybrid CSI-RS is largely dependent on the definition of CSI process and NZP CSI-RS resource.

In Rel.12 and Rel. 13, the above precoding codebooks are utilized for CSI reporting. Two schemes of CSI reporting modes are supported: PUSCH-based aperiodic CSI (A-CSI) and PUCCH-based periodic CSI (P-CSI). In

each scheme, different modes are defined based on frequency selectivity of CQI and/or PMI, that is, whether wideband or subband reporting is performed. The supported CSI reporting modes are given in **Table 1** and **Table 2**.

Table 1: CQI and PMI Feedback Types for PUSCH CSI reporting Modes

		PMI Feedback Type		
		No PMI	Single PMI	Multiple PMI
PUSCH CQI Feedback Type	Wideband (wideband CQI)			Mode 1-2
	UE Selected (subband CQI)	Mode 2-0		Mode 2-2
	Higher Layer-configured (subband CQI)	Mode 3-0	Mode 3-1	Mode 3-2

Table 2: CQI and PMI Feedback Types for PUCCH CSI reporting Modes

		PMI Feedback Type	
		No PMI	Single PMI
PUCCH CQI Feedback Type	Wideband (wideband CQI)	Mode 1-0	Mode 1-1
	UE Selected (subband CQI)	Mode 2-0	Mode 2-1

In Rel. 14, the enhanced FD-MIMO will be specified, in accordance with the approved work item (WI) [6]. According to the WI, the hybrid CSI reporting based on non-precoded and beam-formed CSI-RS associated with two eMIMO-Types will be supported in Rel. 14. In this invention, details of various different hybrid eMIMO-Types are proposed.

Aspects, features, and advantages of the invention are readily apparent from the following detailed description, simply by illustrating a number of particular embodiments and implementations, including the best mode contemplated for carrying out the invention. The invention is also capable of other and different embodiments, and its several details can be modified in various obvious respects, all without departing from the spirit and scope of the invention. Accordingly, the drawings and description are to be regarded as illustrative in nature, and not as restrictive. The invention is illustrated by way of example, and not by way of limitation, in the figures of the accompanying drawings.

In the following, for brevity, FDD is considered as the duplex method for both DL and UL signaling but the embodiments of the invention are also directly applicable to TDD.

Terms such as ‘non-precoded’ (or ‘NP’) CSI-RS and ‘beamformed’ (or ‘BF’) CSI-RS are used throughout this invention disclosure. The essence of this invention does not change when different terms or names are used to refer to these two CSI-RS types. The same holds for CSI-RS resource. CSI-RS resources associated with these two types of CSI-RS can be referred to as ‘a first CSI-RS resource’ and ‘a second CSI-RS resource’, or ‘CSI-RS-A resource’ and ‘CSI-RS-B resource’. Subsequently, the labels ‘NP’ and ‘BF’ (or ‘np’ and ‘bf’) are exemplary and can be substituted with other labels such as ‘1’ and ‘2’, ‘A’ or ‘B’. Alternatively, instead of using categories such as CSI-RS type or CSI-RS resource type, a category of CSI reporting class can also be used. For instance, NP CSI-RS is associated with *eMIMO-Type* of ‘CLASS A’ while UE-specific BF CSI-RS is associated with *eMIMO-Type* of ‘CLASS B’ with one CSI-RS resource.

Throughout this invention, 2D dual-polarized array is used solely for illustrative purposes, unless stated otherwise. Extensions to 2D single-polarized array are straightforward for those skilled in the art.

Figure 8 depicts example 2D antenna arrays which are constructed from $N_1 \times N_2$ dual-polarized antenna elements arranged in a (N_1, N_2) rectangular format for 2,4,8,12,16 antenna ports. In this figure, each antenna element is logically mapped onto a single antenna port. In general, one antenna port may correspond to multiple antenna

elements (physical antennas) combined via a virtualization. This $N_1 \times N_2$ dual polarized array can then be viewed as $2N_1N_2$ -element array of elements.

The first dimension consists of N_1 columns and facilitates azimuth beamforming. The second dimension similarly consists of N_2 rows and allows elevation beamforming. MIMO precoding in Rel.12 LTE standardization (per TS36.211 section 6.3.4.2, 6.3.4.4, and TS36.213 section 7.2.4) was largely designed to offer precoding (beamforming) gain for one-dimensional (1D) antenna array using 2,4,8 antenna ports, which correspond to (N_1, N_2) belonging to $\{(1,1), (2,1), (4,1)\}$. While fixed beamforming (i.e. antenna virtualization) can be implemented across the elevation dimension, it is unable to reap the potential gain offered by the spatial and frequency selective nature of the channel. Therefore, MIMO precoding in Rel.13 LTE standardization is designed to offer precoding gain for two-dimensional (2D) antenna array using 8,12,16 antenna ports, which correspond to (N_1, N_2) belonging to $\{(2,2), (2,3), (3,2), (8,1), (4,2), (2,4)\}$.

Although $(N_1, N_2) = (6,1)$ case has not been supported in Rel. 13, it may be supported in future releases. The embodiments of this invention are general and are applicable to any (N_1, N_2) values including $(N_1, N_2) = (6,1)$. The first and second dimensions as shown in **Figure 8** are for illustration only. The invention is applicable to the case in which they are swapped, i.e., first and second dimensions respectively correspond to elevation and azimuth or any other pair of directions.

Number of ports	Port layouts, and (N_1, N_2) values		
2	(1,1)	x	
4	(2,1)	x x	
8	(2,2)	x x x x	(4,1) x x x x
12	(2,3)	x x x x x x	(3,2) x x x (6,1) x x x x x x
16	(2,4)	x x x x x x x x	(4,2) x x x x (8,1) x x x x x x x x

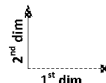


Figure 8: An illustration of dual-polarized antenna port layouts for {2,4,8,12,16} ports

According to [6], eFD-MIMO will support {20, 24, 28, 32} antenna ports in Rel. 14. Assuming rectangular (1D or 2D) port layouts, there are several possible (N_1, N_2) values for {20, 24, 28, 32} ports. An illustration of 1D and 2D antenna port layouts for these (N_1, N_2) values are shown in **Figure 9**.

# ports	Port layouts, and (N_1, N_2) values		# ports	Port layouts, and (N_1, N_2) values	
20		(2,5) xx xx xx xx	28		(2,7) xx xx xx xx xx
	(5,2)	xxxxxx xxxxxx		(7,2)	xxxxxx xxxxxx xxxxxx xxxxxx xxxxxx xxxxxx xxxxxx
	(10,1)	xxxxxxxxxx		(14,1)	xxxxxxxxxxxxxxxxxx
24		(3,4) xx xx xx xx	32		(2,8) xx xx xx xx xx xx xx
	(4,3)	xxxx xxxx xxxx xxxx		(4,4)	xxxx xxxx xxxx xxxx
	(6,2)	xxxxxx xxxxxx		(8,2)	xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
	(12,1)	xxxxxxxxxxxxxx		(16,1)	xxxxxxxxxxxxxxxxxxxxxxxxxx

Figure 9: An illustration of dual-polarized antenna port layouts for {20, 24, 28, 32} ports

In some embodiments, a UE is configured with one or both of the two types of CSI-RS resources:

- The “first non-zero-power (NZP) CSI-RS resource” corresponds to either
 - Full port: CSI-RS is transmitted from all $2N_1N_2$ ports and it is non-precoded (NP) or Class A eMIMO-Type, or
 - Partial port: CSI-RS is transmitted from a subset of $2N_1N_2$ ports, and it is either
 - NP CSI-RS or Class A eMIMO-Type, or
 - beam-formed (BF) CSI-RS or Class B eMIMO-Type with $K_1 \geq 1$ resources.
- The “second NZP CSI-RS resource” corresponds to a BF CSI-RS or Class B eMIMO-Type with either
 - $K_2 = 1$ resource or
 - $K_2 > 1$ resources.

In some embodiments, the configured first CSI-RS has one component for each of the two dimensions. For 1D antenna port configurations, the first CSI-RS has one component, and for 2D antenna port configurations, the first CSI-RS has two components

- first CSI-RS 1 or first CSI-RS component 1, and
- first CSI-RS 2 or first CSI-RS component 2.

In some embodiments, the configured second CSI-RS has one component for each of the two dimensions. For 1D antenna port configurations, the second CSI-RS has one component, and for 2D antenna port configurations, the second CSI-RS has two components

- second CSI-RS 1 or second CSI-RS component 1, and
- second CSI-RS 2 or second CSI-RS component 2.

In some embodiments, the full-port first CSI-RS resource is also referred to as Class A CSI-RS or eMIMO-Type, the partial-port first CSI-RS resource is also referred to as Class B ($K > 1$) CSI-RS or eMIMO-Type, and the second CSI-RS resource is also referred to as Class B CSI-RS or eMIMO-Type.

In LTE Rel. 13, the following CSI reporting types or *eMIMO-Type* are supported:

- ‘Class A’ *eMIMO-Type* in which “First CSI-RS resource” is full-port, NP and CSI is reported using Class A codebook.
- ‘Class B’ *eMIMO-Type* in which “Second CSI-RS resource” is beamformed and CSI is reported using Class B codebook.
 - $K = 1$: CQI, PMI, RI feedback.
 - $K > 1$: CRI, CQI, PMI, RI feedback.

In LTE Rel. 13 ‘Class A’ *eMIMO-Type*, a UE is configured with a CSI process comprising of a “first” CSI-RS resource for all $2N_1N_2$ ports. Upon receiving the CSI-RS for these ports, the UE derives and feeds back the Class A CSI feedback content comprising of the first PMI index pair, $(i_{1,1}, i_{1,2})$, the second PMI index i_2 , CQI, and RI. An exemplary use case of the Class A CSI feedback scheme is described in **Figure 10**. The UE derives the two PMIs using the Class A PMI codebook.

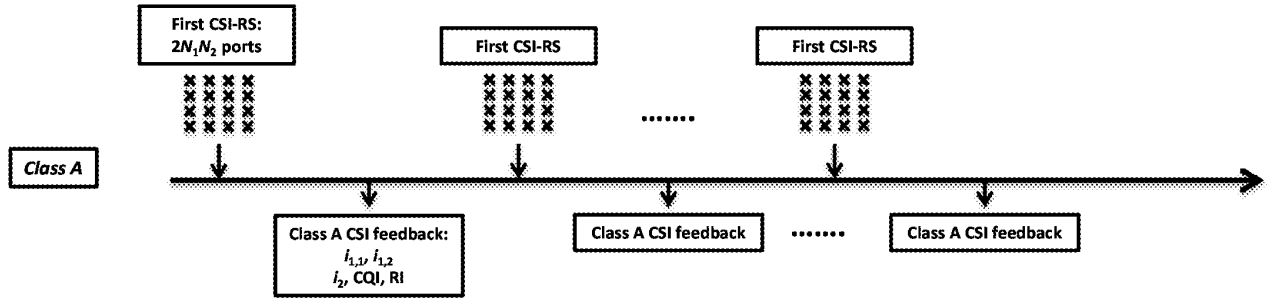


Figure 10: (Rel. 13) Class A CSI feedback scheme

In LTE Rel. 13 ‘Class B’ *eMIMO-Type*, a UE is configured with a CSI process comprising of a “second” CSI-RS resource for a *subset* of $2N_1N_2$ ports. For example, the number of configured ports is 2. Upon receiving the CSI-RS for these ports, the UE derives and feeds back the Class B CSI feedback content comprising of a single PMI i , CQI, and RI. An exemplary use case of the Class B CSI feedback scheme is described in **Figure 11**. The UE derives the PMI using the Class B PMI codebook.

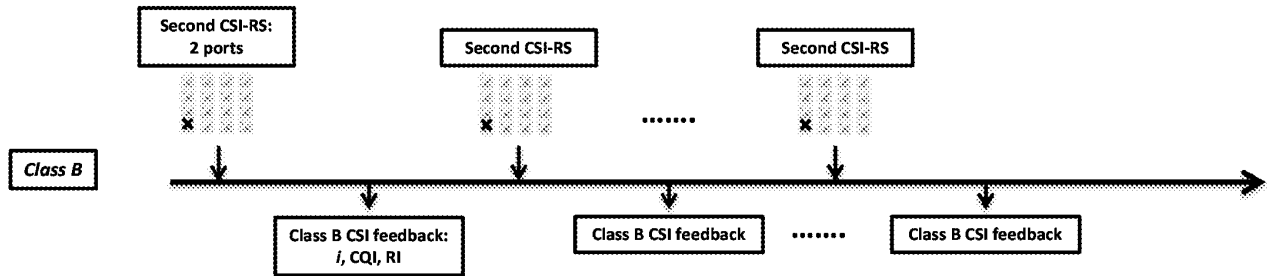


Figure 11: (Rel. 13) Class B CSI feedback scheme

Note that the CSI-RS overhead with the Class A CSI feedback scheme is large, which may lead to performance loss. The overhead is small for Class B CSI feedback scheme, but it relies on the availability of beam-forming weights to beam-form Class B CSI-RS. The beam-forming weights may be obtained from UL SRS measurements assuming UL-DL duplex distance is small. Alternatively, it may be obtained through a Class A feedback configured with larger periodicity. The later alternative is an example of “Hybrid” CSI feedback scheme which is the focus of this invention.

An issue with the Class A CSI feedback scheme for the future generation of communication systems (LTE Rel. 14 and beyond, 5G), is the increase in CSI-RS overhead to support larger number of antenna ports. In particular, as the number of supported antenna ports increases beyond a certain number, i.e. 32, they can't be transmitted and measured in the same subframe. Hence, CSI-RS transmission and reception will require multiple subframes, which may not be desirable in practice.

Another issue with the Class A CSI feedback scheme is that the increase in overhead is unclear to bring justifiable performance benefits. In other words, to achieve certain performance, it may not be necessary to transmit CSI-RS from all $2N_1N_2$ ports in every CSI-RS transmission instance as is the case with Class A CSI feedback scheme. The same performance may perhaps be achieved by a so-called "hybrid CSI feedback scheme" in which there are two types of CSI-RS resources, the first CSI-RS resource is transmitted from all or a subset of $2N_1N_2$ ports with a larger periodicity and the second CSI-RS resource is transmitted from fewer than $2N_1N_2$ ports, e.g. 2, with a smaller periodicity. The two CSI-RS resources are associated with two CSI reportings or eMIMO-Types. In 2015.03.006.SR0, 2016.03.001.SR0, and 2016.03.011.SR0, the hybrid CSI feedback scheme and hybrid eMIMO-Type alternatives are proposed. The focus of this invention is the details about some of the candidate hybrid eMIMO-Type alternatives and reported CSI contents.

In some embodiments, a UE is configured with either one CSI process with two NZP CSI-RS resources (each of the two associated with an eMIMO-Type) or two CSI processes each with one NZP CSI-RS resource associated with an eMIMO-Type, where

- 1st CSI-RS resource is associated with either Class A eMIMO-Type or Class B eMIMO-Type with $K_1 \geq 1$ resource
 - In terms of use cases, these two alternatives correspond to non-precoded (NP) CSI-RS and partial-port CSI-RS, respectively
- 2nd CSI-RS resource is associated with Class B eMIMO-Type with $K_2 \geq 1$ resources.

The two NZP CSI-RS resources are associated with two eMIMO-Types according to the configuration where examples of supported eMIMO-Type combinations are according to **Table 3**. The RI reported in the 1st eMIMO-Type is denoted as $RI^{(1)}$ and that reported in the 2nd eMIMO-Type is denoted as $RI^{(2)}$.

Some of these configurations such as Configuration 0 have multiple alternatives such as a, b, and c depending on CSI reporting contents. In one method, one of these alternatives is configured to the UE via higher-layer RRC signaling. In another method, the alternative is fixed, for example, 0-a, and hence does not need to be configured.

Table 3: Supported eMIMO-Type combinations for hybrid CSI reporting

Configuration		CSI derived with the first CSI-RS resource		CSI derived with the second (BF) CSI-RS resource	
		eMIMO-Type	CSI reporting content	eMIMO-Type	CSI reporting content
0	0-a	Class A	i_1 or $(i_{1,1}, i_{1,2}), RI^{(1)}$	Class B $K_2 = 1$	CQI, PMI
	0-b		i_1 or $(i_{1,1}, i_{1,2})$		$RI^{(2)}$, CQI, PMI
	0-c		i_1 or $(i_{1,1}, i_{1,2}), RI^{(1)}$		$RI^{(2)}$, CQI, PMI
1	1-a	Class B $K_1 = 1$	PMI (Alt0: Rel. 13 Class B codebook Alt1: Rel. 12 codebooks)	Class B $K_2 = 1$	$RI^{(2)}$, CQI, PMI
	1-b		CQI, $RI^{(1)}$, PMI (Alt0: Rel. 13 Class B codebook Alt1: Rel. 12 codebooks)		$RI^{(2)}$, CQI, PMI
2	2-a	Class B $K_1 > 1$	CRI	Class B $K_2 = 1$	$RI^{(2)}$, CQI, PMI
	2-b		PMI (Alt0: Rel. 13 Class B codebook Alt1: Rel. 12 codebooks)/ $RI^{(1)}$ for each CSI-		$RI^{(2)}$, CQI, PMI

			RS resource		
3	3-a	Class B $K_1 = 1$	i_1 or $(i_{1,1}, i_{1,2})$	Class B $K_2 > 1$	CRI, and $\{RI^{(2)}, CQI, PMI\}$ conditioned on CRI
4	3-a	Class A	i_1 or $(i_{1,1}, i_{1,2})$	Class B $K_2 > 1$	CRI, and $\{RI^{(2)}, CQI, PMI\}$ conditioned on CRI
	3-b		i_1 or $(i_{1,1}, i_{1,2}), RI^{(1)}$		CRI, and $\{RI^{(2)}, CQI, PMI\}$ conditioned on CRI

Embodiment on Configuration 0 (Class A + Class B, $K = 1$)

In some embodiments, a UE is configured with a hybrid CSI reporting in which the 1st eMIMO-Type is Class A and the 2nd eMIMO-Type is Class B, $K = 1$. The CSI reported in the Class A eMIMO-Type includes i_1 or $(i_{1,1}, i_{1,2})$ and that reported in Class B eMIMO-Type includes CQI and PMI. Depending on whether both or at least one of $RI^{(1)}$ and $RI^{(2)}$ are reported, we have the following alternatives (as shown in **Table 3**):

- 0-a: Only $RI^{(1)}$ is reported.
- 0-b: Only $RI^{(2)}$ is reported.
- 0-c: Both $RI^{(1)}$ and $RI^{(2)}$ are reported.

The UE is configured with the Rel. 13 Class A codebook (or its extension in Rel. 14) for the Class A eMIMO-Type. Alternatively, the UE is configured with a new codebook for the Class A eMIMO-Type. An example of a new codebook is the Class A linear combination codebook proposed in 2016.03.017.SR0. The Rel. 13 Class A codebook is a dual-codebook: $\mathbf{W}_1 \mathbf{W}_2$ with $\mathbf{W}_1$ is used to indicate a beam group comprising of multiple (e.g. 4) beams, and $\mathbf{W}_2$ is used to indicate one out of multiple beam selection and a QPSK co-phase value. For the Class A eMIMO-Type in Configuration 0 (**Table 3**), the $\mathbf{W}_1$ component of the Class A codebook is used. An example of rank 1-2 Class A $\mathbf{W}_1$ codebook is shown in **Table 5**, where the group of beams indicated by $(i_{1,1}, i_{1,2})$ is expressed as $\mathbf{W}_{i_{1,1}, i_{1,2}}$, where the quantities u_m and $v_{l,m}$ are given by

$$u_m = \begin{bmatrix} 1 & e^{j \frac{2\pi m}{O_2 N_2}} & \dots & e^{j \frac{2\pi m(N_2-1)}{O_2 N_2}} \end{bmatrix}$$

$$v_{l,m} = \begin{bmatrix} u_m & e^{j \frac{2\pi l}{O_1 N_1}} u_m & \dots & e^{j \frac{2\pi l(N_1-1)}{O_1 N_1}} u_m \end{bmatrix}^T$$

- The values of N_1 , N_2 , O_1 , and O_2 are configured with the higher-layer parameters *codebook-Config-N1*, *codebook-Config-N2*, *codebook-Over-Sampling-RateConfig-O1*, and *codebook-Over-Sampling-RateConfig-O2*, respectively. The supported configurations of (O_1, O_2) and (N_1, N_2) for a given number of CSI-RS ports in the Class A eMIMO-Type are given in **Table 4**. For 20, 24, 28, and 32 CSI-RS ports, the supported configurations of (O_1, O_2) and (N_1, N_2) can be added to the table. The number of CSI-RS ports, P , is $2N_1N_2$.
- UE is not expected to be configured with value of *Codebook-Config* set to 2 or 3, if the value of *codebook-Config-N2* is set to 1.
- UE shall only use $i_{1,2} = 0$ and shall not report $i_{1,2}$ if the value of *codebook-Config-N2* is set to 1.

Table 4: Supported configurations of (O_1, O_2) and (N_1, N_2)

Number of CSI-RS antenna ports, P	(N_1, N_2)	(O_1, O_2)
--	--------------	--------------

8	(2,2)	(4,4), (8,8)
12	(2,3)	(8,4), (8,8)
	(3,2)	(8,4), (4,4)
16	(2,4)	(8,4), (8,8)
	(4,2)	(8,4), (4,4)
	(8,1)	(4,-), (8,-)
20		
24		
28		
32		

Table 5: W_1 Codebook for 1-layer and 2-layer CSI reporting using antenna ports 15 to 14+P

Value of Codebook- Config	$i_{1,1}$	$i_{1,2}$	$W_{i_{1,1}, i_{1,2}}$
1	$0, 1, \dots, N_1 O_1 - 1$	$0, 1, \dots, N_2 O_2 - 1$	$w_{i_{1,1}, i_{1,2}} = \frac{1}{\sqrt{N_1 N_2}} v_{i_{1,1}, i_{1,2}}$
2	$0, 1, \dots, \frac{N_1 O_1}{2} - 1$	$0, 1, \dots, \frac{N_2 O_2}{2} - 1$	$w_{i_{1,1}, i_{1,2}} = \frac{1}{\sqrt{N_1 N_2}} \begin{bmatrix} v_{2i_{1,1}, 2i_{1,2}} & v_{2i_{1,1}+1, 2i_{1,2}} & v_{2i_{1,1}, 2i_{1,2}+1} & v_{2i_{1,1}+1, 2i_{1,2}+1} \end{bmatrix}$
3	$0, 1, \dots, \frac{N_1 O_1}{2} - 1$	$0, 1, \dots, \frac{N_2 O_2}{2} - 1$	$w_{i_{1,1}, i_{1,2}} = \frac{1}{\sqrt{N_1 N_2}} \begin{bmatrix} v_{2i_{1,1}, 2i_{1,2}} & v_{2i_{1,1}+2, 2i_{1,2}} & v_{2i_{1,1}+1, 2i_{1,2}+1} & v_{2i_{1,1}+3, 2i_{1,2}+1} \end{bmatrix}$, if $N_1 \geq N_2$ $w_{i_{1,1}, i_{1,2}} = \frac{1}{\sqrt{N_1 N_2}} \begin{bmatrix} v_{2i_{1,1}, 2i_{1,2}} & v_{2i_{1,1}, 2i_{1,2}+2} & v_{2i_{1,1}+1, 2i_{1,2}+1} & v_{2i_{1,1}+1, 2i_{1,2}+3} \end{bmatrix}$, if $N_1 < N_2$
4	$0, 1, \dots, \frac{N_1 O_1}{2} - 1$	$0, 1, \dots, \frac{N_2 O_2}{2} - 1$	$w_{i_{1,1}, i_{1,2}} = \frac{1}{\sqrt{N_1 N_2}} \begin{bmatrix} v_{2i_{1,1}, 2i_{1,2}} & v_{2i_{1,1}+1, 2i_{1,2}} & v_{2i_{1,1}+2, 2i_{1,2}} & v_{2i_{1,1}+3, 2i_{1,2}} \end{bmatrix}$, if $N_1 \geq N_2$ $w_{i_{1,1}, i_{1,2}} = \frac{1}{\sqrt{N_1 N_2}} \begin{bmatrix} v_{2i_{1,1}, 2i_{1,2}} & v_{2i_{1,1}, 2i_{1,2}+1} & v_{2i_{1,1}, 2i_{1,2}+2} & v_{2i_{1,1}, 2i_{1,2}+3} \end{bmatrix}$, if $N_1 < N_2$

The W_1 codebook for rank 3-4 and rank 5-8 can be constructed similarly.

The UE is configured with the Rel. 13 Class B codebook (or its extension in Rel. 14) for the Class B eMIMO-Type. Alternatively, the UE is configured with a new codebook for the Class B eMIMO-Type. An example of a new codebook is the Class B linear combination codebook proposed in 2016.06.003.SR0.

In the following embodiments, Rel. 13 Class A and Class B codebooks are assumed for two eMIMO-Types as examples. The embodiments, however, are applicable to other Class A and Class B codebooks such as the linear combination codebook.

There are at least the following alternatives for the Class A codebook parameter *Codebook-Config*:

- In one alternative, the *Codebook-Config* for Class A eMIMO-Type is fixed or pre-determined (hence, not configured). For example, *Codebook-Config* is fixed to 1.
- In another alternative, the *Codebook-Config* for Class A eMIMO-Type is configured, where the set of values of *Codebook-Config* include 1, 2, 3, and 4, which are identical to Rel. 13 Class A codebook parameter.
- In another alternative, a restricted subset of *Codebook-Config* parameter values is configurable, for example *Codebook-Config* = 2, 3, and 4.
- In yet another alternative, new *Codebook-Config* parameters (or beam groups) that are different from Rel. 13 Class A codebook are defined for the hybrid configuration.

In general, the number and type (adjacent or orthogonal) of beams reported in Class A eMIMO-Type by i_1 or $(i_{1,1}, i_{1,2})$ depends on *Codebook-Config* parameter and $\mathbf{W}_1$ codebook rank. For example, beams are adjacent for rank 1 $\mathbf{W}_1$ codebook, and are orthogonal for rank 8 $\mathbf{W}_1$ codebook. Also, *Codebook-Config* 1 indicates 1 rank-1 beam and *Codebook-Config* 2,3,4 indicate 4 rank-1 beams. The reported beams (indicated by i_1 or $(i_{1,1}, i_{1,2})$) are used by eNB to beam-form N_P ports associated with Class B eMIMO-Type. Depending on whether all or a subset of the reported beams are used by the eNB, there are multiple possible hybrid configurations, the details of which are provided later in the invention.

In one method, the hybrid configuration is fixed for each (*Codebook-Config*, N_P) configuration. So, no additional signaling about hybrid configuration is required once (*Codebook-Config*, N_P) is configured.

In another method, the UE is configured with one of multiple hybrid configurations for each (*Codebook-Config*, N_P) configuration via RRC signaling, where the set of possible configurable hybrid configurations can be a subset of the set of all possible hybrid configurations.

The details of possible hybrid configurations are as follows.

In alternative 0-a, only $RI^{(1)}$ is reported. Since $RI^{(2)}$ is not reported in Class B eMIMO-Type, there are at least the following alternatives for PMI and CQI reporting:

- The reported PMI and CQI in Class B eMIMO-Type correspond to the rank (r) which is equal to $RI^{(1)}$ reported in Class A eMIMO-Type, i.e. $r = RI^{(1)}$.
- The reported PMI and CQI in Class B eMIMO-Type correspond to the rank (r) which is smaller than or equal to $RI^{(1)}$ reported in Class A eMIMO-Type, i.e. $r \leq RI^{(1)}$, where r is either fixed (for example rank 1) or configured via RRC signaling.

The set of possible values of $RI^{(1)}$ can either be $\{1, 2, \dots, 8\}$ (i.e., 3-bit $RI^{(1)}$ indication) or a subset of $\{1, 2, \dots, 8\}$. In one example, the rank subset is $\{1, 2, 3, 4\}$ (i.e., 2-bit $RI^{(1)}$ indication) or $\{1, 3, 5, 7\}$ (i.e., 2-bit $RI^{(1)}$ indication) or $\{1, 2\}$ (i.e., 1-bit $RI^{(1)}$ indication). In another example, for $N_P = 2$, the rank subset is $\{1, 2\}$, for $N_P = 4$, it is $\{1, 2, 3, 4\}$, and for $N_P = 8$, it is $\{1, 2, \dots, 8\}$.

In alternative 0-b, only $RI^{(2)}$ is reported. Since $RI^{(1)}$ is not reported in Class A eMIMO-Type, there are at least the following alternatives for i_1 or $(i_{1,1}, i_{1,2})$ reporting:

- The reported i_1 or $(i_{1,1}, i_{1,2})$ corresponds to (or is conditioned on) a fixed and pre-determined rank Class A $\mathbf{W}_1$ codebook. For example, rank = 1 or 8.
- The rank on which i_1 or $(i_{1,1}, i_{1,2})$ reporting is conditioned is configured via higher layer (RRC) signaling, where
 - the set of configurable rank is 1-8 (resulting in a 3-bit RRC parameter), or
 - the set of configurable rank is a subset of 1-8. For example, $\{1, 3, 7\}$ or $\{1, 3, 5, 7\}$ (each resulting in a 2-bit RRC parameter)
- The rank on which i_1 or $(i_{1,1}, i_{1,2})$ reporting is conditioned depends on the number of ports (N_P) configured for the CSI-RS resource associated with Class B eMIMO-Type. For example,
 - The rank for i_1 or $(i_{1,1}, i_{1,2})$ reporting is 1 if $N_P = 2$.
 - The rank for i_1 or $(i_{1,1}, i_{1,2})$ reporting is 3 if $N_P = 4$.
 - The rank for i_1 or $(i_{1,1}, i_{1,2})$ reporting is 7 if $N_P = 8$.

The details about the possible hybrid configurations in this case are provided next.

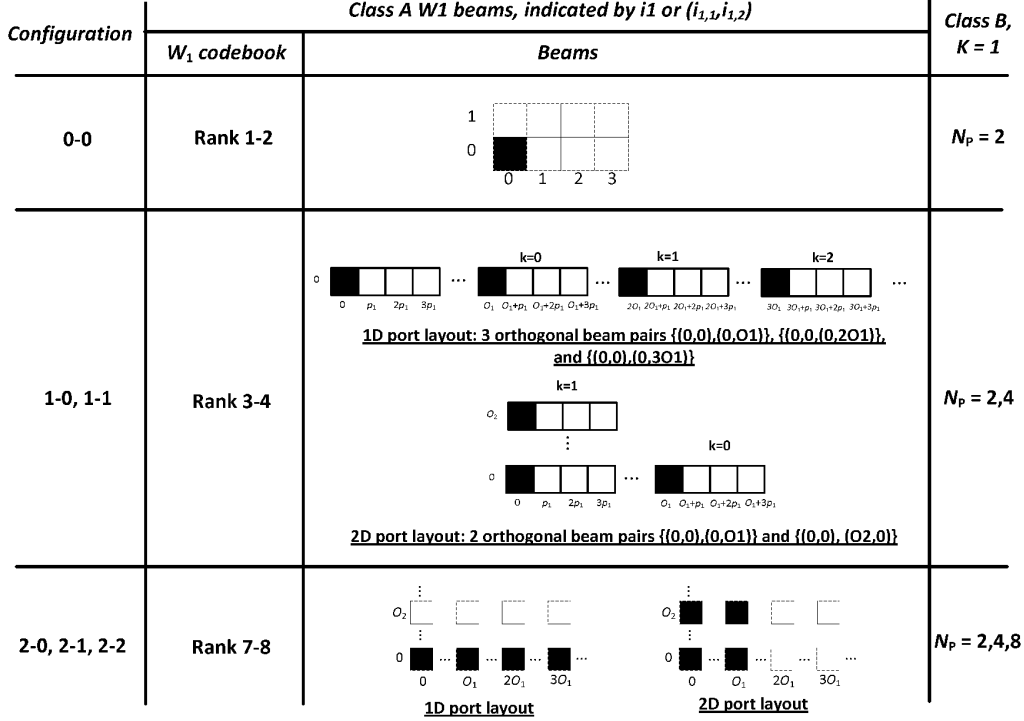


Figure 12: An illustration of hybrid configuration for Codebook-Config = 1

Table 6: Class A (Codebook-Config = 1), Class B ($N_P = 2, 4, 8$), Only $RI^{(2)}$ is reported

Configuration		Class A			Class B, $K = 1$			
		Number of beams indicated by i_1	Beam types	Class A Codebook	N_P	Rank $RI^{(2)}$	#RI bits	Class B Codebook
0	0-0	1	Single beam	Rel. 13 (or 14) Rank 1-2 W_1	2	1-2	1	Rel. 13 (or 14)
1	1-0	2	2 orthogonal pairs for 2D port layout; 3 orthogonal pairs for 1D port layout	Rel. 13 (or 14) Rank 3-4 W_1	2	1-2	1	
	1-1				4	1-4	2	
2	2-0	4	4 orthogonal beams	Rel. 13 (or 14) Rank 7-8 W_1	2	1-2	1	
	2-1				4	1-4	2	
	2-2				8	1-8	3	

If Codebook-Config = 1, then the UE can be configured with one of the following hybrid configurations. An illustration of the beams for these configurations is shown in **Figure 12**, and the relevant details of the configurations are summarized in **Table 6**.

- Configuration 0: The UE is configured with
 - Rel. 13 (or its extension in Rel. 14) Class A rank 1-2 W_1 codebook to derive i_1 or $(i_{1,1}, i_{1,2})$ indicating one beam, and
 - The following sub-configuration for Class B eMIMO-Type.
 - Configuration 0-0: Rel. 13 Class B, $K = 1$ codebook for $N_P = 2$ ports (which are beamformed using the beam indicated by i_1 or $(i_{1,1}, i_{1,2})$).

- The UE does not need to perform any beam selection.
 - The UE reports up to rank 2 PMI (i.e., 1-bit $RI^{(2)}$) in Class B eMIMO-Type.
- Configuration 1: The UE is configured with
 - Rel. 13 (or its extension in Rel. 14) Class A rank 3-4 $\mathbf{W}_1$ codebook to derive i_1 or $(i_{1,1}, i_{1,2})$ indicating one of the two (three) orthogonal beam pairs for 2D (1D) antenna port layouts, and
 - One of the following two sub-configurations for Class B eMIMO-Type.
 - Configuration 1-0: Rel. 13 Class B, $K = 1$ codebook for $N_P = 2$ ports (which are beamformed using 1 out of 2 beams indicated by i_1 or $(i_{1,1}, i_{1,2})$).
 - The UE does not need to perform any beam selection.
 - The UE reports up to rank 2 PMI (i.e., 1-bit $RI^{(2)}$) in Class B eMIMO-Type.
 - Configuration 1-1: Rel. 13 Class B, $K = 1$ codebook for $N_P = 4$ ports (which are beamformed using 2 beams indicated by i_1 or $(i_{1,1}, i_{1,2})$).
 - The UE performs 1 out of 2 beam selection for rank 1-2, and selects both beams for rank 3-4.
 - The UE reports up to rank 4 PMI (i.e., 2-bit $RI^{(2)}$) in Class B eMIMO-Type.
- Configuration 2: The UE is configured with
 - Rel. 13 (or its extension in Rel. 14) Class A rank 7-8 $\mathbf{W}_1$ codebook to derive i_1 or $(i_{1,1}, i_{1,2})$ indicating four orthogonal beams, and
 - One of the following three sub-configurations for Class B eMIMO-Type.
 - Configuration 2-0: Rel. 13 Class B, $K = 1$ codebook for $N_P = 2$ ports (which are beamformed using 1 out of 4 orthogonal beams indicated by i_1 or $(i_{1,1}, i_{1,2})$).
 - The UE does not need to perform any beam selection.
 - The UE reports up to rank 2 PMI (i.e., 1-bit $RI^{(2)}$) in Class B eMIMO-Type.
 - Configuration 2-1: Rel. 13 Class B, $K = 1$ codebook for $N_P = 4$ ports (which are beamformed using 2 out of 4 orthogonal beams indicated by i_1 or $(i_{1,1}, i_{1,2})$).
 - The UE performs 1 out of 2 beam selection for rank 1-2, and selects both beams for rank 3-4.
 - The UE reports up to rank 4 PMI (i.e., 2-bit $RI^{(2)}$) in Class B eMIMO-Type.
 - Configuration 2-2: Rel. 13 Class B, $K = 1$ codebook for $N_P = 8$ ports (which are beamformed using 4 orthogonal beams indicated by i_1 or $(i_{1,1}, i_{1,2})$).
 - The UE performs 1 out 4 beam selection for rank 1-2, 2 out of 4 beam selection for rank 3-4, 3 out of 4 beam selection for rank 5-6, and selects all 4 beams for rank 7-8.
 - The UE reports up to rank 8 PMI (i.e., 3-bit $RI^{(2)}$) in Class B eMIMO-Type.

Configuration	Class A W1 beams, indicated by i_1 or $(i_{1,1}, i_{1,2})$				Class B, $K = 1$
	W_1 CB	Codebook-Config 2	Codebook-Config 3	Codebook-Config 4	
0-0, 0-1, 0-2	Rank 1-2				$N_P = 2, 4, 8$
1-0, 1-1, 1-2	Rank 3-4	2D port layout: 2 orthogonal beam groups 1D port layout: 3 orthogonal beam groups (same as Codebook-Config 1)	2D port layout: 2 orthogonal beam groups 1D port layout: 3 orthogonal beam groups (same as Codebook-Config 1)	2D port layout: 2 orthogonal beam groups 1D port layout: 3 orthogonal beam groups (same as Codebook-Config 1)	$N_P = 2, 4, 8$
2-0, 2-1, 2-2	Rank 7-8				$N_P = 2, 4, 8$

Figure 13: An illustration of hybrid configuration for Codebook-Config = 2,3,4

Table 7: Class A (Codebook-Config = 2,3,4), Class B ($N_P = 2, 4, 8$), Only $RI^{(2)}$ is reported

Configuration		Class A			Class B, $K = 1$			
		Number of beams indicated by i_1	Beam types	Class A Codebook	N_P	Rank $RI^{(2)}$	#RI bits	Class B Codebook
0	0-0	4	4 closely spaced beams	Rel. 13 (or 14) Rank 1-2 $\mathbf{W}_1$	2	1-2	1	Rel. 13 (or 14)
	0-1				4			
	0-2				8			
1	1-0	8	2 orthogonal groups for 2D port layout; 3 orthogonal groups for 1D port layout	Rel. 13 (or 14) Rank 3-4 $\mathbf{W}_1$	2	1-2	1	
	1-1				4	1-4	2	
	1-2				8			
2	2-0	4	4 orthogonal beams	Rel. 13 (or 14) Rank 7-8 $\mathbf{W}_1$	2	1-2	1	
	2-1				4	1-4	2	
	2-2				8	1-8	3	

If *Codebook-Config* = 2,3,4, then the UE is configured with one of the following hybrid configurations. An illustration of the beams for the three configurations is shown in Figure 13, and the relevant details of the configurations are summarized in Table 7.

- Configuration 0: The UE is configured with
 - Rel. 13 (or its extension in Rel. 14) Class A rank 1-2 $\mathbf{W}_1$ codebook to derive i_1 or $(i_{1,1}, i_{1,2})$ indicating four beams, and
 - One of the following three sub-configurations for Class B eMIMO-Type.
 - Configuration 0-0: Rel. 13 Class B, $K = 1$ codebook for $N_P = 2$ ports (which are beamformed using 1 out of 4 beams indicated by i_1 or $(i_{1,1}, i_{1,2})$).
 - The UE does not need to perform any beam selection.
 - The UE reports up to rank 2 PMI (i.e., 1-bit $\text{RI}^{(2)}$) in Class B eMIMO-Type.
 - Configuration 0-1: Rel. 13 Class B, $K = 1$ codebook for $N_P = 4$ ports (which are beamformed using 2 out of 4 beams indicated by i_1 or $(i_{1,1}, i_{1,2})$).
 - The UE performs 1 out of 2 beam selection.
 - The UE reports up to rank 2 PMI (i.e., 1-bit $\text{RI}^{(2)}$) in Class B eMIMO-Type.
 - Configuration 0-2: Rel. 13 Class B, $K = 1$ codebook for $N_P = 8$ ports (which are beamformed using all 4 beams indicated by i_1 or $(i_{1,1}, i_{1,2})$).
 - The UE performs 1 out of 4 beam selection.
 - The UE reports up to rank 2 PMI (i.e., 1-bit $\text{RI}^{(2)}$) in Class B eMIMO-Type.
- Configuration 1: The UE is configured with
 - Rel. 13 (or its extension in Rel. 14) Class A rank 3-4 $\mathbf{W}_1$ codebook to derive i_1 or $(i_{1,1}, i_{1,2})$ indicating one of the two (three) orthogonal beam groups for 2D (1D) antenna port layouts where each orthogonal beam group has eight beams, four of which are located at location (0,0) and the remaining four are located at an orthogonal location, for example $(0_1, 0)$ or $(0, 0_2)$, and
 - One of the following three sub-configurations for Class B eMIMO-Type.
 - Configuration 1-0: Rel. 13 Class B, $K = 1$ codebook for $N_P = 2$ ports (which are beamformed using 1 out of 8 beams indicated by i_1 or $(i_{1,1}, i_{1,2})$).
 - The UE does not need to perform any beam selection.
 - The UE reports up to rank 2 PMI (i.e., 1-bit $\text{RI}^{(2)}$) in Class B eMIMO-Type.
 - Configuration 1-1: Rel. 13 Class B, $K = 1$ codebook for $N_P = 4$ ports (which are beamformed using 2 out of 8 beams indicated by i_1 or $(i_{1,1}, i_{1,2})$).
 - The UE performs 1 out of 2 beam selection for rank 1-2, and selects both beams for rank 3-4.
 - The UE reports up to rank 4 PMI (i.e., 2-bit $\text{RI}^{(2)}$) in Class B eMIMO-Type.
 - Configuration 1-2: Rel. 13 Class B, $K = 1$ codebook for $N_P = 8$ ports (which are beamformed using 4 out of 8 beams indicated by i_1 or $(i_{1,1}, i_{1,2})$).
 - The UE performs 1 out of 4 beam selection for rank 1-2, and 2 out of 4 beam selection for rank 3-4.
 - The UE reports up to rank 4 PMI (i.e., 2-bit $\text{RI}^{(2)}$) in Class B eMIMO-Type.
- Configuration 2: The UE is configured with
 - Rel. 13 (or its extension in Rel. 14) Class A rank 7-8 $\mathbf{W}_1$ codebook to derive i_1 or $(i_{1,1}, i_{1,2})$ indicating four orthogonal beams, and
 - One of the following three sub-configurations.
 - Configuration 2-0: Rel. 13 Class B, $K = 1$ codebook for $N_P = 2$ ports (which are beamformed using 1 out of 4 orthogonal beams indicated by i_1 or $(i_{1,1}, i_{1,2})$).
 - The UE does not need to perform any beam selection.
 - The UE reports up to rank 2 PMI (i.e., 1-bit $\text{RI}^{(2)}$) in Class B eMIMO-Type.
 - Configuration 2-1: Rel. 13 Class B, $K = 1$ codebook for $N_P = 4$ ports (which are beamformed using 2 out of 4 orthogonal beams indicated by i_1 or $(i_{1,1}, i_{1,2})$).
 - The UE performs 1 out of 2 beam selection for rank 1-2, and selects both beams for rank 3-4.

- The UE reports up to rank 4 PMI (i.e., 2-bit $RI^{(2)}$) in Class B eMIMO-Type.
- Configuration 2-2: Rel. 13 Class B, $K = 1$ codebook for $N_P = 8$ ports (which are beamformed using 4 orthogonal beams indicated by i_1 or $(i_{1,1}, i_{1,2})$).
 - The UE performs 1 out of 4 beam selection for rank 1-2, 2 out of 4 beam selection for rank 3-4, 3 out of 4 beam selection for rank 5-6, and selects all 4 beams for rank 7-8.
- The UE reports up to rank 8 PMI (i.e., 3-bit $RI^{(2)}$) in Class B eMIMO-Type.

The present disclosure covers the use of all the above configurations or sub-configurations. It also covers the use of only a subset of all the above configurations or sub-configurations. If more than one configurations or sub-configurations are used, the choice of configuration or sub-configuration is performed via higher layer signaling.

For example, a subset of hybrid configurations or sub-configurations in Table 6 and Table 7 is used to configure one hybrid configuration to the UE. An example of such a subset is shown in **Table 8**. The number of configurations in the table is 18. At least two possible configuration schemes can be used. First, a 5-bit RRC parameter can be used to configure a UE with one of the 18 hybrid configurations. Second, only one bit RRC parameter which configures a UE with one of the two configurations in case of *Codebook-Config* 2,3,4 and $N_P = 4,8$. This RRC signaling is not needed if *Codebook-Config* = 1 or (*Codebook-Config* 2,3,4 and $N_P = 2$). In this later configuration, *Codebook-Config* for Class A and the number of ports N_P for Class B are already configurable via higher-layer signaling.

Table 8: Configurable hybrid configurations; Only $RI^{(2)}$ is reported

Class A: <i>Codebook-Config</i>	Class B: N_P	Hybrid Configuration	# $RI^{(2)}$ bits
1	2	0-0 (Table 6)	1
	4	1-1 (Table 6)	2
	8	2-2 (Table 6)	3
2, 3, or 4	2	0-0 (Table 7)	1
	4	0-1 (Table 7)	1
	8	0-2 (Table 7)	1
	4	1-1 (Table 7)	2
	8	2-2 (Table 7)	3
	8	2-2 (Table 7)	3

A variation of the above example where only one configuration is supported for *Codebook-Config* = 2,3,4 and $N_P = 4,8$ can be described as follows. Two examples are given in **Table 9** and **Table 10** below where the number of bits for $RI^{(2)}$ is 1 and $\log_2(N_P)$, respectively. In this case, an additional RRC parameter is not needed.

Table 9: Configurable hybrid configurations; Only $RI^{(2)} = 1$ bit is reported

Class A: <i>Codebook-Config</i>	Class B: N_P	Hybrid Configuration	# $RI^{(2)}$ bits
2, 3, or 4	2	0-0 (Table 7)	1
	4	0-1 (Table 7)	1
	8	0-2 (Table 7)	1

Table 10: Configurable hybrid configurations; Only $RI^{(2)} = \log_2(N_P)$ bits is reported

Class A: <i>Codebook-Config</i>	Class B: N_P	Hybrid Configuration	# $RI^{(2)}$ bits
2, 3, or 4	2	0-0 (Table 7)	1
	4	1-1 (Table 7)	2
	8	2-2 (Table 7)	3

In alternative 0-c, both $RI^{(1)}$ and $RI^{(2)}$ are reported. Since $RI^{(1)}$ is reported in Class A eMIMO-Type, there are at least the following alternatives for i_1 or $(i_{1,1}, i_{1,2})$ reporting:

- The reported i_1 or $(i_{1,1}, i_{1,2})$ corresponds to (or is conditioned on) any of rank 1-8 Class A W_1 codebooks, i.e. $RI^{(1)} = 1, 2, \dots, 8$ (i.e., 3-bit $RI^{(1)}$).

- The reported i_1 or $(i_{1,1}, i_{1,2})$ is conditioned on a subset of all rank 1-8 Class A $\mathbf{W}_1$ codebooks, where the subset is either pre-determined or RRC configured. For example,
 - $\text{RI}^{(1)} = 1,3$ (i.e., 1-bit $\text{RI}^{(1)}$) or
 - $\text{RI}^{(1)} = 1,3,5$ (i.e., 2-bit $\text{RI}^{(1)}$) or
 - $\text{RI}^{(1)} = 1,3,5,7$ (i.e., 2-bit $\text{RI}^{(1)}$).
- The rank on which i_1 or $(i_{1,1}, i_{1,2})$ reporting is conditioned depends on the number of ports (N_P) configured for the CSI-RS resource associated with Class B eMIMO-Type. For example,
 - $\text{RI}^{(1)} = 1$ (so, no $\text{RI}^{(1)}$ indication is needed) if $N_P = 2$.
 - $\text{RI}^{(1)} = 1,3$ (i.e., 1-bit $\text{RI}^{(1)}$) if $N_P = 4$.
 - $\text{RI}^{(1)} = 1,3,5,7$ (i.e., 2-bit $\text{RI}^{(1)}$) if $N_P = 8$.

Also, since RI is reported in both eMIMO-Types (associated with the two configured NZP CSI-RS resources), we can have the following two cases:

- Case 0: $\text{RI}^{(1)}$ and $\text{RI}^{(2)}$ are dependent. For example, $\text{RI}^{(2)}$ reporting is only 1-bit for $N_P = 2,4,8$.
 - One possible embodiment for this is to utilize rank inheritance feature in Rel.12. That is, a RI reference resource for the second eMIMO-Type is defined to as the resource associated with the first eMIMO-Type.
- Case 1: $\text{RI}^{(1)}$ and $\text{RI}^{(2)}$ are independent. In particular, $\text{RI}^{(2)}$ reporting is 1, 2, and 3 bits for $N_P = 2, 4$, and 8, respectively.
 - In this case, CQI and PMI associated with the second eMIMO-Type (of Class B) are calculated conditioned on the reported $\text{RI}^{(2)}$. For periodic PUCCH-based CSI reporting, the reported $\text{RI}^{(2)}$ is the last reported periodic $\text{RI}^{(2)}$.

One of the above two cases can be configured to a UE via RRC signaling. Alternatively, the case is pre-determined, for example Case 0.

Similar to alternative 0-b, if Codebook-Config = 1, then the UE can be configured with one of the several hybrid configurations (or sub-configurations). Example configurations are summarized in **Table 11** and **Table 12** respectively for Case 0 and Case 1 of rank reportings and $N_P = 2,4,8$.

Table 11: Class A (Codebook-Config = 1) and Class B ($N_P = 2,4,8$), both $\text{RI}^{(1)}$ and $\text{RI}^{(2)}$ are report, Case 0: $\text{RI}^{(1)}$ and $\text{RI}^{(2)}$ are dependent

Configuration	Class A					Class B, $K = 1$			
	#RI bits	Rank $\text{RI}^{(1)}$	Number of beams indicated by i_1	Beam types	Class A Codebook	N_P	Rank $\text{RI}^{(2)}$	#RI bits	Class B Codebook
0	2	1-2	1	-	Rel. 13 (or 14) Rank 1-2 $\mathbf{W}_1$	2	1-2	1	Rel. 13 (or 14)
1		3-4	2	2 orthogonal pairs for 2D port layout; 3 orthogonal pairs for 1D port layout	Rel. 13 (or 14) Rank 3-4 $\mathbf{W}_1$	4	3-4		
2		5-6	3	3 orthogonal beams	Rel. 13 (or 14) Rank 5-6 $\mathbf{W}_1$	8	5-6		
3		7-8	4	4 orthogonal beams	Rel. 13 (or 14) Rank 7-8 $\mathbf{W}_1$	8	7-8		

Table 12: Class A (Codebook-Config = 1) and Class B ($N_P = 2,4,8$), both $RI^{(1)}$ and $RI^{(2)}$ are report, Case 1: $RI^{(1)}$ and $RI^{(2)}$ are independent

Configuration		Class A					Class B, $K = 1$			
		#RI bits	Rank $RI^{(1)}$	Number of beams indicated by i_1	Beam types	Class A Codebook	N_P	Rank $RI^{(2)}$	#RI bits	Class B Codebook
0	0-0	2	1-2	1	-	Rel. 13 (or 14) Rank 1-2 W_1	2	1-2	1	Rel. 13 (or 14)
1	1-0		3-4	2	2 orthogonal pairs for 2D port layout; 3 orthogonal pairs for 1D port layout	Rel. 13 (or 14) Rank 3-4 W_1	2	1-2	1	
	1-1						4	1-4	2	
2	2-0		5-6	3	3 orthogonal beams	Rel. 13 (or 14) Rank 7-8 W_1	2	1-2	1	
	2-1						4	1-4	2	
	2-2						8	1-6	3	
3	3-0		7-8	4	4 orthogonal beams	Rel. 13 (or 14) Rank 7-8 W_1	2	1-2	1	
	3-1						4	1-4	2	
	3-2						8	1-8	3	

Another example configurations are summarized in **Table 13** and **Table 14** for Case 0 and Case 1 of rank reportings, and $N_P = 2,4,6,8$. Note that in this case, a new Class B codebook for $N_P = 6$ needs to be configured.

Table 13: Class A (Codebook-Config = 1) and Class B ($N_P = 2,4,6,8$), both $RI^{(1)}$ and $RI^{(2)}$ are report, Case 0: $RI^{(1)}$ and $RI^{(2)}$ are dependent

Configuration		Class A					Class B, $K = 1$			
		#RI bits	Rank $RI^{(1)}$	Number of beams indicated by i_1	Beam types	Class A Codebook	N_P	Rank $RI^{(2)}$	#RI bits	Class B Codebook
0		2	1-2	1	-	Rel. 13 (or 14) Rank 1-2 W_1	2	1-2	1	Rel. 13 (or 14)
1			3-4	2	2 orthogonal pairs for 2D port layout; 3 orthogonal pairs for 1D port layout	Rel. 13 (or 14) Rank 3-4 W_1	4	3-4		
2			5-6	3	3 orthogonal beams	Rel. 13 (or 14) Rank 5-6 W_1	6	5-6		
3			7-8	4	4 orthogonal beams	Rel. 13 (or 14) Rank 7-8 W_1	8	7-8		

Table 14: Class A (Codebook-Config = 1) and Class B ($N_P = 2,4,6,8$), both $RI^{(1)}$ and $RI^{(2)}$ are report, Case 1: $RI^{(1)}$ and $RI^{(2)}$ are independent

Configuration		Class A					Class B, $K = 1$			
		#RI bits	Rank $RI^{(1)}$	Number of beams indicated by i_1	Beam types	Class A Codebook	N_P	Rank $RI^{(2)}$	#RI bits	Class B Codebook
0	0-0	2	1-2	1	-	Rel. 13 (or 14) Rank 1-2 W_1	2	1-2	1	Rel. 13 (or 14)
1	1-0		3-4	2	2 orthogonal pairs for 2D port layout; 3 orthogonal pairs for 1D port layout	Rel. 13 (or 14) Rank 3-4 W_1	2	1-2	1	
	1-1						4	1-4	2	
2	2-0		5-6	3	3 orthogonal beams	Rel. 13 (or 14) Rank 5-6 W_1	2	1-2	1	
	2-1						4	1-4	2	
	2-2						6	1-6	3	
3	3-0		7-8	4	4 orthogonal beams	Rel. 13 (or 14) Rank 7-8 W_1	2	1-2	1	
	3-1						4	1-4	2	
	3-2						6	1-6	3	
	3-3						8	1-8	3	

If Codebook-Config = 2,3,4, then the hybrid eMIMO-Type configurations can be formulated similarly. Example configurations are summarized in **Table 15** and **Table 16** respectively for Case 0 and Case 1 of rank reportings and $N_P = 2,4,8$.

Table 15: Class A (Codebook-Config = 2,3,4) and Class B ($N_P = 2,4,8$), both $RI^{(1)}$ and $RI^{(2)}$ are report, Case 0: $RI^{(1)}$ and $RI^{(2)}$ are dependent

Configuration		Class A					Class B, $K = 1$			
		#RI bits	Rank RI ⁽¹⁾	Number of beams indicated by i_1	Beam types	Class A Codebook	N_P	Rank RI ⁽²⁾	#RI bits	Class B Codebook
0	0-0	2	1-2	4	-	Rel. 13 (or 14) Rank 1-2 $\mathbf{W}_1$	2	1-2	1	Rel. 13 (or 14)
	0-1					4				
	0-2					8				
1	1-1		3-4	8	2 orthogonal pairs for 2D port layout; 3 orthogonal pairs for 1D port layout	Rel. 13 (or 14) Rank 3-4 $\mathbf{W}_1$	4	3-4		
	1-2					8				
2	2-2		5-6	3	3 orthogonal beams	Rel. 13 (or 14) Rank 5-6 $\mathbf{W}_1$	8	5-6		
3	3-2		7-8	4	4 orthogonal beams	Rel. 13 (or 14) Rank 7-8 $\mathbf{W}_1$	8	7-8		

Table 16: Class A (Codebook-Config = 2,3,4) and Class B ($N_P = 2,4,8$), both $RI^{(1)}$ and $RI^{(2)}$ are report, Case 1: $RI^{(1)}$ and $RI^{(2)}$ are independent

Configuration		Class A					Class B, $K = 1$			
		#RI bits	Rank RI ⁽¹⁾	Number of beams indicated by i_1	Beam types	Class A Codebook	N_P	Rank RI ⁽²⁾	#RI bits	Class B Codebook
0	0-0	2	1-2	4	-	Rel. 13 (or 14) Rank 1-2 $\mathbf{W}_1$	2	1-2	1	Rel. 13 (or 14)
	0-1						4			
	0-2						8			
1	1-0		3-4	8	2 orthogonal pairs for 2D port layout; 3 orthogonal pairs for 1D port layout	Rel. 13 (or 14) Rank 3-4 $\mathbf{W}_1$	2	1-2	1	
	1-1						4	1-4	2	
							1-2			
2	2-0		5-6	3	3 orthogonal beams	Rel. 13 (or 14) Rank 7-8 $\mathbf{W}_1$	2	1-2	1	
	2-1						4	1-4	2	
	2-2						8	1-6	3	
	3-0		7-8	4	4 orthogonal beams	Rel. 13 (or 14) Rank 7-8 $\mathbf{W}_1$	2	1-2	1	
	3-1						4	1-4	2	
	3-2						8	1-8	3	

The present disclosure covers the use of all the above configurations or sub-configurations. It also covers the use of only a subset of all the above configurations or sub-configurations. If more than one configurations or sub-configurations are used, the choice of configuration or sub-configuration is performed via higher layer signaling.

For example, a subset of hybrid configurations or sub-configurations in **Table 11**, **Table 12**, **Table 15**, and **Table 16** is used to configure one hybrid configuration to the UE. An example of such a subset is shown in **Table 17**. In this subset, $RI^{(1)} = 2$ bits corresponds to rank 1-2, rank 3-4, rank 5-6, and rank 7-8 Class A W_1 codebooks. The total number of configurations in the table is 32. At least two possible configuration schemes can be used. First, a 5-bit RRC parameter can be used to configure a UE with one of the 32 hybrid configurations. Second, only one bit RRC parameter which configures a UE for either Case 0 ($RI^{(1)}$ and $RI^{(2)}$ calculation are dependent) or Case 1 ($RI^{(1)}$ and $RI^{(2)}$ calculation are independent) is used. Since *Codebook-Config* for Class A and the number of ports N_P for Class B are already configurable via higher-layer signaling, the choice of hybrid configuration for a given combination of *Codebook-Config* for Class A and the number of ports N_P for Class B, along with the sets of possible values for $RI^{(1)}$ and $RI^{(2)}$, are fixed.

Table 17: Configurable hybrid configurations; both $RI^{(1)}$ and $RI^{(2)}$ are reported

Case	Class A: <i>Codebook-Config</i>	Class B: N_P	Hybrid Configuration	# $RI^{(1)}$ bits	# $RI^{(2)}$ bits
0: $RI^{(1)}$ and $RI^{(2)}$ calculation are <u>dependent</u>	1	2	0 (Table 11)	2	1
		4	1 (Table 11)		
		8	2 (Table 11)		
		8	3 (Table 11)		
	2, 3, or 4	2	0-0 (Table 15)	2	1
		4	1-1 (Table 15)		
		8	2-2 (Table 15)		
		8	2-3 (Table 15)		
1: $RI^{(1)}$ and $RI^{(2)}$ calculation are	1	2	0-0 (Table 12)	2	1
		4	1-1 (Table 12)		2

<u>independent</u>		8	2-2 (Table 12)		3
		8	3-2 (Table 12)		3
		2	0-0 (Table 16)		1
	2, 3, or 4	4	1-1 (Table 16)	2	2
		8	2-2 (Table 16)		3
		8	3-2 (Table 16)		3

Another example of the subset with only one hybrid configuration (instead of two) for $N_P = 8$ is shown in **Table 18**. In this subset, $RI^{(1)} = 2$ bits corresponds to rank 1-2, rank 3-4, and rank 7-8 Class A W_1 codebooks.

Table 18: Configurable hybrid configurations; both $RI^{(1)}$ and $RI^{(2)}$ are reported

Case	Class A: <i>Codebook-Config</i>	Class B: N_P	Hybrid Configuration	# $RI^{(1)}$ bits	# $RI^{(2)}$ bits
0: $RI^{(1)}$ and $RI^{(2)}$ calculation are <u>dependent</u>	1	2	0 (Table 11)	2	1
		4	1 (Table 11)		
		8	3 (Table 11)		
	2, 3, or 4	2	0-0 (Table 15)	2	1
		4	1-1 (Table 15)		
		8	2-3 (Table 15)		
1: $RI^{(1)}$ and $RI^{(2)}$ calculation are <u>independent</u>	1	2	0-0 (Table 12)	2	1
		4	1-1 (Table 12)		2
		8	3-2 (Table 12)		3
	2, 3, or 4	2	0-0 (Table 16)	2	1
		4	1-1 (Table 16)		2
		8	3-2 (Table 16)		3

A variation of the above example where only independent $RI^{(1)}$ and $RI^{(2)}$ calculation is supported can be described as follows. Two examples are given in **Table 19** and **Table 20** below where the number of bits for $RI^{(1)}$ is 2 and 1, respectively. In this case, an additional RRC parameter is not needed. In **Table 19**, $RI^{(1)} = 2$ bits corresponds to rank 1-2, rank 3-4, and rank 7-8 Class A W_1 codebooks. In **Table 20**, $RI^{(1)} = 1$ bit corresponds to rank 1-2 and rank 7-8 Class A W_1 codebooks.

Table 19: Configurable hybrid configurations; both $RI^{(1)}$ (2 bits) and $RI^{(2)}$ are reported

Class A: <i>Codebook-Config</i>	Class B: N_P	Hybrid Configuration	# $RI^{(1)}$ bits	# $RI^{(2)}$ bits
1	2	0-0 (Table 12)	2	1
	4	1-1 (Table 12)		2
	8	3-2 (Table 12)		3
2, 3, or 4	2	0-0 (Table 16)	2	1
	4	1-1 (Table 16)		2
	8	3-2 (Table 16)		3

Table 20: Configurable hybrid configurations; both $RI^{(1)}$ (1 bit) and $RI^{(2)}$ are reported

Class A: <i>Codebook-Config</i>	Class B: N_P	Hybrid Configuration	# $RI^{(1)}$ bits	# $RI^{(2)}$ bits
1	2	0-0 (Table 12)	1	1
	4	3-1 (Table 12)		2
	8	3-2 (Table 12)		3
2, 3, or 4	2	0-0 (Table 16)	1	1
	4	3-1 (Table 16)		2
	8	3-2 (Table 16)		3

A few other examples of $RI^{(1)}$ and $RI^{(2)}$ reportings are shown in **Table 21**, **Table 22**, **Table 23**, and **Table 24**, where

- the number of bits for $RI^{(1)} = 0$ for $N_p = 2$ Class B ports (i.e., $RI^{(1)}$ is not reported), and
- the number of bits for $RI^{(1)} \neq 0$ for $N_p = 4$ and 8 Class B ports.

In the example in Table 21, $RI^{(1)} = \log_2(N_p/2)$ bits and $RI^{(2)} = \log_2(N_p)$ bits. The reported $RI^{(1)}$ indicates a Class A codebook rank as follows.

- 0-bit $RI^{(1)}$ indicates rank 1 for $N_p = 2$ (i.e., $RI^{(1)}$ is not reported).
- 1-bit $RI^{(1)}$ indicates rank 1 or 3 for $N_p = 4$.
- 2-bit $RI^{(1)}$ indicates rank 1, 3, 5, or 7 for $N_p = 8$.

The reported $RI^{(2)}$ indicates a Class B codebook rank 1, 2,..., or N_p .

In the example in Table 22, $RI^{(1)} = 0$ or 1 bit and $RI^{(2)} = \log_2(N_p)$ bits. The reported $RI^{(1)}$ indicates a Class A codebook rank as follows.

- 0-bit $RI^{(1)}$ indicates rank 1 for $N_p = 2$ (i.e., $RI^{(1)}$ is not reported).
- 1-bit $RI^{(1)}$ indicates rank 1 or 3 for $N_p = 4$.
- 1-bit $RI^{(1)}$ indicates rank either (Alt 0) 1 or 3, or (Alt 1) 1 or 7 for $N_p = 8$.

The reported $RI^{(2)}$ indicates a Class B codebook rank 1, 2,..., or N_p .

In the example in Table 23, $RI^{(1)} = \log_2(N_p/2)$ bits and $RI^{(2)} = 1$ bit. The reported $RI^{(1)}$ indicates a Class A codebook rank as follows.

- 0-bit $RI^{(1)}$ indicates rank 1 for $N_p = 2$ (i.e., $RI^{(1)}$ is not reported).
- 1-bit $RI^{(1)}$ indicates rank 1 or 3 for $N_p = 4$.
- 2-bit $RI^{(1)}$ indicates rank 1, 3, 5, or 7 for $N_p = 8$.

The reported 1-bit $RI^{(2)}$ indicates a Class B codebook rank which depends on the reported $RI^{(1)}$. For example,

- 1-bit $RI^{(2)}$ indicates rank 1 or 2 for $N_p = 2$.
- For $N_p = 4$, 1-bit $RI^{(2)}$ indicates
 - rank 1 or 2 if $RI^{(1)}$ indicates rank 1.
 - rank 3 or 4 if $RI^{(1)}$ indicates rank 3.
- For $N_p = 8$, 1-bit $RI^{(2)}$ indicates
 - rank 1 or 2 if $RI^{(1)}$ indicates rank 1.
 - rank 3 or 4 if $RI^{(1)}$ indicates rank 3.
 - rank 5 or 6 if $RI^{(1)}$ indicates rank 5.
 - rank 7 or 8 if $RI^{(1)}$ indicates rank 7.

In the example in Table 19Table 24, $RI^{(1)} = \log_2(N_p/2)$ bits and $RI^{(2)} = 1$ or 3 bits. The reported $RI^{(1)}$ indicates a Class A codebook rank as follows.

- 0-bit $RI^{(1)}$ indicates rank 1 for $N_p = 2$ (i.e., $RI^{(1)}$ is not reported).
- 1-bit $RI^{(1)}$ indicates rank 1 or 3 for $N_p = 4$.
- 2-bit $RI^{(1)}$ indicates rank 1, 3, 5, or 7 for $N_p = 8$.

The reported 1-bit $RI^{(2)}$ indicates a Class B codebook rank which depends on the reported $RI^{(1)}$. For example,

- 1-bit $RI^{(2)}$ indicates rank 1 or 2 for $N_p = 2$.
- For $N_p = 4$, 1-bit $RI^{(2)}$ indicates
 - rank 1 or 2 if $RI^{(1)}$ indicates rank 1.
 - rank 3 or 4 if $RI^{(1)}$ indicates rank 3.
- For $N_p = 8$, 3-bit $RI^{(2)}$ indicates rank 1 – 8.

Table 21: Configurable hybrid configurations; $RI^{(1)} = \log_2(N_p/2)$ bit and $RI^{(2)} = \log_2(N_p)$ bit

Class A: Codebook-Config	Class B: N_p	# $RI^{(1)}$ bits	Class A codebook rank	# $RI^{(2)}$ bits
1, 2, 3 or 4	2	0	1	1
	4	1	1,3	2

	8	2	1,3,5,7	3
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Table 22: Configurable hybrid configurations; both $RI^{(1)} = 0$ or 1 bit and $RI^{(2)} = \log_2(N_P)$ bit

Class A: <i>Codebook-Config</i>	Class B: N_P	# $RI^{(1)}$ bits	<u>Alt 0: Class A codebook rank</u>	# $RI^{(2)}$ bits
1, 2, 3 or 4	2	0	1	1
	4	1	1,3	2
	8	1	1,3	3

Class A: <i>Codebook-Config</i>	Class B: N_P	# $RI^{(1)}$ bits	<u>Alt 1: Class A codebook rank</u>	# $RI^{(2)}$ bits
1, 2, 3 or 4	2	0	1	1
	4	1	1,3	2
	8	1	1,7	3

Table 23: Configurable hybrid configurations; $RI^{(1)} = \log_2(N_P/2)$ bit and $RI^{(2)} = 1$ bit

Class A: <i>Codebook-Config</i>	Class B: N_P	# $RI^{(1)}$ bits	Class A codebook rank	# $RI^{(2)}$ bits
1, 2, 3 or 4	2	0	1	1
	4	1	1,3	1
	8	2	1,3,5,7	1

Table 24: Configurable hybrid configurations; $RI^{(1)} = \log_2(N_P/2)$ bit and $RI^{(2)} = 1$ or 3 bit

Class A: <i>Codebook-Config</i>	Class B: N_P	# $RI^{(1)}$ bits	<u>Alt 0: Class A codebook rank</u>	# $RI^{(2)}$ bits
1, 2, 3 or 4	2	0	1	1
	4	1	1,3	1
	8	2	1,3,5,7	3

In some embodiments, a UE is configured with hybrid configuration 0-c in Table 3 with

- Reporting content
 - For the 1st eMIMO-Type (CLASS A), $i1^{(1)}$ and x-bit $RI^{(1)}$ are reported, while $CQI^{(1)}$ and $i2^{(1)}$ are not reported
 - If UE supports up to 2 layers, x=0
 - If UE supports up to 4 layer, x=1 where $RI^{(1)}=\{1, 3\}$
 - If UE supports up to 8 layer, x=2 where $RI^{(1)}=\{1, 3, 5, 7\}$
 - For the 2nd eMIMO-Type (CLASS B K=1), $CQI^{(2)}$, $PMI^{(2)}$, $RI^{(2)}$ are reported
 - Note: Superscript (y) represents the y-th eMIMO-Type, where y=1,2.
- No inter-dependence between CSI calculations across two eMIMO-Types.

In some embodiments, a UE is configured with hybrid configuration 0-c in Table 3 with rank indication according to one of Table 25 to Table 29, where the tables show the fields and the corresponding bit width for the rank indication feedback for PDSCH transmissions associated with transmission mode 3, transmission mode 4, transmission mode 8 configured with PMI/RI reporting, transmission mode 9 configured with PMI/RI reporting with 2/4/8 antenna ports, transmission mode 10 configured with PMI/RI reporting with 2/4/8 antenna ports, and transmission mode 9/10 configured with PMI/RI reporting with 2/4/8 antenna ports and higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to 'CLASS B' with K=1, transmission mode 9/10 configured with PMI/RI reporting with 8/12/16 antenna ports and higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to 'CLASS A', and transmission mode 9/10 configured without PMI reporting and higher layer parameter *eMIMO-Type*, and *eMIMO-Type* is set to 'CLASS B' with K=1 with 2/4/8 antenna ports.

Table 25: Fields for rank indication feedback

Field	Bit width					
	2 antenna ports	4 antenna ports		8/12/16/20/24/28/32 antenna ports		
		Max 1 or 2 layers	Max 4 layers	Max 1 or 2 layers	Max 4 layers	Max 8 layers
Rank indication	1	1	2	1	2	3
Rank	{1,2}	{1,2}	{1,2,3,4}	{1,2}	{1,2,3,4}	{1,2,3,4,5,6,7,8}

Table 26: Fields for rank indication feedback

Field	Bit width					
	2 antenna ports	4 antenna ports		8/12/16/20/24/28/32 antenna ports		
		Max 1 or 2 layers	Max 4 layers	Max 1 or 2 layers	Max 4 layers	Max 8 layers
Rank indication	0	0	1	0	1	2
Rank	{1}	{1}	{1,3}	{1}	{1,3}	{1,3,5,7}

Table 27: Fields for rank indication feedback

Field	Bit width					
	2 antenna ports	4 antenna ports		8/12/16/20/24/28/32 antenna ports		
		Max 1 or 2 layers	Max 4 layers	Max 1 or 2 layers	Max 4 layers	Max 8 layers
Rank indication	0	0	1	0	1	1
Rank	{1}	{1}	{1,3}	{1}	{1,3}	{1,3}

Table 28: Fields for rank indication feedback

Field	Bit width					
	2 antenna ports	4 antenna ports		8/12/16/20/24/28/32 antenna ports		
		Max 1 or 2 layers	Max 4 layers	Max 1 or 2 layers	Max 4 layers	Max 8 layers
Rank indication	0	0	1	0	1	1
Rank	{1}	{1}	{1,3}	{1}	{1,3}	{1,7}

Table 29: Fields for rank indication feedback

Field	Bit width					
	2 antenna ports	4 antenna ports		8/12/16/20/24/28/32 antenna ports		
		Max 1 or 2 layers	Max 4 layers	Max 1 or 2 layers	Max 4 layers	Max 8 layers
Rank indication	0	0	2	0	2	2
Rank	{1}	{1}	{1,2,3,4}	{1}	{1,2,3,4}	{1,3,5,7}

Embodiment on Configuration 2 (Class B, $K > 1$ + Class B, $K = 1$)

In some embodiments, a UE is configured with a hybrid CSI reporting in which the 1st eMIMO-Type is Class B, $K_1 > 1$ and the 2nd eMIMO-Type is Class B, $K_2 = 1$. The CSI reported in the first Class B eMIMO-Type is either

- Alternative 2-a (Table 3): CRI and associated PMI (and RI⁽¹⁾) or
- Alternative 2-b (Table 3): PMI (and RI(1), if applicable) for each CSI-RS resource,

and that reported in the 2nd Class B eMIMO-Type includes RI⁽²⁾, CQI, and PMI.

In one example of alternative 2-b, the 1st eMIMO-Type is associated with $K_1 = 2$ CSI-RS resources. An exemplary use case is to implement the so-called partial-port (non-precoded) CSI-RS where the $K_1 = 2$ CSI-RS resources are used to represent the two dimensions of two-dimensional antenna port layouts (Figure 8 and **Figure 9**). Note that for the special case of one-dimensional (1D) antenna port layouts, only one dimension is present. Therefore, the 1st eMIMO-Type is associated with $K_1 = 1$ CSI-RS resource. With $K_1 = 2$ CSI-RS resources, the first of the two CSI-RS resources can be associated with the 1st antenna port dimension and the second of the two CSI-RS resources can be associated with the 2nd antenna port dimension. For instance, the first of the two CSI-RS resources can be associated with one of the rows (e.g. row 1) of antenna ports and the second of the two CSI-RS resources can be associated with one of the columns (e.g. column 1) of antenna ports.

The 2nd CSI-RS resource is BF using the two reported PMIs in the 1st eMIMO-Type.

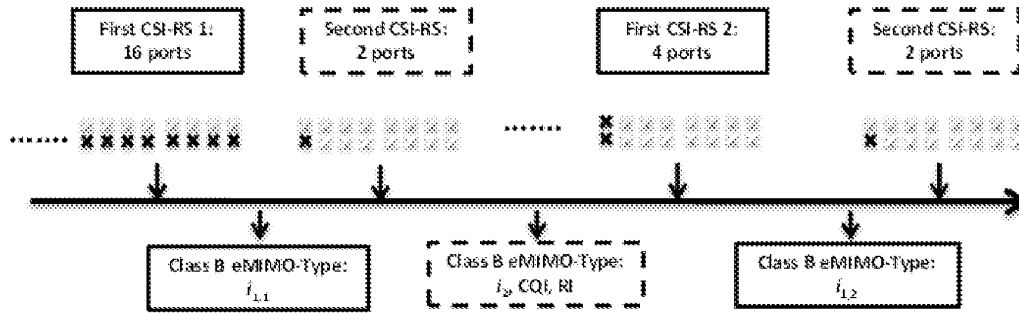


Figure 14: Illustration of hybrid CSI reporting

An example of this scheme is shown in Figure 14. As shown,

- The first CSI-RS corresponds to “Class B $K_1 = 2$ eMIMO-Type” in which NP CSI-RS is transmitted from a subset (one row or one column) of antenna ports. There are two CSI-RS resources: first CSI-RS 1 is for the row and first CSI-RS 2 is for the column.
- The second CSI-RS corresponds to “Class B $K_2 = 1$ eMIMO-Type” in which BF CSI-RS is transmitted from two beam-formed ports which are beam-formed using the beams associated with the first PMI.
- The UE derives
 - 1st CSI: $i_{1,1}$ of the first PMI pair $(i_{1,1}, i_{1,2})$ using the NP CSI-RS corresponding to the row and a 16 port codebook, and $i_{1,2}$ of the first PMI pair $(i_{1,1}, i_{1,2})$ using the NP CSI-RS corresponding to the column and a 4 port codebook; and
 - 2nd CSI: the second PMI i_2 , CQI and RI using BF CSI-RS and a 2 port codebook.

Embodiments on codebooks for Class B $K_1 = 2$ (alternative 2-b)

Table 30: Codebook alternatives for 1st Class B eMIMO-Type in alternative 2-b (Table 3)

Codebook Type	1st dimension codebook	2nd dimension codebook
0	Co-pol	Co-pol
1	Co-pol	Dual-pol
2	Dual-pol	Co-pol
3	Dual-pol	Dual-pol

Type	1 st dimension	2 nd dimension
0		
1		
2		
3		

Figure 15: Illustration of codebook types for Class B $K_1 = 2$ eMIMO-Type

In some embodiments, the codebook for the 1st Class B $K_1 = 2$ eMIMO-Type is one of the four types as tabulated in Table 30 and shown in Figure 15, where there are two types of codebooks for the two dimensions.

- The co-pol codebook is used for PMI calculation if the CSI-RS is transmitted from the antenna ports with one polarization only (e.g. +45 or -45).
- The dual-pol codebook is used for PMI calculation if the CSI-RS is transmitted from the antenna ports with both polarizations. Examples of dual-pol codebooks include Rel. 10 8-Tx, Rel. 12 4-Tx, and Rel. 13 Class A codebooks.

An example of the 1st eMIMO-Type codebook for different antenna port layouts shown in Figure 8 and Figure 9 is shown in Table 31. In this table, codebook types 1 and 2 (Table 30) is assumed, i.e. the co-pol codebook is configured in one of the two dimensions, and the other dimension is configured with a dual-pol (legacy) codebook. The other combinations of the 1st eMIMO-Type codebook can be constructed similarly.

Table 31: 1st eMIMO-Type codebook for 1st and 2nd dimensions

Number of CSI-RS antenna ports, P	(N_1, N_2)	1st eMIMO-Type Codebook			
		(N_1, P_1)	1st dimension	(N_2, P_2)	2nd dimension

8	(2,2)	(2,2)	Rel. 12 4-Tx W1	(2,1)	Co-pol 2-Tx
12	(2,3)	(2,2)	Rel. 12 4-Tx W1	(3,1)	Co-pol 3-Tx
	(3,2)	(3,1)	Co-pol 3-Tx	(2,2)	Rel. 12 4-Tx W1
16	(2,4)	(2,1)	Co-pol 2-Tx	(4,2)	Rel. 10 8-Tx W1
	(4,2)	(4,2)	Rel. 10 8-Tx W1	(2,1)	Co-pol 2-Tx
	(8,1)	(8,1)	Co-pol 8-Tx	-	-
20	(1,10)	-	-	(10,1)	Co-pol 10-Tx
	(2,5)	(2,2)	Rel. 12 4-Tx W1	(5,1)	Co-pol 5-Tx
	(5,2)	(5,1)	Co-pol 5-Tx	(2,2)	Rel. 12 4-Tx W1
	(10,1)	(10,1)	Co-pol 10-Tx	-	-
24	(1,12)	-	-	(12,1)	Co-pol 12-Tx
	(2,6)	(2,2)	Rel. 12 4-Tx W1	(6,1)	Co-pol 6-Tx
	(3,4)	(3,1)	Co-pol 3-Tx	(4,2)	Rel. 10 8-Tx W1
	(4,3)	(4,2)	Rel. 10 8-Tx W1	(3,1)	Co-pol 3-Tx
	(6,2)	(6,1)	Co-pol 6-Tx	(2,2)	Rel. 12 4-Tx W1
	(12,1)	(12,1)	Co-pol 12-Tx	-	-
28	(1,14)	-	-	(14,1)	Co-pol 14-Tx
	(2,7)	(2,2)	Rel. 12 4-Tx W1	(7,1)	Co-pol 7-Tx
	(7,2)	(7,1)	Co-pol 7-Tx	(2,2)	Rel. 12 4-Tx W1
	(14,1)	(14,1)	Co-pol 14-Tx	-	-
32	(1,16)	-	-	(16,1)	Co-pol 16-Tx
	(2,8)	(2,1)	Co-pol 2-Tx	(8,2)	Rel. 13 16-Tx W1
	(4,4)	(4,2)	Rel. 10 8-Tx W1	(4,1)	Co-pol 4-Tx
	(8,2)	(8,2)	Rel. 13 16-Tx W1	(2,1)	Co-pol 2-Tx
	(16,1)	(16,1)	Co-pol 16-Tx	-	-

A few examples of the co-pol codebook are as follows.

In [example 1](#), the co-pol codebook is rank 1 and the corresponding PMI indicates a single beam. An example of such a codebook is shown in **Table 32**, where the dimension $d = 1, 2$, and

$$u_{m_d} = \begin{bmatrix} 1 & e^{j\frac{2\pi m_d}{O_d N_d}} & \dots & e^{j\frac{2\pi m_d (N_d - 1)}{O_d N_d}} \end{bmatrix}^T.$$

Table 32: W_1 Co-pol Codebook for 1-layer CSI reporting using antenna ports 15 to 14+ P

m_d	Precoder
$0, 1, \dots, O_d N_d - 1$	$W_{m_d}^{(1)} = \frac{u_{m_d}}{\sqrt{N_d}}$

The overall rank of the 1st eMIMO-Type depends on the co-pol codebook type (**Table 30**):

- For Codebook Type = 0, the overall rank is 1. So, $RI^{(1)}$ is not reported.
- For Codebook Type = 1, 2, the overall rank can be > 1 if rank > 1 is reported from the dimension associated with the dual-pol codebook.

In [example 2](#), the co-pol codebook is rank > 1 and the corresponding PMI indicates orthogonal beams. An example of rank-2 co-pol codebook is shown in **Table 33**, where the dimension $d = 1, 2$.

Table 33: W_1 Co-pol Codebook for 2-layer CSI reporting using antenna ports 15 to 14+ P

$N_1, N_2 > 1$	
m_d	Precoder
$0, 1, \dots, O_d N_d - 1$	$W_{m_d}^{(2)} = \frac{1}{\sqrt{2N_d}} \begin{bmatrix} u_{m_d} & u_{m_d+O_d} \end{bmatrix}$

$N_1 \text{ or } N_2 = 1$	
m_d	Precoder
$0, 1, \dots, O_d N_d - 1$	$W_{m_d}^{(2)} = \frac{1}{\sqrt{2N_d}} \begin{bmatrix} u_{m_d} & u_{m_d+O_d} \end{bmatrix}$
$O_d N_d, O_d N_d + 1, \dots, 2O_d N_d - 1$	$W_{m_d}^{(2)} = \frac{1}{\sqrt{2N_d}} \begin{bmatrix} u_{m_d} & u_{m_d+2O_d} \end{bmatrix}$
$2O_d N_d, O_d N_d + 1, \dots, 3O_d N_d - 1$	$W_{m_d}^{(2)} = \frac{1}{\sqrt{2N_d}} \begin{bmatrix} u_{m_d} & u_{m_d+3O_d} \end{bmatrix}$

In [example 3](#), the co-pol codebook is rank 1 and the corresponding PMI indicates a group of beams. An example of such a codebook is shown in **Table 34** where the dimension $d = 1, 2$, and the type of beam group is indicated by the higher layer RRC parameter *Codebook-Config*.

Table 34: W_1 Co-pol Codebook for 1-layer CSI reporting using antenna ports 15 to 14+P

Value of <i>Codebook-Config</i>	m_d	Precoder
1	$0, 1, \dots, O_d N_d - 1$	$W_{m_d}^{(1)} = \frac{u_{m_d}}{\sqrt{N_d}}$
2	$0, 1, \dots, \frac{O_d N_d}{2} - 1$	$W_{m_d}^{(1)} = \frac{1}{\sqrt{N_d}} \begin{bmatrix} u_{2m_d} & u_{2m_d+1} \end{bmatrix}$
3	$0, 1, \dots, \frac{O_d N_d}{2} - 1$	$W_{m_d}^{(1)} = \frac{1}{\sqrt{N_d}} \begin{bmatrix} u_{2m_d} & u_{2m_d+1} & u_{2m_d+2} & u_{2m_d+3} \end{bmatrix}$, if $N_d \geq N_e$ $e = \{1, 2\} - d$ $W_{m_d}^{(1)} = \frac{1}{\sqrt{N_d}} \begin{bmatrix} u_{2m_d} & u_{2m_d+1} \end{bmatrix}$, if $N_d < N_e$ $e = \{1, 2\} - d$
4	$0, 1, \dots, \frac{O_d N_d}{2} - 1$	$W_{m_d}^{(1)} = \frac{1}{\sqrt{N_d}} \begin{bmatrix} u_{2m_d} & u_{2m_d+1} & u_{2m_d+2} & u_{2m_d+3} \end{bmatrix}$, if $N_d \geq N_e$ $e = \{1, 2\} - d$ $W_{m_d}^{(1)} = \frac{u_{2m_d}}{\sqrt{N_d}}$, if $N_d < N_e$ $e = \{1, 2\} - d$

In [example 4](#), the co-pol codebook is rank > 1 and the corresponding PMI indicates orthogonal beam groups. An example of such a rank-2 codebook is shown in **Table 36**, where the dimension $d = 1, 2$, and the type of beam group is indicated by the higher layer RRC parameter *Codebook-Config*. An example of values for parameters (s_1, s_2) and (p_1, p_2) in the table is shown in **Table 35**.

Table 35: example parameter values

<i>Codebook-Config</i>	(s_1, s_2)	(p_1, p_2)
1	(1,1)	(-, -)

2	$\left(\frac{o_1}{2}, \frac{o_2}{2}\right)$	$\left(\frac{o_1}{4}, \frac{o_2}{4}\right)$
3	$\left(o_1, \frac{o_2}{2}\right)$	$\left(\frac{o_1}{4}, \frac{o_2}{4}\right)$
4	$\left(o_1, \frac{o_2}{4}\right)$	$\left(\frac{o_1}{4}, -\right)$

Table 36: W_1 Co-pol Codebook for 2-layer CSI reporting using antenna ports 15 to 14+P

$N_1, N_2 > 1$		
Value of Codebook-Config	m_d	Precoder
1	$0, 1, \dots, O_d N_d - 1$	$W_{m_d}^{(2)} = \frac{1}{\sqrt{2N_d}} \begin{bmatrix} u_{m_d} & u_{m_d+O_d} \end{bmatrix}$
2	$0, 1, \dots, \frac{O_d N_d}{s_d} - 1$	$W_{m_d}^{(2)} = \frac{1}{\sqrt{2N_d}} \begin{bmatrix} u_{s_d m_d} & u_{s_d m_d + p_d} & u_{s_d m_d + O_d} & u_{s_d m_d + O_d + p_d} \end{bmatrix}$
3	$0, 1, \dots, \frac{O_d N_d}{s_d} - 1$	$W_{m_d}^{(2)} = \frac{1}{\sqrt{2N_d}} \begin{bmatrix} u_{s_d m_d} & u_{s_d m_d + p_d} & u_{s_d m_d + 2p_d} & u_{s_d m_d + 3p_d} & u_{s_d m_d + O_d} & u_{s_d m_d + O_d + p_d} & u_{s_d m_d + O_d + 2p_d} & u_{s_d m_d + O_d + 3p_d} \end{bmatrix}$, if $N_d \geq N_e$ $e = \{1, 2\} - d$ $W_{m_d}^{(1)} = \frac{1}{\sqrt{N_d}} \begin{bmatrix} u_{s_d m_d} & u_{s_d m_d + 1} \end{bmatrix}$, if $N_d < N_e$ $e = \{1, 2\} - d$
4	$0, 1, \dots, \frac{O_d N_d}{s_d} - 1$	$W_{m_d}^{(2)} = \frac{1}{\sqrt{2N_d}} \begin{bmatrix} u_{s_d m_d} & u_{s_d m_d + p_d} & u_{s_d m_d + 2p_d} & u_{s_d m_d + 3p_d} & u_{s_d m_d + O_d} & u_{s_d m_d + O_d + p_d} & u_{s_d m_d + O_d + 2p_d} & u_{s_d m_d + O_d + 3p_d} \end{bmatrix}$, if $N_d \geq N_e$ $e = \{1, 2\} - d$ $W_{m_d}^{(1)} = \frac{u_{s_d m_d}}{\sqrt{N_d}}$, if $N_d < N_e$ $e = \{1, 2\} - d$

N_1 or $N_2 = 1$		
Value of Codebook k -Config	m_d	Precoder
1	$0, 1, \dots, O_d N_d - 1$	$W_{m_d}^{(2)} = \frac{1}{\sqrt{2N_d}} \begin{bmatrix} u_{m_d} & u_{m_d+O_d} \end{bmatrix}$
	$O_d N_d, O_d N_d + 1, \dots, 2O_d N_d - 1$	$W_{m_d}^{(2)} = \frac{1}{\sqrt{2N_d}} \begin{bmatrix} u_{m_d} & u_{m_d+2O_d} \end{bmatrix}$
	$2O_d N_d, O_d N_d + 1, \dots, 3O_d N_d - 1$	$W_{m_d}^{(2)} = \frac{1}{\sqrt{2N_d}} \begin{bmatrix} u_{m_d} & u_{m_d+3O_d} \end{bmatrix}$
4	$0, 1, \dots, \frac{O_d N_d}{s_d} - 1$	$W_{m_d}^{(2)} = \frac{1}{\sqrt{2N_d}} \begin{bmatrix} u_{s_d m_d} & u_{s_d m_d + p_d} & u_{s_d m_d + 2p_d} & u_{s_d m_d + 3p_d} & u_{s_d m_d + O_d} & u_{s_d m_d + O_d + p_d} & u_{s_d m_d + O_d + 2p_d} & u_{s_d m_d + O_d + 3p_d} \end{bmatrix}$, if $N_d \geq N_e$ $e = \{1, 2\} - d$ $W_{m_d}^{(1)} = \frac{u_{s_d m_d}}{\sqrt{N_d}}$, if $N_d < N_e$ $e = \{1, 2\} - d$
	$\frac{O_d N_d}{s_d}, \frac{O_d N_d}{s_d} + 1, \dots, \frac{2O_d N_d}{s_d} - 1$	$W_{m_d}^{(2)} = \frac{1}{\sqrt{2N_d}} \begin{bmatrix} u_{s_d m_d} & u_{s_d m_d + p_d} & u_{s_d m_d + 2p_d} & u_{s_d m_d + 3p_d} & u_{s_d m_d + 2O_d} & u_{s_d m_d + 2O_d + p_d} & u_{s_d m_d + 2O_d + 2p_d} & u_{s_d m_d + 2O_d + 3p_d} \end{bmatrix}$, if $N_d \geq N_e$ $e = \{1, 2\} - d$ $W_{m_d}^{(1)} = \frac{u_{s_d m_d}}{\sqrt{N_d}}$, if $N_d < N_e$ $e = \{1, 2\} - d$
	$\frac{2O_d N_d}{s_d}, \frac{2O_d N_d}{s_d} + 1, \dots, \frac{3O_d N_d}{s_d} - 1$	$W_{m_d}^{(2)} = \frac{1}{\sqrt{2N_d}} \begin{bmatrix} u_{s_d m_d} & u_{s_d m_d + p_d} & u_{s_d m_d + 2p_d} & u_{s_d m_d + 3p_d} & u_{s_d m_d + 3O_d} & u_{s_d m_d + 3O_d + p_d} & u_{s_d m_d + 3O_d + 2p_d} & u_{s_d m_d + 3O_d + 3p_d} \end{bmatrix}$, if $N_d \geq N_e$ $e = \{1, 2\} - d$ $W_{m_d}^{(1)} = \frac{u_{s_d m_d}}{\sqrt{N_d}}$, if $N_d < N_e$ $e = \{1, 2\} - d$

Embodiments on RI reporting alternatives for Class B $K_1 = 2$ (alternative 2-b)

In some embodiments, in the case of 1st Class B eMIMO-Type with $K_1 = 2$ CSI-RS resources, two RIs can be reported in two CSI reports associated with the two CSI-RS resources. Let us denote the two RIs as $RI^{(1,1)}$ and $RI^{(1,2)}$. We have the following alternatives:

- 2-b-a: $RI^{(1,1)}$ and $RI^{(1,2)}$ are not reported. There are two sub-alternatives:
 - $RI^{(1,1)}$ and $RI^{(1,2)}$ are fixed, for example $RI^{(1,1)} = RI^{(1,2)} = 1$ or 8, or $RI^{(1,1)} = 1$, $RI^{(1,2)} = 8$, or $RI^{(1,1)} = 8$, $RI^{(1,2)} = 1$.
 - $RI^{(1,1)}$ and $RI^{(1,2)}$ are configured (via RRC signaling).
- 2-b-b: Only $RI^{(1,1)}$ is reported, where the reported $RI^{(1,1)}$ can either be
 - restricted*, for example to rank $\{1, 2\}$ for co-pol and $\{1, 3\}$ for dual-pol (1-bit $RI^{(1,1)}$), or $\{1, 2, 3, 4\}$ for co-pol and $\{1, 3, 5, 7\}$ for dual-pol (2-bit $RI^{(1,1)}$), or
 - unrestricted*, for example to rank 1-8 (3-bit $RI^{(1,1)}$).

There are two sub-alternatives for $RI^{(1,2)}$:

- $RI^{(1,2)}$ is fixed, for example, $RI^{(1,2)} = 1$ or 8.
- $RI^{(1,2)}$ is configured (via RRC signaling).
- 2-b-c: Only $RI^{(1,2)}$ is reported, where the reported $RI^{(1,2)}$ can either be
 - restricted*, for example to rank $\{1, 2\}$ for co-pol and $\{1, 3\}$ for dual-pol (1-bit $RI^{(1,2)}$), or $\{1, 2, 3, 4\}$ for co-pol and $\{1, 3, 5, 7\}$ for dual-pol (2-bit $RI^{(1,2)}$), or
 - unrestricted*, for example to rank 1-8 (3-bit $RI^{(1,2)}$).

There are two sub-alternatives for $RI^{(1,1)}$:

- $RI^{(1,1)}$ is fixed, for example, $RI^{(1,1)} = 1$ or 8.
- $RI^{(1,1)}$ is configured (via RRC signaling).
- 2-b-d: Both $RI^{(1,1)}$ and $RI^{(1,2)}$ are reported, where one or both of them are restricted or unrestricted. Two examples of rank configurations in this case are shown in **Table 37** and **Table 38**. Note that the maximum rank depends on the antenna port layouts (i.e., N_1, N_2 values) and the type of codebook (co-pol or dual-pol). In general, the maximum rank is N_d for co-pol and $2N_d$ for dual-pol where $d = 1, 2$.

Table 37: Example rank combinations for $(N_1, N_2) = (8, 2)$

Rank configuration	RI ^(1,1)					RI ^(1,2)			
	Type	Co-pol	Dual-pol	#bits	Type	Co-pol	#bits	Dual-pol	#bits
0	Restricted	{1,2}	{1,3}	1	Restricted	{1,2}	1	{1,3}	1
1		{1,2,3,4}	{1,3,5,7}	2					
2	Restricted	{1,2}	{1,3}	1	Unrestricted	{1,2}	1	{1,2,3,4}	2
3		{1,2,3,4}	{1,3,5,7}	2					
4	Unrestricted	{1,2,...,8}	{1,2,...,8}	3	Restricted	{1,2}	1	{1,3}	1
5	Unrestricted	{1,2,...,8}	{1,2,...,8}	3	Unrestricted	{1,2}	1	{1,2,3,4}	2

Table 38: Example rank combinations $(N_1, N_2) = (8, 8)$

Rank configuration	$RI^{(1,1)}$				$RI^{(1,2)}$			
	Type	Co-pol	Dual-pol	#bits	Type	Co-pol	Dual-pol	#bits
0	Restricted	{1,2}	{1,3}	1	Restricted	{1,2}	{1,3}	1
1		{1,2,3,4}	{1,3,5,7}	2		{1,2}	{1,3}	1
2		{1,2}	{1,3}	1		{1,2,3,4}	{1,3,5,7}	2
3		{1,2,3,4}	{1,3,5,7}	2		{1,2,3,4}	{1,3,5,7}	2
4	Restricted	{1,2}	{1,3}	1	Unrestricted	{1,2,...,8}	{1,2,...,8}	3
5		{1,2,3,4}	{1,3,5,7}	2				
6	Unrestricted	{1,2,...,8}	{1,2,...,8}	3	Restricted	{1,2}	{1,3}	1
7						{1,2,3,4}	{1,3,5,7}	2
8	Unrestricted	{1,2,...,8}	{1,2,...,8}	3	Unrestricted	{1,2,...,8}	{1,2,...,8}	3

Note that for 1D antenna port layouts, only alternatives 2-b-a and 2-b-b are applicable (assuming antenna ports are in the 1st dimension). The overall rank of the 1st eMIMO-Type $RI^{(1)}$ depends on the reported $RI^{(1,1)}$ and $RI^{(1,2)}$. For example, $1 \leq RI^{(1)} \leq \max(RI^{(1,1)}, RI^{(1,2)})$. Once $RI^{(1)}$ is determined from $RI^{(1,1)}$ and $RI^{(1,2)}$, all embodiments mentioned earlier in the invention on dependent and independent reportings of $RI^{(1)}$ and $RI^{(2)}$ in Class A + Class B $K = 1$ eMIMO-Types are applicable.

The present disclosure covers the use of all the above configurations or sub-configurations. It also covers the use of only a subset of all the above configurations or sub-configurations. If more than one configurations or sub-configurations are used, the choice of configuration or sub-configuration is performed via higher layer signaling.

For example, a subset of rank configurations is used to configure one hybrid configuration to the UE. An example of such a subset is shown in **Table 39**. As example use case for this is when the first dimension is co-polarized and the second dimension is dual-polarized. The number of configurations in the table is 2, so 1-bit RRC signaling is required to configure one of the two rank configurations.

Table 39: Configurable rank configurations

Rank configuration	$RI^{(1,1)}$			$RI^{(1,2)}$		
	Type	Co-pol	#bits	Type	Dual-pol	#bits
0	Restricted	{1,2}	1	Restricted	{1,3}	1
1		{1,2}	1		{1,3,5,7}	2

A variation of the above example where only one rank configuration is supported can be described as follows. Two examples are given in **Table 40** and **Table 41** below where the number of bits for $RI^{(1,2)}$ is 1 and 2, respectively. In this case, an additional RRC parameter is not needed.

Table 40: Configurable rank configurations; $RI^{(1,2)} = 1$

$RI^{(1,1)}$			$RI^{(1,2)}$		
Type	Co-pol	#bits	Type	Dual-pol	#bits
Restricted	{1,2}	1	Restricted	{1,3}	1

Table 41: Configurable rank configurations; $RI^{(1,2)} = 2$

$RI^{(1,1)}$			$RI^{(1,2)}$		
Type	Co-pol	#bits	Type	Dual-pol	#bits
Restricted	{1,2}	1	Restricted	{1,3,5,7}	2

Embodiments on RI reporting alternatives for Class B $K_1 > 1$ (alternative 2-b)

In some embodiments, in the case of 1st Class B eMIMO-Type with $K_1 > 1$ CSI-RS resources, K_1 RIs can be reported in K_1 CSI reports associated with the K_1 CSI-RS resources. Let us denote the two RIs as $RI^{(1,1)}, RI^{(1,2)}, \dots, RI^{(1,K_1)}$. We have the following alternatives:

- 2-b-a: $RI^{(1,1)}, RI^{(1,2)}, \dots, RI^{(1,K_1)}$ are not reported. There are two sub-alternatives:
 - $RI^{(1,1)}, RI^{(1,2)}, \dots, RI^{(1,K_1)}$ are fixed, for example all of them are 1 or 8, or a subset (S_1) of reported RIs is fixed to 1 and another subset (S_2) to 8 where S_1 and S_2 are disjoint and their union covers all RIs.
 - $RI^{(1,1)}, RI^{(1,2)}, \dots, RI^{(1,K_1)}$ are configured (via RRC signaling).
- 2-b-b: Only a subset (S_1) of RIs is reported, where the reported $RI^{(1,x)}$ for x in S_1 can either be
 - *restricted*, for example to rank {1,2} for co-pol and {1,3} for dual-pol (1-bit $RI^{(1,x)}$), or {1,2,3,4} for co-pol and {1,3,5,7} for dual-pol (2-bit $RI^{(1,x)}$), or
 - *unrestricted*, for example to rank 1-8 (3-bit $RI^{(1,x)}$).

Also, $RI^{(1,x)}$ s for all x in S_1 are either the same or they can be different. There are two sub-alternatives for $RI^{(1,y)}$ for y not in S_1 :

- $RI^{(1,y)}$ is fixed, for example, 1 or 8.
- $RI^{(1,y)}$ is configured (via RRC signaling).

Also, $RI^{(1,y)}$ s for all y not in S_1 are either the same or they can be different.

- 2-b-d: All of $RI^{(1,1)}, RI^{(1,2)}, \dots, RI^{(1,K_1)}$ are reported, where some or all of them are restricted or unrestricted. When the reported $RI^{(1,y)}$ for y in $\{1,2,\dots,K_1\}$ is restricted, it can be 1 bit indicating rank {1,3} or {1,2} or 2 bits indicating rank {1,3,5,7} or {1,2,3,4}. When the reported RI is unrestricted, then all possible ranks can be reported. For example, the reported RI can be 3 bits indicating rank 1-8.

The codebooks for $RI^{(1,1)}, RI^{(1,2)}, \dots, RI^{(1,K_1)}$ reporting can be legacy (up to Rel. 13) codebooks or the co-pol codebook proposed in this invention.

Embodiment on Configuration 1 (Class B, $K = 1$ + Class B, $K = 1$)

In some embodiments, a UE is configured with a hybrid CSI reporting in which the 1st eMIMO-Type is Class B, $K_1 = 1$ with N_{P1} ports and the 2nd eMIMO-Type is Class B, $K_2 = 1$ with N_{P2} ports, where $N_{P1}, N_{P2} = 2,4,8$. The CSI reported in the first Class B eMIMO-Type is either

- Alternative 1-a (Table 3): PMI or
- Alternative 1-b (Table 3): CQI, $RI^{(1)}$, PMI

and that reported in the 2nd Class B eMIMO-Type includes $RI^{(2)}$, CQI, and PMI. The codebooks for the two eMIMO-Types can be according to one of the following alternatives:

- Alt0: Rel. 13 Class B codebook
- Alt1: One of Rel. 12 codebooks.

There are two alternatives for configuring N_{P1}, N_{P2} :

- $N_{P1} = N_{P2}$
- $N_{P1} \neq N_{P2}$.

Depending on whether both or at least one of $RI^{(1)}$ and $RI^{(2)}$ are reported, we have the following alternatives (as shown in **Table 3**):

- 1-a: Only $RI^{(1)}$ is reported.
- 1-b: Only $RI^{(2)}$ is reported.
- 1-c: Both $RI^{(1)}$ and $RI^{(2)}$ are reported.

All embodiments on RI reporting alternatives (alternatives 0-a, 0-b, 0-c) for the case of Class A + Class B $K = 1$ described earlier in the invention are applicable in this case too.

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Application Data Sheet 37 CFR 1.76		Attorney Docket Number	2016.06.013.SR0
		Application Number	
Title of Invention	HYBRID CSI REPORTING FOR MIMO WIRELESS COMMUNICATION SYSTEMS		
The application data sheet is part of the provisional or nonprovisional application for which it is being submitted. The following form contains the bibliographic data arranged in a format specified by the United States Patent and Trademark Office as outlined in 37 CFR 1.76. This document may be completed electronically and submitted to the Office in electronic format using the Electronic Filing System (EFS) or the document may be printed and included in a paper filed application.			

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Title of Invention	HYBRID CSI REPORTING FOR MIMO WIRELESS COMMUNICATION SYSTEMS		

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Attorney Docket Number	2016.06.013.SR0	Small Entity Status Claimed	☐
Application Type	Provisional		
Subject Matter	Utility		
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Only complete this section when filing an application by reference under 35 U.S.C. 111(c) and 37 CFR 1.57(a). Do not complete this section if application papers including a specification and any drawings are being filed. Any domestic benefit or foreign priority information must be provided in the appropriate section(s) below (i.e., "Domestic Benefit/National Stage Information" and "Foreign Priority Information").

For the purposes of a filing date under 37 CFR 1.53(b), the description and any drawings of the present application are replaced by this reference to the previously filed application, subject to conditions and requirements of 37 CFR 1.57(a).

Application number of the previously filed application	Filing date (YYYY-MM-DD)	Intellectual Property Authority or Country

Publication Information:

☐ Request Early Publication (Fee required at time of Request 37 CFR 1.219)
☐ Request Not to Publish. I hereby request that the attached application not be published under 35 U.S.C. 122(b) and certify that the invention disclosed in the attached application has not and will not be the subject of an application filed in another country, or under a multilateral international agreement, that requires publication at eighteen months after filing.

Representative Information:

Representative information should be provided for all practitioners having a power of attorney in the application. Providing this information in the Application Data Sheet does not constitute a power of attorney in the application (see 37 CFR 1.32). Either enter Customer Number or complete the Representative Name section below. If both sections are completed the customer Number will be used for the Representative Information during processing.			
Please Select One:	☒ Customer Number	☐ US Patent Practitioner	☐ Limited Recognition (37 CFR 11.9)
Customer Number	96817		

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

Application Data Sheet 37 CFR 1.76		Attorney Docket Number	2016.06.013.SR0
		Application Number	
Title of Invention	HYBRID CSI REPORTING FOR MIMO WIRELESS COMMUNICATION SYSTEMS		

Domestic Benefit/National Stage Information:

This section allows for the applicant to either claim benefit under 35 U.S.C. 119(e), 120, 121, 365(c), or 386(c) or indicate National Stage entry from a PCT application. Providing benefit claim information in the Application Data Sheet constitutes the specific reference required by 35 U.S.C. 119(e) or 120, and 37 CFR 1.78.

When referring to the current application, please leave the "Application Number" field blank.

Prior Application Status		Remove	
Application Number	Continuity Type	Prior Application Number	Filing or 371(c) Date (YYYY-MM-DD)
Additional Domestic Benefit/National Stage Data may be generated within this form by selecting the Add button.			

Foreign Priority Information:

This section allows for the applicant to claim priority to a foreign application. Providing this information in the application data sheet constitutes the claim for priority as required by 35 U.S.C. 119(b) and 37 CFR 1.55. When priority is claimed to a foreign application that is eligible for retrieval under the priority document exchange program (PDX)ⁱ the information will be used by the Office to automatically attempt retrieval pursuant to 37 CFR 1.55(i)(1) and (2). Under the PDX program, applicant bears the ultimate responsibility for ensuring that a copy of the foreign application is received by the Office from the participating foreign intellectual property office, or a certified copy of the foreign priority application is filed, within the time period specified in 37 CFR 1.55(g)(1).

Application Number	Country ⁱ	Filing Date (YYYY-MM-DD)	Remove
			Access Code ⁱ (if applicable)
Additional Foreign Priority Data may be generated within this form by selecting the Add button.			

Statement under 37 CFR 1.55 or 1.78 for AIA (First Inventor to File) Transition Applications

This application (1) claims priority to or the benefit of an application filed before March 16, 2013 and (2) also contains, or contained at any time, a claim to a claimed invention that has an effective filing date on or after March 16, 2013. ☐ NOTE: By providing this statement under 37 CFR 1.55 or 1.78, this application, with a filing date on or after March 16, 2013, will be examined under the first inventor to file provisions of the AIA.
--

Application Data Sheet 37 CFR 1.76		Attorney Docket Number	2016.06.013.SR0
		Application Number	
Title of Invention	HYBRID CSI REPORTING FOR MIMO WIRELESS COMMUNICATION SYSTEMS		

Authorization or Opt-Out of Authorization to Permit Access:

When this Application Data Sheet is properly signed and filed with the application, applicant has provided written authority to permit a participating foreign intellectual property (IP) office access to the instant application-as-filed (see paragraph A in subsection 1 below) and the European Patent Office (EPO) access to any search results from the instant application (see paragraph B in subsection 1 below).

Should applicant choose not to provide an authorization identified in subsection 1 below, applicant **must opt-out** of the authorization by checking the corresponding box A or B or both in subsection 2 below.

NOTE: This section of the Application Data Sheet is **ONLY** reviewed and processed with the **INITIAL** filing of an application. After the initial filing of an application, an Application Data Sheet cannot be used to provide or rescind authorization for access by a foreign IP office(s). Instead, Form PTO/SB/39 or PTO/SB/69 must be used as appropriate.

1. Authorization to Permit Access by a Foreign Intellectual Property Office(s)

A. Priority Document Exchange (PDX) - Unless box A in subsection 2 (opt-out of authorization) is checked, the undersigned hereby **grants the USPTO authority** to provide the European Patent Office (EPO), the Japan Patent Office (JPO), the Korean Intellectual Property Office (KIPO), the State Intellectual Property Office of the People's Republic of China (SIPO), the World Intellectual Property Organization (WIPO), and any other foreign intellectual property office participating with the USPTO in a bilateral or multilateral priority document exchange agreement in which a foreign application claiming priority to the instant patent application is filed, access to: (1) the instant patent application-as-filed and its related bibliographic data, (2) any foreign or domestic application to which priority or benefit is claimed by the instant application and its related bibliographic data, and (3) the date of filing of this Authorization. See 37 CFR 1.14(h)(1).

B. Search Results from U.S. Application to EPO - Unless box B in subsection 2 (opt-out of authorization) is checked, the undersigned hereby **grants the USPTO authority** to provide the EPO access to the bibliographic data and search results from the instant patent application when a European patent application claiming priority to the instant patent application is filed. See 37 CFR 1.14(h)(2).

The applicant is reminded that the EPO's Rule 141(1) EPC (European Patent Convention) requires applicants to submit a copy of search results from the instant application without delay in a European patent application that claims priority to the instant application.

2. Opt-Out of Authorizations to Permit Access by a Foreign Intellectual Property Office(s)

☐ A. Applicant **DOES NOT** authorize the USPTO to permit a participating foreign IP office access to the instant application-as-filed. If this box is checked, the USPTO will not be providing a participating foreign IP office with any documents and information identified in subsection 1A above.

☐ B. Applicant **DOES NOT** authorize the USPTO to transmit to the EPO any search results from the instant patent application. If this box is checked, the USPTO will not be providing the EPO with search results from the instant application.

NOTE: Once the application has published or is otherwise publicly available, the USPTO may provide access to the application in accordance with 37 CFR 1.14.

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

Application Data Sheet 37 CFR 1.76		Attorney Docket Number	2016.06.013.SR0
		Application Number	
Title of Invention	HYBRID CSI REPORTING FOR MIMO WIRELESS COMMUNICATION SYSTEMS		

Applicant Information:

Providing assignment information in this section does not substitute for compliance with any requirement of part 3 of Title 37 of CFR to have an assignment recorded by the Office.			
Applicant 1			
If the applicant is the inventor (or the remaining joint inventor or inventors under 37 CFR 1.45), this section should not be completed. The information to be provided in this section is the name and address of the legal representative who is the applicant under 37 CFR 1.43; or the name and address of the assignee, person to whom the inventor is under an obligation to assign the invention, or person who otherwise shows sufficient proprietary interest in the matter who is the applicant under 37 CFR 1.46. If the applicant is an applicant under 37 CFR 1.46 (assignee, person to whom the inventor is obligated to assign, or person who otherwise shows sufficient proprietary interest) together with one or more joint inventors, then the joint inventor or inventors who are also the applicant should be identified in this section.			
Clear			
☐ Assignee	☐ Legal Representative under 35 U.S.C. 117	☐ Joint Inventor	
☐ Person to whom the inventor is obligated to assign.		☐ Person who shows sufficient proprietary interest	
If applicant is the legal representative, indicate the authority to file the patent application, the inventor is:			
Name of the Deceased or Legally Incapacitated Inventor:			
If the Applicant is an Organization check here. ☒			
Organization Name	Samsung Electronics Co., Ltd.		
Mailing Address Information For Applicant:			
Address 1	129, Samsung-ro, Yeongtong-gu		
Address 2			
City	Suwon-si, Gyeonggi-do	State/Province	
Country	KR	Postal Code	443-742
Phone Number		Fax Number	
Email Address	patent.srad@samsung.com		
Additional Applicant Data may be generated within this form by selecting the Add button.			

Assignee Information including Non-Applicant Assignee Information:

Providing assignment information in this section does not substitute for compliance with any requirement of part 3 of Title 37 of CFR to have an assignment recorded by the Office.

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

Application Data Sheet 37 CFR 1.76		Attorney Docket Number	2016.06.013.SR0
		Application Number	
Title of Invention	HYBRID CSI REPORTING FOR MIMO WIRELESS COMMUNICATION SYSTEMS		

Assignee 1

Complete this section if assignee information, including non-applicant assignee information, is desired to be included on the patent application publication. An assignee-applicant identified in the "Applicant Information" section will appear on the patent application publication as an applicant. For an assignee-applicant, complete this section only if identification as an assignee is also desired on the patent application publication.

If the Assignee or Non-Applicant Assignee is an Organization check here. ☐

Prefix	Given Name	Middle Name	Family Name	Suffix

Mailing Address Information For Assignee including Non-Applicant Assignee:

Address 1			
Address 2			
City		State/Province	
Country ¹		Postal Code	
Phone Number		Fax Number	
Email Address			

Additional Assignee or Non-Applicant Assignee Data may be generated within this form by selecting the Add button.

Signature:

NOTE: This Application Data Sheet must be signed in accordance with 37 CFR 1.33(b). However, if this Application Data Sheet is submitted with the **INITIAL** filing of the application and either box A or B is **not** checked in subsection 2 of the "Authorization or Opt-Out of Authorization to Permit Access" section, then this form must also be signed in accordance with 37 CFR 1.14(c).

This Application Data Sheet **must** be signed by a patent practitioner if one or more of the applicants is a **juristic entity** (e.g., corporation or association). If the applicant is two or more joint inventors, this form must be signed by a patent practitioner, **all** joint inventors who are the applicant, or one or more joint inventor-applicants who have been given power of attorney (e.g., see USPTO Form PTO/AIA/81) on behalf of **all** joint inventor-applicants.

See 37 CFR 1.4(d) for the manner of making signatures and certifications.

Signature	/Ravindranath V. Kanamangala/		Date (YYYY-MM-DD)	2016-08-23	
First Name	Ravindranath	Last Name	Kanamangala	Registration Number	60914

Additional Signature may be generated within this form by selecting the Add button.

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

Application Data Sheet 37 CFR 1.76		Attorney Docket Number	2016.06.013.SR0
		Application Number	
Title of Invention	HYBRID CSI REPORTING FOR MIMO WIRELESS COMMUNICATION SYSTEMS		

This collection of information is required by 37 CFR 1.76. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 23 minutes to complete, including gathering, preparing, and submitting the completed application data sheet form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

Privacy Act Statement

The Privacy Act of 1974 (P.L. 93-579) requires that you be given certain information in connection with your submission of the attached form related to a patent application or patent. Accordingly, pursuant to the requirements of the Act, please be advised that: (1) the general authority for the collection of this information is 35 U.S.C. 2(b)(2); (2) furnishing of the information solicited is voluntary; and (3) the principal purpose for which the information is used by the U.S. Patent and Trademark Office is to process and/or examine your submission related to a patent application or patent. If you do not furnish the requested information, the U.S. Patent and Trademark Office may not be able to process and/or examine your submission, which may result in termination of proceedings or abandonment of the application or expiration of the patent.

The information provided by you in this form will be subject to the following routine uses:

1. The information on this form will be treated confidentially to the extent allowed under the Freedom of Information Act (5 U.S.C. 552) and the Privacy Act (5 U.S.C. 552a). Records from this system of records may be disclosed to the Department of Justice to determine whether the Freedom of Information Act requires disclosure of these records.
2. A record from this system of records may be disclosed, as a routine use, in the course of presenting evidence to a court, magistrate, or administrative tribunal, including disclosures to opposing counsel in the course of settlement negotiations.
3. A record in this system of records may be disclosed, as a routine use, to a Member of Congress submitting a request involving an individual, to whom the record pertains, when the individual has requested assistance from the Member with respect to the subject matter of the record.
4. A record in this system of records may be disclosed, as a routine use, to a contractor of the Agency having need for the information in order to perform a contract. Recipients of information shall be required to comply with the requirements of the Privacy Act of 1974, as amended, pursuant to 5 U.S.C. 552a(m).
5. A record related to an International Application filed under the Patent Cooperation Treaty in this system of records may be disclosed, as a routine use, to the International Bureau of the World Intellectual Property Organization, pursuant to the Patent Cooperation Treaty.
6. A record in this system of records may be disclosed, as a routine use, to another federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).
7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (i.e., GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.
8. A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspections or an issued patent.
9. A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.

TRANSMITTAL FOR POWER OF ATTORNEY TO ONE OR MORE REGISTERED PRACTITIONERS

NOTE: This form is to be submitted with the Power of Attorney by Applicant form (PTO/AIA/82B) to identify the application to which the Power of Attorney is directed, in accordance with 37 CFR 1.5, unless the application number and filing date are identified in the Power of Attorney by Applicant form. If neither form PTO/AIA/82A nor form PTO/AIA82B identifies the application to which the Power of Attorney is directed, the Power of Attorney will not be recognized in the application.

Application Number	TBD
Filing Date	Herewith
First Named Inventor	Md Saifur Rahman
Title	HYBRID CSI REPORTING FOR MIMO WIRELESS COMMUNICATION SYSTEMS
Art Unit	TBD
Examiner Name	TBD
Attorney Docket Number	2016.06.013.SR0

SIGNATURE of Applicant or Patent Practitioner

Signature	/Ravindranath V. Kanamangala/	Date (Optional)	08/23/2016
Name	Ravindranath V. Kanamangala	Registration Number	60914
Title (if Applicant is a juristic entity)			
Applicant Name (if Applicant is a juristic entity)			

NOTE: This form must be signed in accordance with 37 CFR 1.33. See 37 CFR 1.4(d) for signature requirements and certifications. If more than one applicant, use multiple forms.

☐

*Total of _____ forms are submitted.

This collection of information is required by 37 CFR 1.131, 1.32, and 1.33. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to take 3 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.

Privacy Act Statement

The **Privacy Act of 1974 (P.L. 93-579)** requires that you be given certain information in connection with your submission of the attached form related to a patent application or patent. Accordingly, pursuant to the requirements of the Act, please be advised that: (1) the general authority for the collection of this information is 35 U.S.C. 2(b)(2); (2) furnishing of the information solicited is voluntary; and (3) the principal purpose for which the information is used by the U.S. Patent and Trademark Office is to process and/or examine your submission related to a patent application or patent. If you do not furnish the requested information, the U.S. Patent and Trademark Office may not be able to process and/or examine your submission, which may result in termination of proceedings or abandonment of the application or expiration of the patent.

The information provided by you in this form will be subject to the following routine uses:

1. The information on this form will be treated confidentially to the extent allowed under the Freedom of Information Act (5 U.S.C. 552) and the Privacy Act (5 U.S.C. 552a). Records from this system of records may be disclosed to the Department of Justice to determine whether the Freedom of Information Act requires disclosure of these records.
2. A record from this system of records may be disclosed, as a routine use, in the course of presenting evidence to a court, magistrate, or administrative tribunal, including disclosures to opposing counsel in the course of settlement negotiations.
3. A record in this system of records may be disclosed, as a routine use, to a Member of Congress submitting a request involving an individual, to whom the record pertains, when the individual has requested assistance from the Member with respect to the subject matter of the record.
4. A record in this system of records may be disclosed, as a routine use, to a contractor of the Agency having need for the information in order to perform a contract. Recipients of information shall be required to comply with the requirements of the Privacy Act of 1974, as amended, pursuant to 5 U.S.C. 552a(m).
5. A record related to an International Application filed under the Patent Cooperation Treaty in this system of records may be disclosed, as a routine use, to the International Bureau of the World Intellectual Property Organization, pursuant to the Patent Cooperation Treaty.
6. A record in this system of records may be disclosed, as a routine use, to another federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).
7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (i.e., GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.
8. A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspections or an issued patent.
9. A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.