3GPP TSG-RAN WG1#80bis **R1-151931**

Belgrade, Serbia, 20th - 24th April 2015

ERICSSON

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TITLE: SPECIFICATION IMPACTS OF NON-PRECODED AND BEAMFORMED CSI-RS

AGENDA ITEM: 7.2.5.2.1

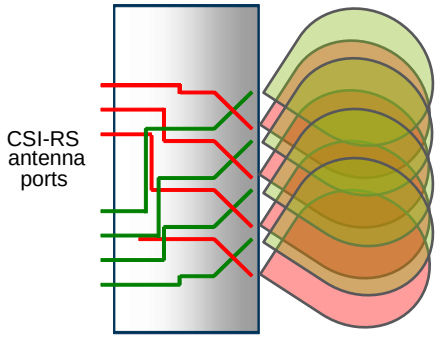
DOCUMENT FOR: DISCUSSION AND DECISION

SUMMARY

- Proposal:
  - Enhance **both** these CSI feedback modes for EBF/FD-MIMO:
    1. Closed loop / Codebook based: Non-precoded CSI-RS for 1D and 2D antenna port configurations and a flexible number of antenna ports
    2. Open loop / Beamformed CSI-RS with a pooled reuse of CSI-RS resources

- Distinguishing use cases:
  - Non-precoded CSI-RS targets **a few up to a moderate number** of antenna elements.
  - Beamformed CSI-RS targets the case of **many antenna elements** and when reciprocity can be utilized (e.g. TDD)

MOTIVATION FOR CODEBOOK ENHANCEMENTS



- Codebook based feedback is robust as it is closed loop operation
  - UE measures the full MIMO channel matrix
  - Only higher layer involvement at configuration, L1 takes care of adaptation
  - Fast tracking of the channel

- This is a necessary CSI feedback mode since it is
  - Well known and simple algorithmically, robust towards e.g. duplex distance, minimizes link adaptation errors, allows instantaneous channel properties to be tracked, enables fast CSI acquisition at wake-up from RRC_IDLE, minimizes assumptions on propagation statistics, allows for frequency selective or high spatial resolution feedback, may allow for relaxed antenna calibration

- Operating range for 2DAA with few to moderate number of antenna ports due to RS overhead

	10 ports	20 ports	40 ports	64 ports
CSI-RS Overhead (1 cell reuse)	1.9%	3.7%	7.4%	12%
CSI-RS Overhead (3 cell reuse)	5.5%	11.2%	22.2%	36%

EXAMPLE OF SCALABLE 2D CODEBOOK DESIGN

- Codebook design follows the well established principles used in Rel.10 and Rel.12 codebook design
  - Simple extension to arbitrary N_a ,M_a by parameterization and using a Kronecker structure to give 2D design [1]
  - Example codebook given below for M_axN_ax2 array with rank 1
    - Grid of beam based on DFT matrix with Q times spatial oversampling, (QM_a)(QN_a) 2D beams, and 4 state polarization co-phasing
    - With 64 CSI-RS ports, Q=2, $\log_2(4M_aN_a)+\log_2(4) = 9$ PMI bits needed
      - Similar to Rel-10, which uses at most 8 PMI bits

$$\mathbf{X}_V^l = \begin{bmatrix} 1 & e^{j2\pi\frac{l}{M_aQ}} & e^{j2\pi\frac{2l}{M_aQ}} & \cdots & e^{j2\pi\frac{(M_a-1)l}{M_aQ}} \end{bmatrix}; \quad l \in \{0,1,..,M_aQ-1\}$$

$$\mathbf{X}_H^k = \begin{bmatrix} 1 & e^{j2\pi\frac{k}{N_aQ}} & e^{j2\pi\frac{2k}{N_aQ}} & \cdots & e^{j2\pi\frac{(N_a-1)k}{N_aQ}} \end{bmatrix}; \quad k \in \{0,1,..,N_aQ-1\}$$

$$W = W_1W_2 = \begin{bmatrix} \mathbf{X}_H^k \otimes \mathbf{X}_V^l & 0 \\ 0 & \mathbf{X}_H^k \otimes \mathbf{X}_V^l \end{bmatrix} \begin{bmatrix} 1 \\ e^{j\alpha} \end{bmatrix}$$

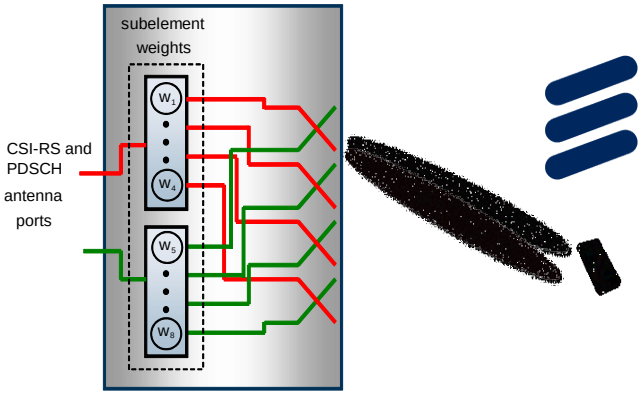
$$\alpha \in \{0,1,2,3\}$$

NON-PRECODED CSI-RS SPEC IMPACT

- Up to 40 CSI-RS ports can be supported without modifying Rel-12 subframe structure
  - More than 40 CSI-RS ports would require new CSI-RS RE mapping
    - More than 40 ports could be supported using more REs in a subframe, lower CSI-RS density, splitting CSI-RS port configurations across subframes, etc.

- Principal L1 spec changes:
  - CSI-RS patterns to support flexible # ports, i.e. M_a, N_a other than 1,2,4,8
    - Some impact to 36.211 e.g. new CSI-RS configuration
  - Modified PMI codebook
    - Extend Rel-10 codebook in 36.213 to flexible and 2D
    - Update CSI reporting procedures in 36.213

MOTIVATION FOR BEAMFORMED CSI-RS ENHANCEMENTS



- Beamformed CSI-RS is open loop mode of operation
  - The mode is agnostic to the number of array antennas, suitable mode for a large number of antennas
  - Suitable when channel reciprocity can be utilized
  - Allows for “codebook-free”, UE specific beamforming w/ MU-MIMO
- Enhancements target UE specific beamforming
  - Reduce CSI-RS overhead and avoid RRC reconfigurations, by a shared pool of CSI-RS resources
  - Hence, a CSI-RS resource may be used in a different beam in each subframe
- Example of CSI-RS overhead savings
  - Assuming a pool of 8 two port beamformed CSI-RSs are shared with the same cell reuse factor as non-precoded CSI-RS

	20 ports	40 ports	64 ports
Beamformed CSI-RS Overhead Saving vs. Non-Precoded CSI-RS	1.25x	2.5x	4.0x

EXAMPLE OF BEAMFORMED CSI-RS DESIGN

- eNB chooses which subset of beams to transmit CSI-RS in
  - E.g. when # UEs reporting CSI < # beams or UEs are concentrated in particular areas of the cell.
  - Beams can be cell-specific or UE specific
- Hence, a given CSI-RS resource may carry a different beam in each subframe.
  - UEs shall not average CSI measurements across subframes
- eNB dynamically selects which CSI-RS resources the UE reports on
  - Similar mechanisms as for aperiodic CSI reporting may be used
- Details in [2]

BEAMFORMED CSI-RS SPEC IMPACT

- Principal L1 spec changes:
  - Subframe averaging of CSI-RS resources can be disabled
    - Change CSI reference resource definition in 36.213
    - Signalling to enable/disable this restriction
  - Enable eNB to dynamically indicate which CSI-RS resource the UE shall report on
    - DCI definitions in 36.212 may need updating

REFERENCES

- [1] R1-151926, “2D Codebook with KP structure and associated feedback”, Ericsson, 3GPP TSG RAN1 Meeting #80bis, Belgrade, Serbia, 20-24 April 2015
- [2] R1-151924, “Enhancements for beamformed CSI-RS”, Ericsson, 3GPP TSG RAN1 Meeting #80bis, Belgrade, Serbia, 20-24 April 2015

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