3GPP TSG-RAN WG1#83 **R1-157208**
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Class A Codebook Design for Rank 1-2

Ericsson

Agenda Item: 6.2.4.3.1

Document for: Discussion and Decision

Overview

- Rank 2 codebook proposed in R1-156381 is summarized
- Performance results for various rank 2 codebook configurations are provided

Rank 2 Precoding Matrix Construction

- Same principles as Rel.10 8 port rank 2 codebook
  - Layers can be on different 2D beams
    - 'horizontal' beams set by $v_{m_1'}$
    - 'vertical' beams set by u_{m_2}
    - Beams determined with $m_i, m_i' = s_i i_{i,1} + cp_i$
      - s_i are 'beam group spacing'; p_i are 'beam group offsets'; see following slides
  - Two state polarization co-phasing φ

$$W^{(2)}_{m_1,m_2,m_1',m_2',n} = \frac{1}{\sqrt{2Q}} \begin{bmatrix} v_{m_1} \otimes u_{m_2} & v_{m_1'} \otimes u_{m_2'} \\ \varphi_n v_{m_1} \otimes u_{m_2} & -\varphi_n v_{m_1'} \otimes u_{m_2'} \end{bmatrix}$$

$$u_{m_2} = \begin{bmatrix} 1 & e^{j\frac{2\pi m_2}{O_2 N_2}} & \dots & e^{j\frac{2\pi m_2 (N_2-1)}{O_2 N_2}} \end{bmatrix}^t$$

$$v_{m_1} = \begin{bmatrix} 1 & e^{j\frac{2\pi m_1}{O_1 N_1}} & \dots & e^{j\frac{2\pi m_1 (N_1-1)}{O_1 N_1}} \end{bmatrix}^t$$

$$\varphi_n = e^{j\pi n/2}$$

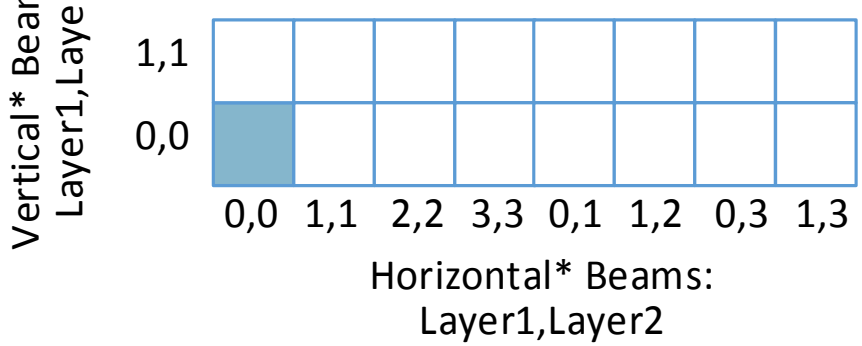
Rank 2 Configurations: Overview

- Configurations provide either low overhead or different performance optimization
  - Config 1 (low overhead)
    - Does not use fast beam selection in i_2
      - 1 bit used for i_2 for polarization cophasing
    - Requires ~ $\log_2(N_1 O_1 N_2 O_2)$ + S bits for i_1 and i_2 where S is the number of subbands for which PMI is reported.
  - Configs 2,3,4 (performance optimized)
    - Allow for fast fast beam selection in i_2 of closely spaced beams using 3 bits
    - Require ~ $\log_2(N_1 O_1 N_2 O_2/(s_1 s_2))$ + $4S$ bits for i_1 and i_2, where S is the number of subbands for which PMI is reported.

Configuration 1

- Uses 1 bit cophasing only, no beam selection
  - W_1 contains 1 column per polarization
- Both layers are transmitted on the same beam
- Any of the $N_1 O_1 N_2 O_2$ beams can be selected by i_1
  - The beam group spacing for each dimension is $s_1 = 1$ and $s_2 = 1$

Beam Combinations in i_2



* 1st and 2nd dimension are interpreted as Horizontal and Vertical here

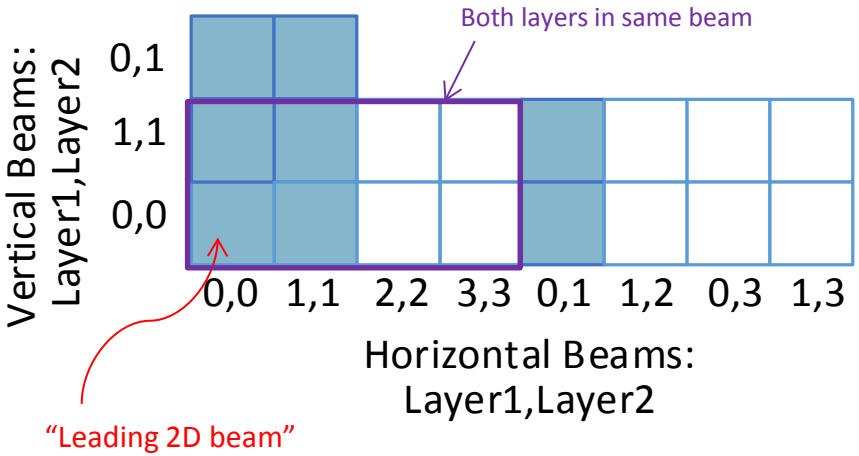
Configurations 2-4: Summary

- Configs 2-4
  - W_1 contain beam groups of 2D beams
    - $N_1 O_1 N_2 O_2/(s_1 s_2)$ beam groups can be selected by i_1
    - The beam group spacing for each dimension is $s_1 = 2$ and $s_2 = 2$
  - W_2 allow beam selection of closely spaced beams
    - Up to 2 of 4 beams can be selected by i_2 for $W^{(2)}$
  - Layers are transmitted on different beams for half of the states of i_2
  - Beams are distributed in a 'square', 'checkerboard', or 'line'.

Configuration 2

- 4 Adjacent 2D beams are distributed in a 'square':
  - The set of 2D beams in the beam group can be decomposed into a set of horizontal and a vertical beams*
  - 3 nearest vertical and horizontal neighbor beams of a leading beam are used
  - Layers 1 and 2 can be on the two horizontal beams and either vertical beam
  - Layers 1 and 2 can be on the two vertical beams and either horizontal beam

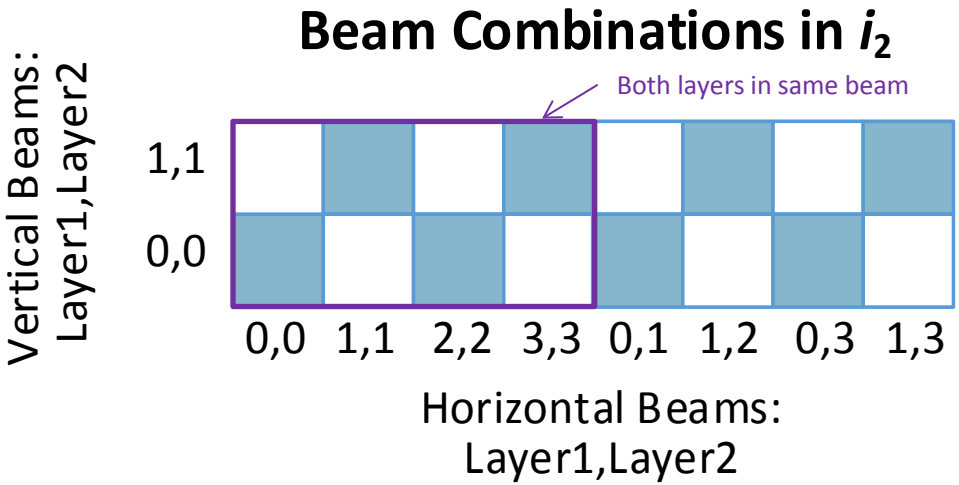
Beam Combinations in i_2



* 1st and 2nd dimension are interpreted as Horizontal and Vertical here

Configuration 3 Alt 1

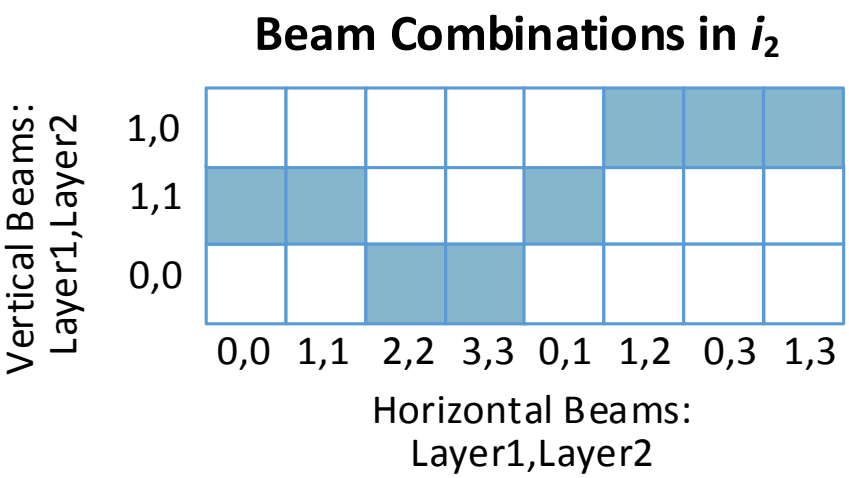
- Every other vertical and horizontal beam combination is selected
  - A horizontal beam combination is used on only one vertical beam
- Layer 1 and 2 can be on different horizontal beams, but both are only on one vertical beam



* 1st and 2nd dimension are interpreted as Horizontal and Vertical here

Configuration 3 Alt 2

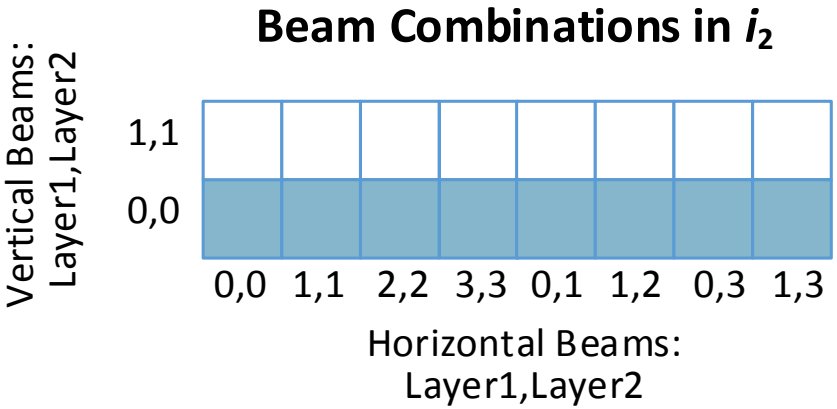
- Horizontal beams 0,1 are always transmitted on vertical beam 1
- Horizontal beams 2,3 are always transmitted on vertical beam 0
- Layers 1 and 2 can be on different horizontal and vertical beams



* 1st and 2nd dimension are interpreted as Horizontal and Vertical here

Configuration 4

- 4 adjacent horizontal beams are used
  - All beams are associated with a single vertical beam '0'
  - i.e. no fast beam switching vertically
  - Layers 1 and 2 can be on different horizontal beams



* 1st and 2nd dimension are interpreted as Horizontal and Vertical here

System Simulation Results

- Results for Configs 2 and 4
  - Have 2-5% mean, 3-7% cell edge gain over Config 1 for 3x2 port layout, UMa (6x2 array)
  - Have -2% to 1% mean, -7% to 1% cell edge gain over Config 1 for 2x4 port layout, UMi (4x4 array)

		3x2 port layout UMa			2x4 port layout UMi		
		Config 1 (baseline)	Config 2	Config 4	Config 1 (baseline)	Config 2	Config 4
Baseline RU = 20 %	Mean User Throughput	3.2615	2%	2%	3.6006	1%	1%
	Cell-edge User Throughput	0.9986	3%	4%	1.2267	1%	1%
Baseline RU = 50 %	Mean User Throughput	2.0479	5%	3%	2.3924	1%	-2%
	Cell-edge User Throughput	0.4007	7%	3%	0.5277	-1%	-7%

Relative performance between configurations depends on scenario/port layout

Conclusion

- Observation:
  - Different configurations have different amounts of gain according to the antenna configuration, port layout and deployment scenario
  - The low overhead configuration (1) and fast beam switching configurations (2,3,4) allow tradeoffs of complexity and overhead vs. improved performance.
- Proposal:
  - Agree on the rank 2 codebook proposed in R1-156381 for Class A FD-MIMO

Appendix

Simulation parameters	
Carrier frequency	2 GHz
Bandwidth	10 MHz
Scenarios	3D UMi 200m ISD, 3D UMa 500m ISD
Cell layout	1 vertical sector per azimuthal sector (baseline), 57 azimuthal sectors in total
Antenna Configuration	6x2 or 4x4 with 2x1 virtualization 130° tilt for UMI; 122° tilt for UMa
Wrapping	Radio distance based
UE receiver	MMSE-IRC
CSI periodicity	5 ms
CSI delay	5 ms
CSI mode	Aperiodic mode 3-2
Outer loop Link Adaptation	Yes, 10% BLER target
UE noise figure	9 dB
eNB Tx power	41 dBm (UMi), 46 dBm (UMa)
Traffic model	FTP Model 1, 500 kB packet size
UE speed	3 km/h
Scheduling	Proportional fair in time and frequency
CRS interference	Not modeled. Overhead accounted for 2 CRS ports.
DMRS overhead	2 antenna ports
CSI-RS	Overhead accounted for. Channel estimation error modeled.
Codebook	Rank-1 codebook as agreed in R1-156217 Rank-2 codebook as proposed in R1-156381
HARQ	Max 5 retransmissions
Antenna spacing	0.8 lambda in vertical, 0.5 lambda in horizontal
Handover margin	3 dB