VQ of the Transmit Correlation Matrix for Codebook Transformation and Interference Nulling

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Background

- We propose a simple vector quantization algorithm for the transmit correlation matrix
- The algorithm uses rank-1 codebooks to quantize the two strongest singular vectors.
- The transmit correlation matrix is already used in 802.16m for codebook transformation but is quantized element-wise. Our approach uses the 802.16m codebooks to reduce overhead by as much as 67% for 4-antenas and 90% for 8 antennas.

- We further propose to use the same algorithm to feed back the interference transmit correlation to allow the BS to perform accurate beamforming and nulling

Vector Quantization Algorithm

1. Compute the transmit correlation matrix R
2. Find the strongest quantized singular vector (SV) by, for example, maximizing $\lambda_1 = c_i^H R c_i$ where c_i is a rank-1 codeword and λ_1 is the approximated strongest singular value of R. Denote by c_m the winning codeword.
3. Find the second strongest quantized SV by maximizing $\lambda_2 = d_i^H R d_i$ where d_i is the orthogonalized rank-1 codeword with respect to c_m Orthogonalization can be done using Gram-Schmidt

   $$d_i = (c_i - (c_m^H c_i) c_m) / \| c_i - (c_m^H c_i) c_m \|$$

   Denote by n the index of the winning codeword.

4. Quantize the ratio λ_2 / λ_1 into a 1bit codebook [0.25 0.5].

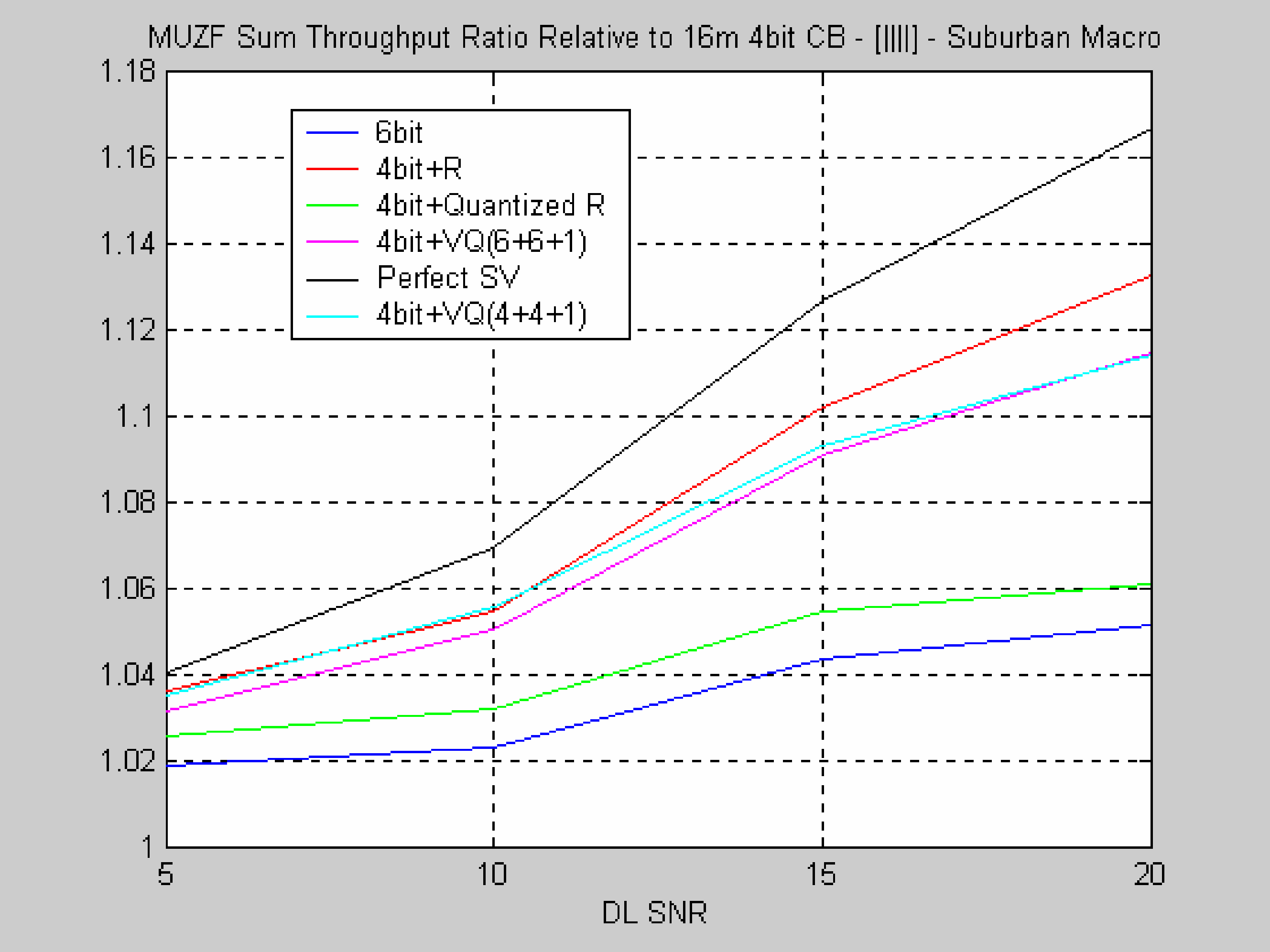
5. Feedback the two winning indices m,n and the index of the quantized singular value ratio.

Codebook Transformation – Simulation Results

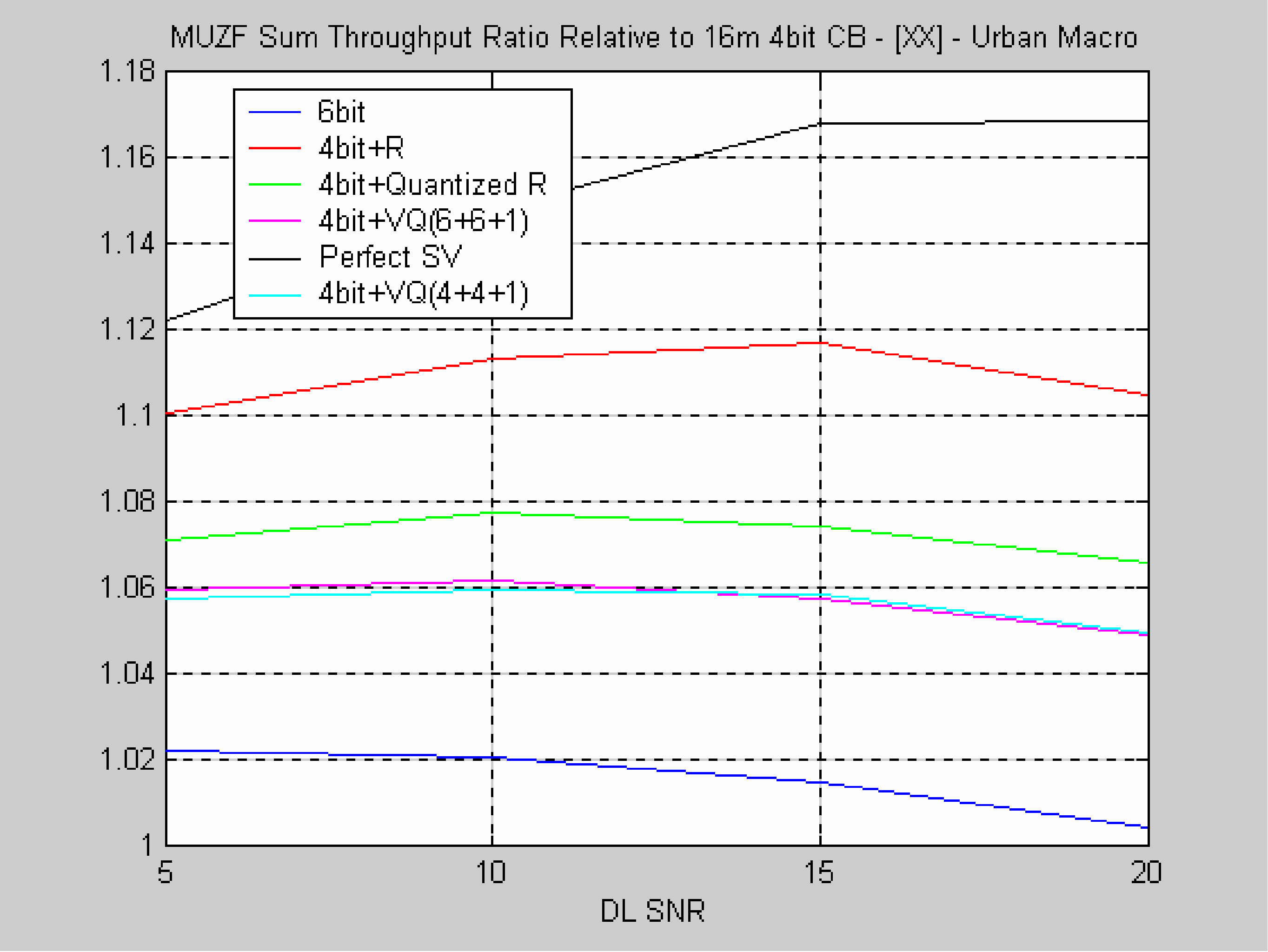
- MUZF simulations based on rank-1 feedback are used. DL spectral efficiencies are calculated assuming an MMSE receiver at the MS and assuming the interference is perfectly known.
- DL channel – SCM Suburban and Urban Macro (15 degrees angular spread).
- DL Band BW – 4 PRB (assuming one precoder per band)
- DL speed and feedback delay – 3kmph, 5mS
- DL midamble estimation – perfect
- User selection: 4 random users with exhaustive selection

- Simulations show spectral efficiency ratio relative to the 4bit subset of the rank-1 4-antenna codebook or the 4bit 8-antenna codebook.

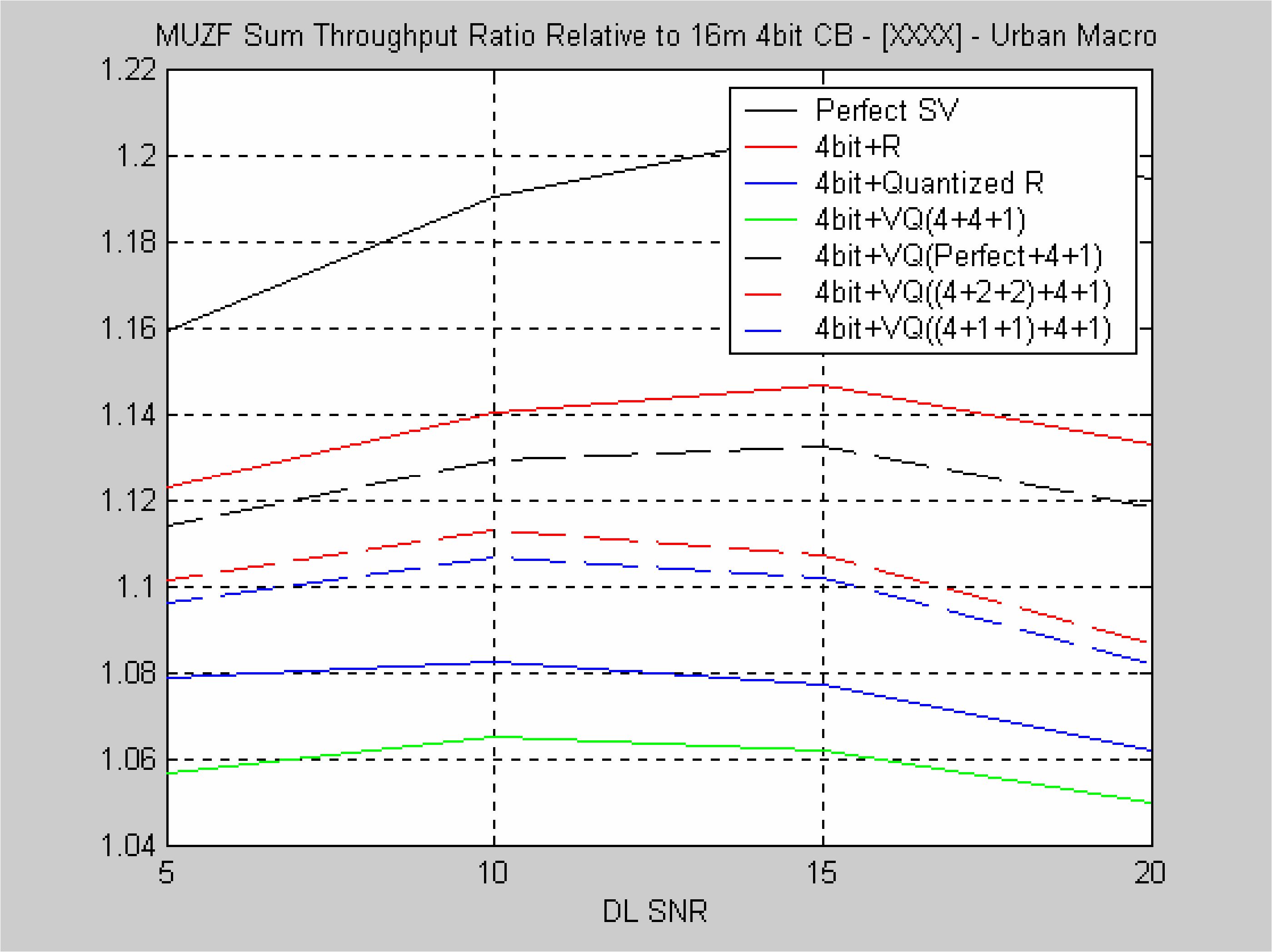
4-Antenna BS results



4-Antenna BS results



8-Antenna BS results



Interference Nulling – Simulation Results

- 3 BS serve 3 cell-edge users applying a beamforming algorithm to balance gain to served MS and leakage to interfered MS.

$$V = P\{(\sum_i R_i + \alpha N_o I)^{-1} R_S\}$$

- Explicit channel modeling using SCM Urban Macro
- Users are chosen randomly
- Rest of interference + noise is modeled as AWGN with SNR between 0 and 10dB.
- MS employs MMSE or MRC

- Table shows DL spectral efficiencies relative to rank-1 PMI feedback.

4-Antenna BS results

4-Antenna Configuration	**Feedback Option**	**DL SNR [dB]**		
		0	**5**	**10**
		MMSE/MRC	*MMSE/MRC*	*MMSE/MRC*
Two 4-lambda spaced cross-pols	Perfect Spatial Correlation	1.17/1.19	1.22/1.29	1.29/1.41
	Unquantized Spatial Correlation @ 6dB pre-combining	1.14/1.17	1.17/1.24	1.11/1.20
	Unquantized Spatial Correlation @ 0dB pre-combining	1.08/1.1	1.03/1.08	0.83/0.85
	16m(28) Transmit Correlation	1.12/1.13	1.14/1.18	1.17/1.24
	VQ((6+4)+1+6) Transmit correlation	1.08/1.09	1.12/1.16	1.16/1.23
	6bit Rank-1 PMI	1/1	1/1	1/1
Two lambda/2 spaced cross-pols	Perfect Spatial Correlation	1.15/1.17	1.21/1.26	1.31/1.41
	Unquantized Spatial Correlation @ 6dB pre-combining	1.13/1.15	1.16/1.21	1.10/1.18
	Unquantized Spatial Correlation @ 0dB pre-combining	1.07/1.09	1.01/1.06	0.78/0.78
	16m(28) Transmit Correlation	1.11/1.12	1.13/1.15	1.17/1.21
	VQ((6+4)+1+4) Transmit correlation	1.08/1.09	1.12/1.14	1.18/1.24
	6bit Rank-1 PMI	1/1	1/1	1/1
Four lambda/2 spaced vertical-pols	Perfect Spatial Correlation	1.06/1.07	1.09/1.12	1.15/1.20
	Unquantized Spatial Correlation @ 6dB pre-combining	1.04/1.05	1.04/1.07	0.84/0.88
	Unquantized Spatial Correlation @ 0dB pre-combining	0.98/0.99	0.87/0.90	0.57/0.56
	16m(28) Transmit Correlation	1.03/1.04	1.04/1.05	1.03/1.06
	VQ(4+1+4) Transmit Correlation	1.01/1.01	1.04/1.04	1.07/1.08
	6bit Rank-1 PMI	1	1	1

8-Antenna BS results

8-Antenna Configuration	**Feedback Option**	**DL SNR [dB]**		
		0	**5**	**10**
		MMSE	*MMSE*	*MMSE*
Two clusters of 4-lambda spaced two lambda/2 spaced cross-pols [XX XX]	Perfect Spatial Correlation	1.52	1.58	1.71
	Perfect Rank-1	1.48	1.49	1.52
	Unquantized Rank-1 @ 6dB pre-combining	1.46	1.46	1.48
	Unquantized Rank-1 @ 0dB pre-combining	1.39	1.38	1.38
	16m(120) Transmit Correlation	1.47	1.49	1.40
	VQ(9+1+9) Transmit correlation	1.30	1.32	1.35
	4bit Rank-1 PMI	1	1	1
Four lambda/2 spaced cross-pols [XXXX]	Perfect Spatial Correlation	1.22	1.26	1.33
	Perfect Rank-1	1.21	1.22	1.23
	Unquantized Rank-1 @ 6dB pre-combining	1.18	1.18	1.18
	Unquantized Rank-1 @ 0dB pre-combining	1.12	1.11	1.09
	16m(120) Transmit Correlation	1.20	1.20	1.11
	VQ(8.6+1+8.6) Transmit Correlation	1.14	1.16	1.18
	4bit Rank-1 PMI	1	1	1
Eight lambda/2 spaced vertical-pols [||||||||]	Perfect Spatial Correlation	1.12	1.14	1.18
	Perfect Rank-1	1.1	1.10	1.09
	Unquantized Rank-1 @ 6dB pre-combining	1.08	1.07	1.05
	Unquantized Rank-1 @ 0dB pre-combining	1.02	1.0	0.97
	16m(120) Transmit Correlation	1.10	1.09	0.98
	VQ(6+1+4) Transmit Correlation	1.06	1.08	1.08
	4bit Rank-1 PMI	1	1	1