Closed-loop MIMO Precoding

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Purpose:

Introduce changes according to IEEEC80216e-04/293r1 in 802.16e/D4

Proposed precoding design

- Motivations
  - Real channels are not i.i.d but have some underline statistics

    Transmit correlation R_t and channel mean H_m → Precoder can exploit channel statistics

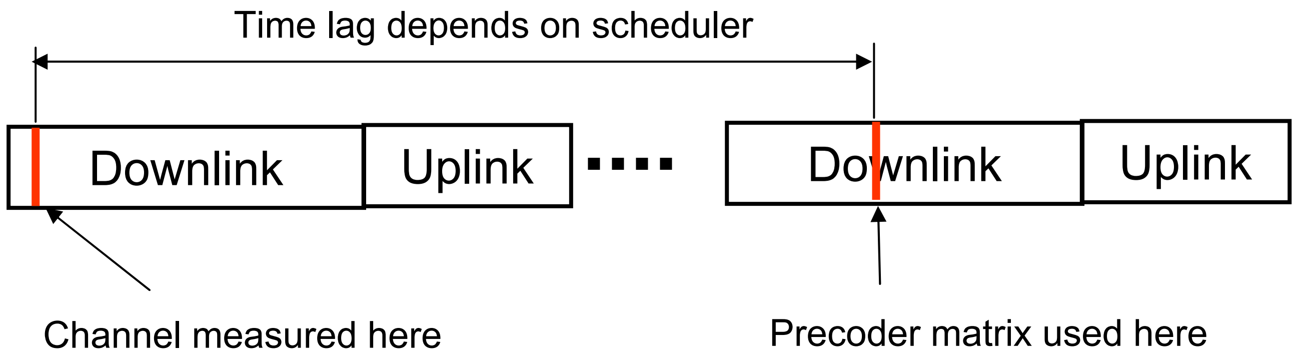
  - Instantaneous channel estimates will have some lags by the time it is used

    Hence precoder based on instantaneous channel estimate only may be not accurate (especially beamforming performance can be degraded severely)

- Information needed
  - Long-term channel statistics
  - Instantaneous channel estimates
  - Lag/aging measure

- Precoder design
  - Based on all the information given
  - Robust to channel measurement errors/lag

Why feedback Statistics?



- Statistics age very slowly, valid statistics are readily available
- Instantaneous channel estimate ages much faster, lag depends on scheduler
- If the correlation ρ between current channel and aged estimate drops below 0.6, the channel estimate should not be used
- Example: low mobility
  - Doppler spread 30Hz = 16.2km/h
  - Carrier frequency 2 GHz

$\rho=0.6 \rightarrow$ maximum lag 8.5 ms

➢ Even for low mobility statistics are very valuable

Feedbacks mechanism

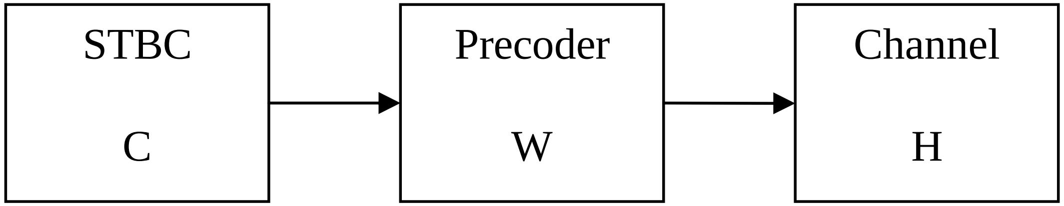
- The feedback information is per-user
  - Can interpolate between subcarriers if needed

- Long-term statistics (R_t and H_m) are on slow feedback
  - Very low data rate feedback
  - Can have separate message for this feedback, so only feedback as needed

- Instantaneous channel estimate feedback
  - Fast feedback channel (CQICH)
  - Feedback in term of singular values and singular vectors
  - Feedback of singular vectors using codebook of unitary matrices

  - Codebook design to accommodate partitioning, hence reduce the amount of feedback

Precoding properties



- Works with all space-time codes in the standards
- Covers from beamforming to diversity coding
- Transits smoothly from basing on pure instantaneous channel estimates to basing on long-term channel statistics

Outline of precoder design algorithm

- Precoding design algorithm for a given channel mean H_m and covariance R_t

$$W = f(H_m, R_t, SNR)$$

- Given aged channel estimate H_0

- With correlation factor ρ between H_0 and the true channel

$$\rho = J_0(2\pi f_d \Delta t)$$

- Apply the same algorithm with effective mean and covariance

$$H_{m,eff} = \rho H_0 + (1-\rho) H_m$$

$$R_{t,eff} = (1-\rho^2) R_t$$

Precoder function $W = f(H_m, R_t, SNR)$

- Form the matrices

$$\Psi = M^2 I_N + 4\upsilon R_t^{-1} H_m^* H_m R_t^{-1}$$

$$A = \frac{1}{2\upsilon}(MI_N + \Psi^{\frac{1}{2}}) - R_t$$

Solve for υ using power constraint (similar to water filling process)

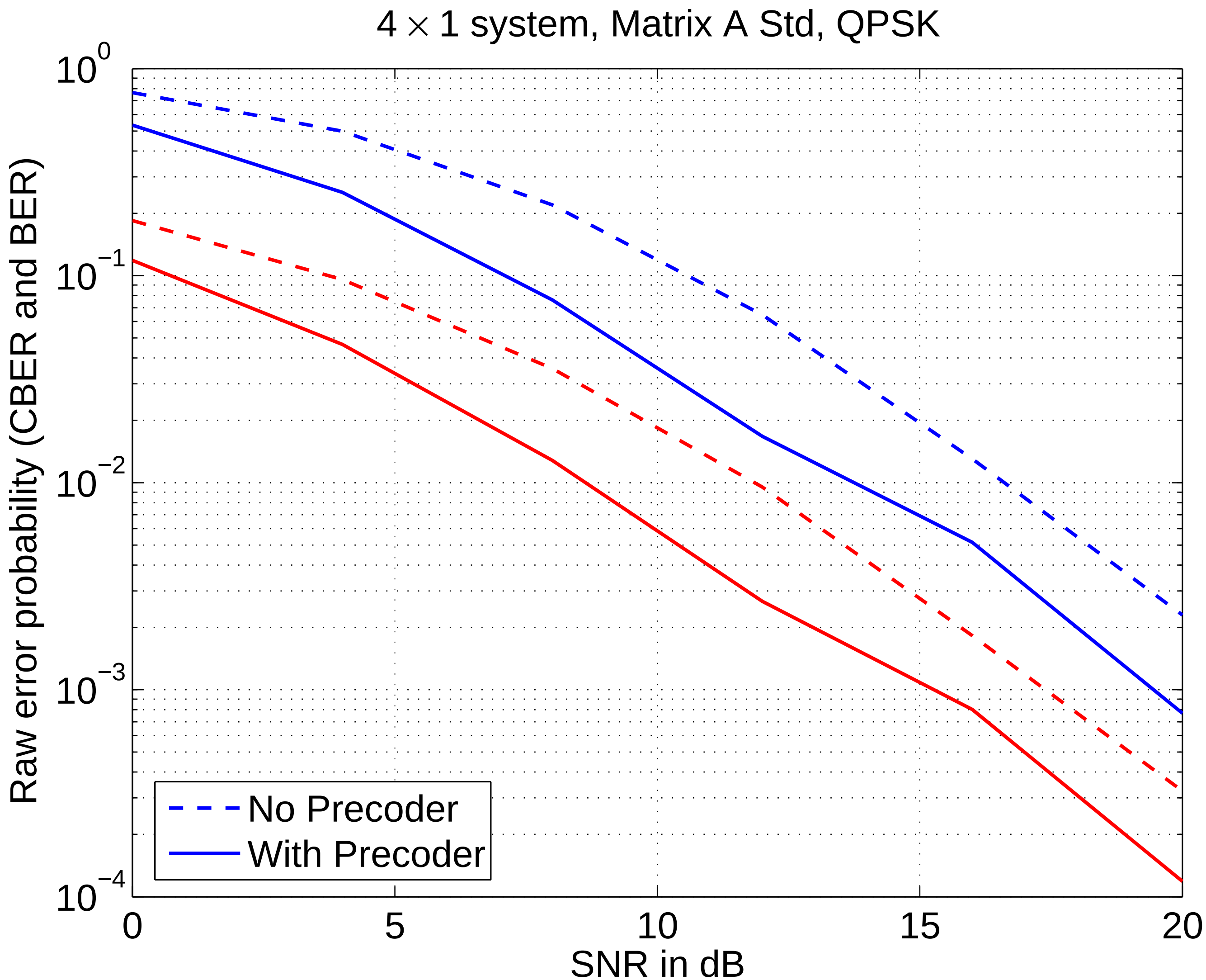
- Then the precoder is given by

$$W = V_A S_A^{1/2} P$$

where V_A and S_A are eigenvectors and eigenvalues of A. P is an orthogonal matrix specified per space-time code and antenna configuration.

Precoder based on long-term statistics

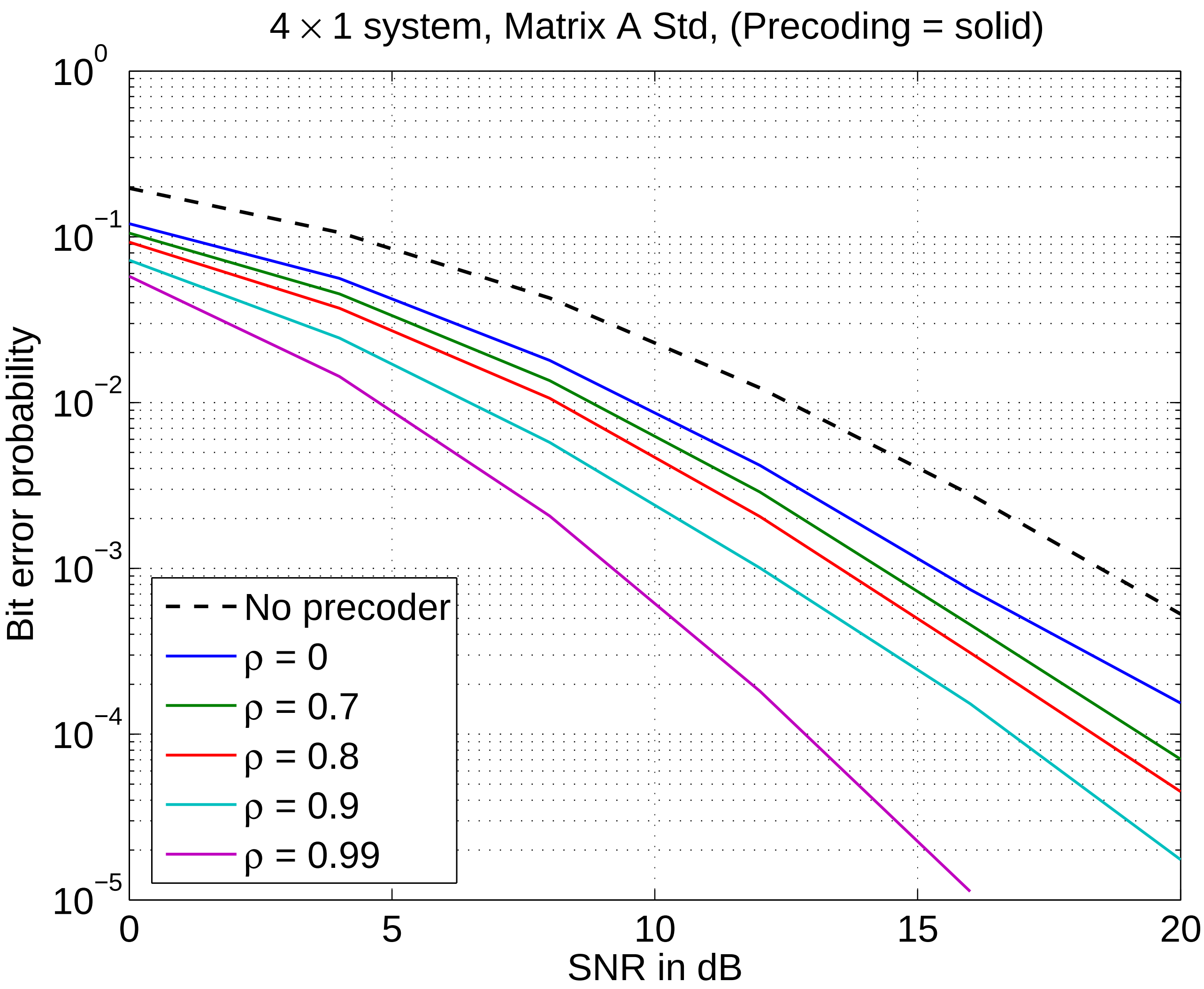
- 4x1 Standard STC Matrix A
- Single precoder over both frequencies
- Statistics channel knowledge
  - Non-zero mean
  - Arbitrary correlation
  - K factor = 0.1
  - (shown in the last page)



Precoder on channel estimates and statistics

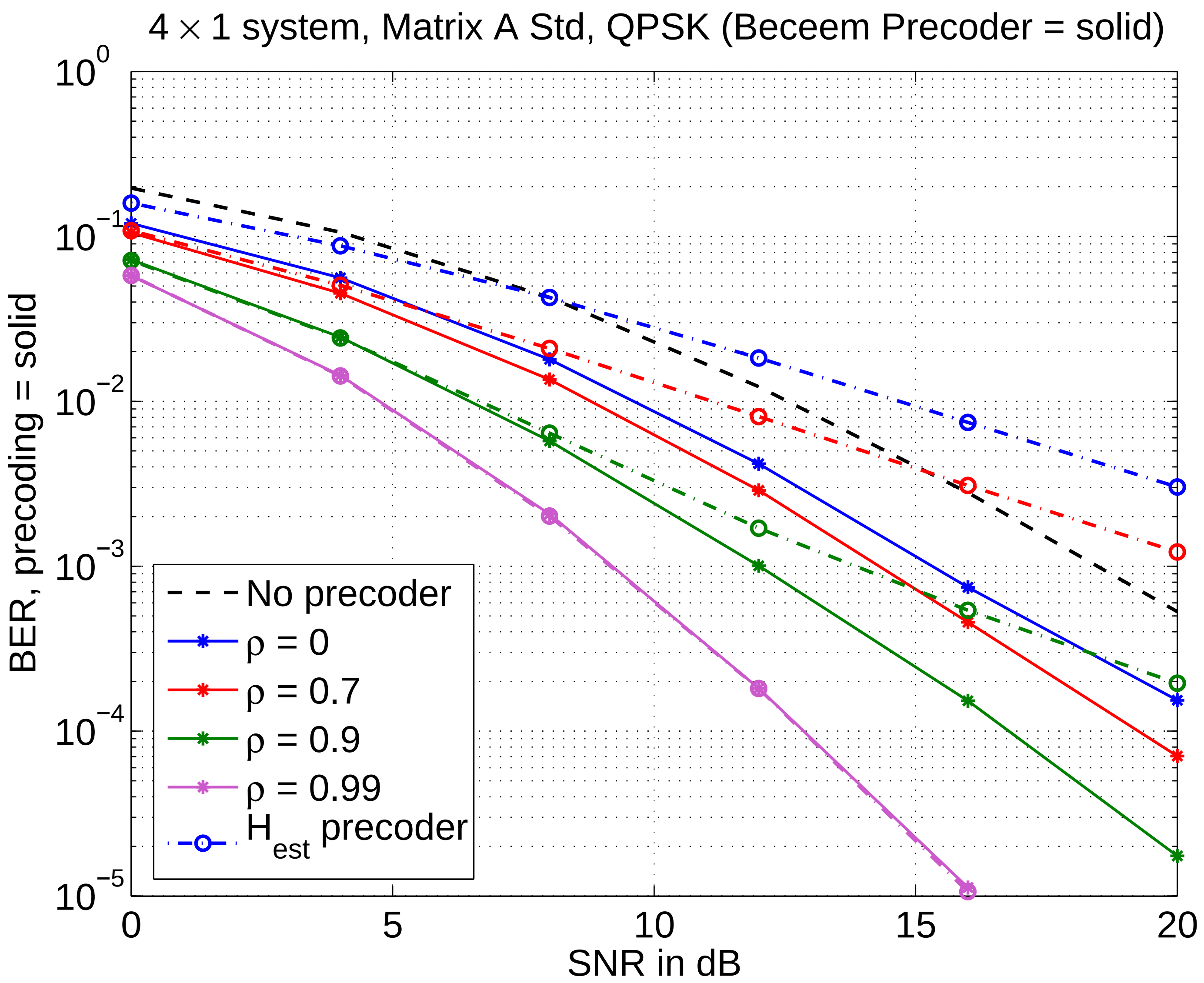
- 4x1 STC Standard Matrix A
- Instantaneous channel estimate
  - ρ is channel time correlation
- New channel statistics
  - Zero mean
  - Pair-wise antenna correlation 0.7

$$R_t = \begin{bmatrix} 1 & 0.7 & 0.49 & 0.343 \\ 0.7 & 1 & 0.7 & 0.49 \\ 0.49 & 0.7 & 1 & 0.7 \\ 0.343 & 0.49 & 0.7 & 1 \end{bmatrix}$$



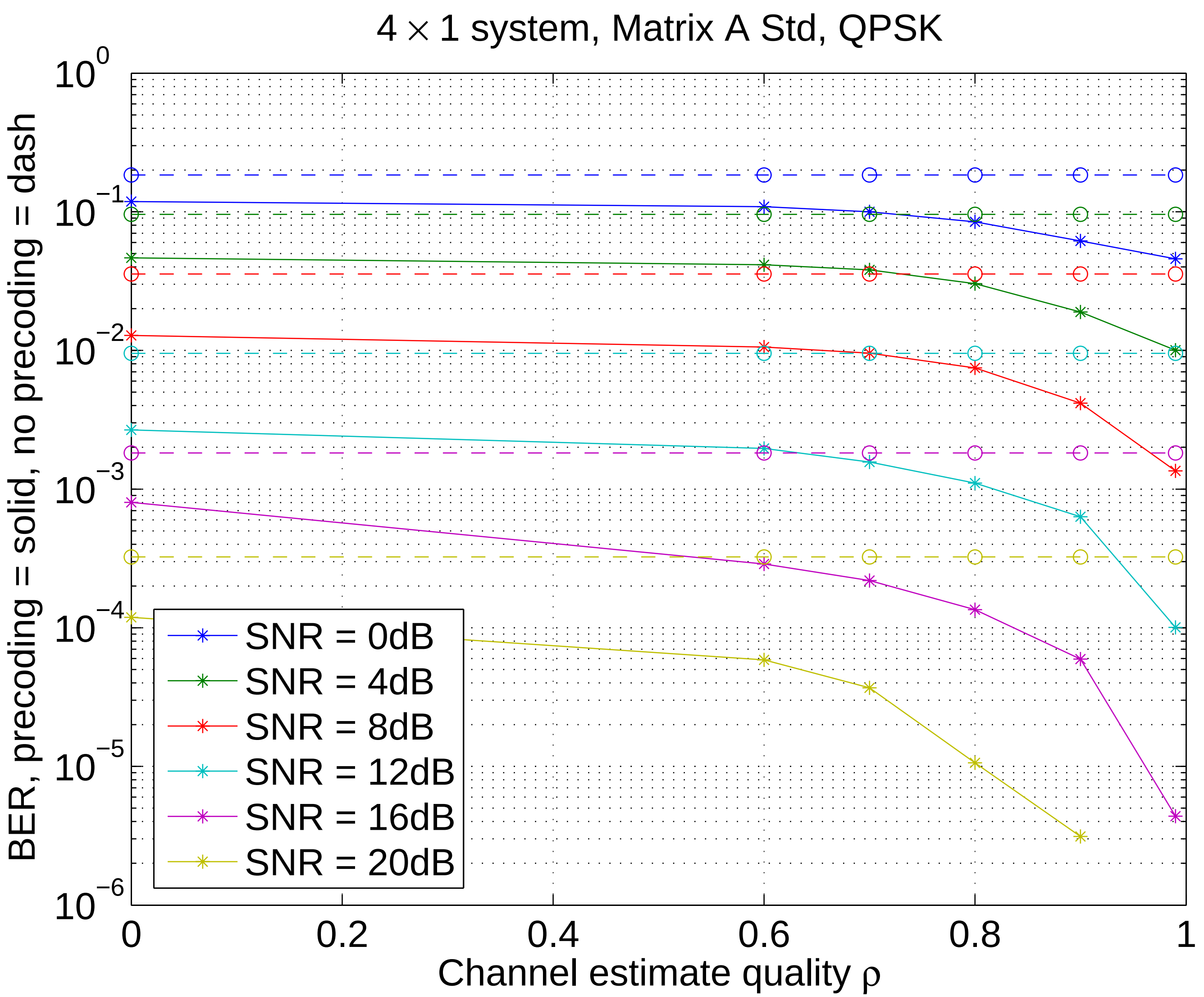
Comparison with channel estimate only design

- 4x1 STC Standard Matrix A
- Same channel as in the previous slide
- H_{est} precoder
  - Only use the (out-of-date) channel estimate to design W (i.e. beamforming in this case)



Correlation between estimate and true channel

- If correlation ρ is below 0.6, statistics information is good enough
- As correlation increases to 1, performance approaches perfect channel knowledge



Channel statistics used in previous slide

- The following channel statistics are used in slide 8 simulation

$$H_m = [-0.15 - 0.12i \quad -0.326 - 0.17i \quad -0.42 + 0.07i \quad 0.20 - 0.033i]$$

$$R_t = \begin{bmatrix} 1.32 & -0.55-0.23i & 0.49-0.46i & 0.103-0.41i \\ -0.55-0.23i & 0.43 & 0.013+0.31i & 0.068-0.074i \\ 0.49-0.46i & 0.013+0.31i & 0.68 & 0.0003-0.56i \\ 0.103-0.41i & 0.068-0.074i & 0.0003-0.56i & 1.56 \end{bmatrix}$$

- K factor = 0.1

- Results when combined with aged channel estimate is given here