Advanced MIMO-OFDM in Wireless Communications

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Motivation (Why)

Unrealistic channel fading (typical research) assumptions significantly distort performance indications.

1. Unrealistic:
   - Rayleigh fading
   - Rician fading with K fixed to typical value, or with uncorrelated AS and K-factor
   - Perfect channel knowledge.
2. Realistic:
   - Rician fading with correlated azimuth spread (AS) and K-factor
   - Existing channel estimation error.

Approach (How)

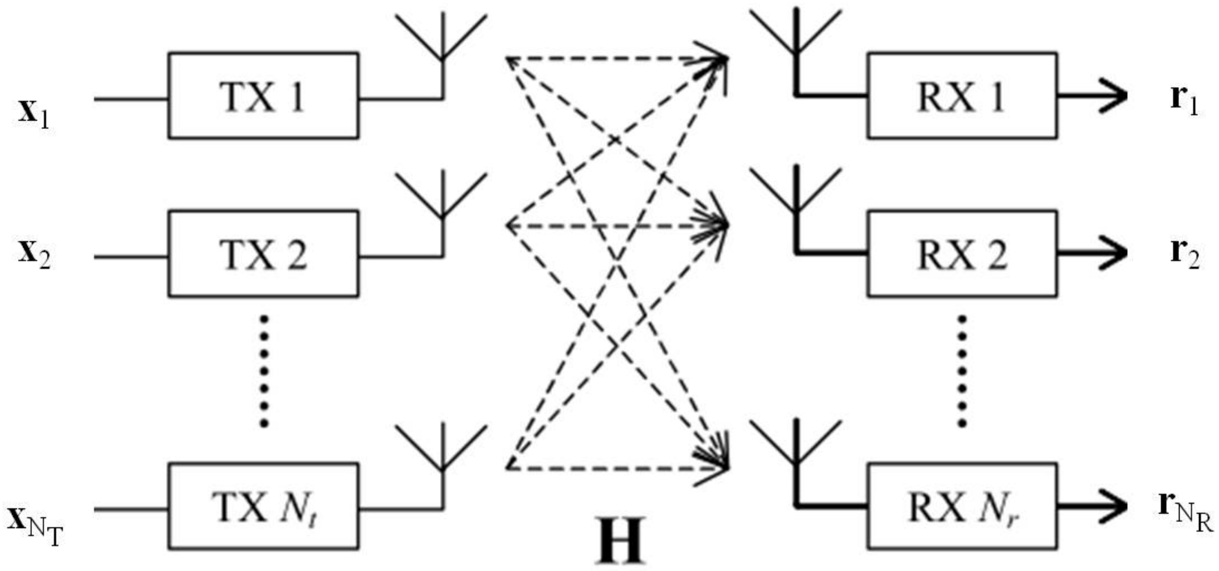
How we approach:

- Unrealistic – realistic: Study performance of MIMO systems for un/realistic assumptions with estimated ICSI
- Accuracy: Derive new error probability analysis for zero-forcing detected symbols with estimated ICSI
- Efficiency: Implement channel coding (LDPC code achieves Shannon limit performance)
- Reliability: Design soft iterative interference cancelation.

Presentation Outline

- MIMO sytem models
- Correlated AS and K-factor statistical models
- Zero-forcing detection
- MIMO-OFDM, iterative receiver.

MIMO Systems Models



- Multiple input multiple output (MIMO)
- Higher spectral efficiency and diversity
- Key technology for next-generation wireless communications.

Signal Models

MIMO with N_{T} transmit and N_{R} receive antennas can represent the received signals as:

$$\mathbf{r} = \sqrt{\frac{E_{\mathsf{s}}}{N_{\mathsf{T}}}}\mathbf{H}\mathbf{x} + \mathbf{n}, \quad \mathbf{n} \sim \mathcal{N}_{\mathsf{c}}(\mathbf{0}, N_0\,\mathbf{I}) \tag{1}$$

- $\mathbf{x}$: N_{T}-dimensional complex-valued vector
- $\mathbf{r}$: N_{R}-dimensional complex-valued vector
- $\frac{E_{\mathsf{s}}}{N_{\mathsf{T}}}$: energy transmitted per symbol and per antenna element.

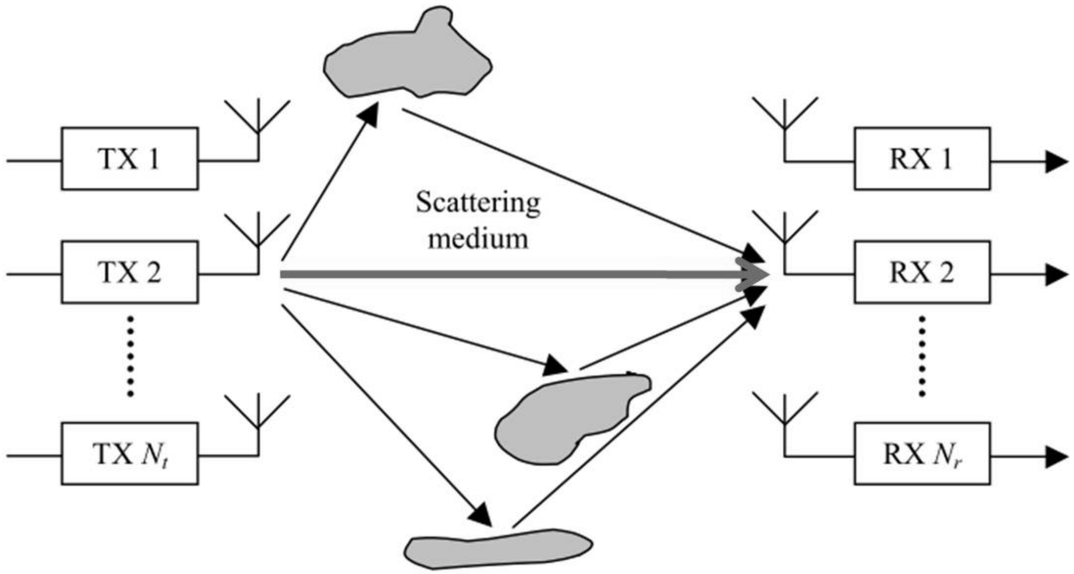
Channel Models

$\mathbf{H}$ is the $N_\mathsf{T} \times N_\mathsf{R}$ channel matrix with complex-valued Gaussian distributed elements with unit variance:

$$\mathbf{H} \;=\; \sqrt{\frac{K}{K+1}}\mathbf{H}_{\mathsf{d,n}} + \sqrt{\frac{1}{K+1}}\mathbf{H}_{\mathsf{r,n}}. \qquad (2)$$

- $\mathbf{H}_{\mathsf{d,n}}$: normalized deterministic components of the channel matrix (rank-one case/full-rank case)
- $\mathbf{H}_{\mathsf{r,n}}$: normalized random components of the channel matrix ($\mathbf{H}_{\mathsf{r,n}} = \mathbf{H}_w \mathbf{R}^{\frac{1}{2}}$)
- Rician K-factor: The power ratio of corresponding elements from $\mathbf{H}_{\mathsf{d,n}}$ and $\mathbf{H}_{\mathsf{r,n}}$ ($K = \frac{|[\mathbf{H}]_{i,j}|^2}{\mathbb{E}\{|[\mathbf{H}]_{i,j}|^2\}}$).

Channel Models



$K = 0$, channel fading is described by the Raleigh distribution

$K \neq 0$, channel fading is described by the Rician distribution.

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AS and K-factor statistical models

Table 1: Base-station AS and K statistics, WINNER II

Scenario	AS [°]	K	ρ
A1: indoor office/residential	$10^{1.64+0.31\chi}$	$10^{0.1(7+6\psi)}$	-0.6
B1: typical urban microcell	$10^{0.40+0.37\chi}$	$10^{0.1(9+6\psi)}$	-0.3
B3: large indoor hall	$10^{1.22+0.18\chi}$	$10^{0.1(2+3\psi)}$	$+0.2$
C1: suburban	$10^{0.78+0.12\chi}$	$10^{0.1(9+7\psi)}$	$+0.2$
C2: typical urban macrocell	$10^{1.00+0.25\chi}$	$10^{0.1(7+3\psi)}$	$+0.1$
D1: rural macrocell	$10^{0.78+0.21\chi}$	$10^{0.1(7+6\psi)}$	$+0.0$
D2a: rural, high-speed	$10^{0.70+0.31\chi}$	$10^{0.1(7+6\psi)}$	$+0.0$

Correlation coefficient Eqn.

$$\psi = \rho \cdot \chi + \sqrt{1-\rho^2} \cdot \omega; \quad \omega \sim \mathcal{N}(0,1). \tag{3}$$

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Zero-forcing detection

- Conventional ZF detection approach: given the estimate $\mathbf{G}$ of $\mathbf{H}$

$$\left[\mathbf{G}^{\mathcal{H}}\mathbf{G}\right]^{-1}\mathbf{G}^{\mathcal{H}}\mathbf{r} = \mathbf{x} + \left[\mathbf{G}^{\mathcal{H}}\mathbf{G}\right]^{-1}\mathbf{G}^{\mathcal{H}}\mathbf{n}. \tag{4}$$

- Employs the channel matrix estimate as if it were the true channel matrix
- Does not use the channel and noise statistics.

Zero-forcing detection

- Channel matrix is re-written as:

$$\mathbf{H} = \mathbf{H}_{\mathsf{m}} + \mathbf{H}_{\mathsf{e}}, \tag{5}$$

- The received signal vector becomes:

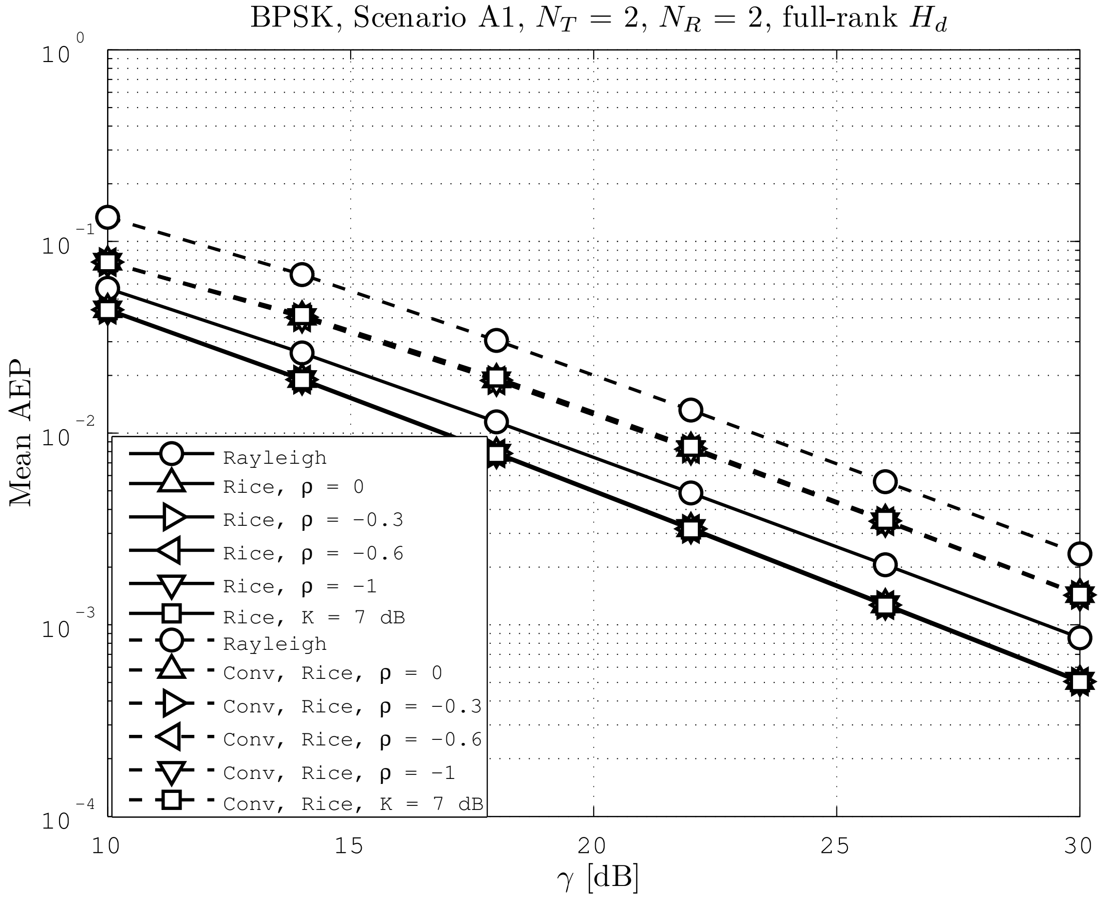
$$\mathbf{r} = \sqrt{\frac{E_{\mathsf{s}}}{N_{\mathsf{T}}}}\mathbf{H}_{\mathsf{m}}\mathbf{x} + \underbrace{\sqrt{\frac{E_{\mathsf{s}}}{N_{\mathsf{T}}}}\mathbf{H}_{\mathsf{e}}\mathbf{x} + \mathbf{n}}_{\boldsymbol{\nu}}, \tag{6}$$

where $\boldsymbol{\nu}$ denotes the effective noise, comprising channel estimation error and actual noise.

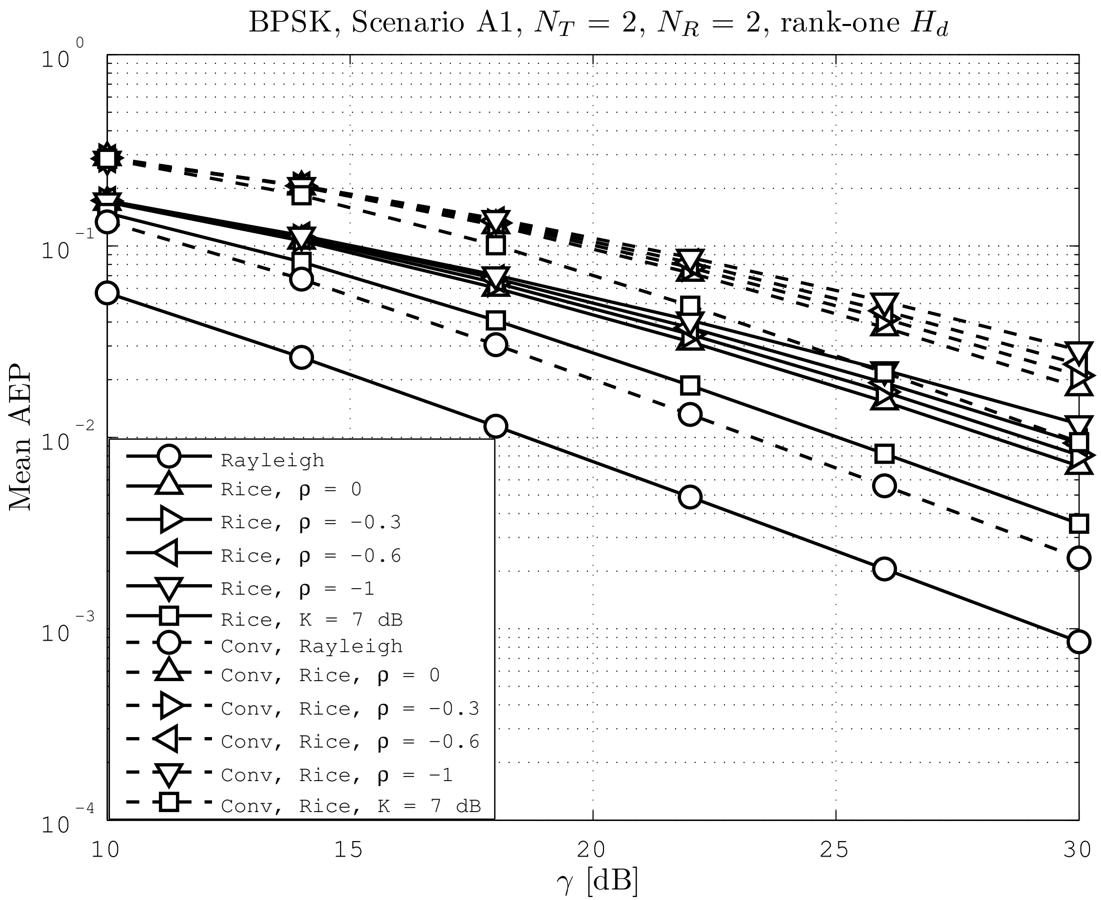
- New ZF detection approach: replace $\mathbf{G}$ with $\mathbf{H}_{\mathsf{m}}$

$$\left[\mathbf{H}_{\mathsf{m}}^{\mathcal{H}}\mathbf{H}_{\mathsf{m}}\right]^{-1}\mathbf{H}_{\mathsf{m}}^{\mathcal{H}}\mathbf{r} = \mathbf{x} + \left[\mathbf{H}_{\mathsf{m}}^{\mathcal{H}}\mathbf{H}_{\mathsf{m}}\right]^{-1}\mathbf{H}_{\mathsf{m}}^{\mathcal{H}}\boldsymbol{\nu}. \tag{7}$$

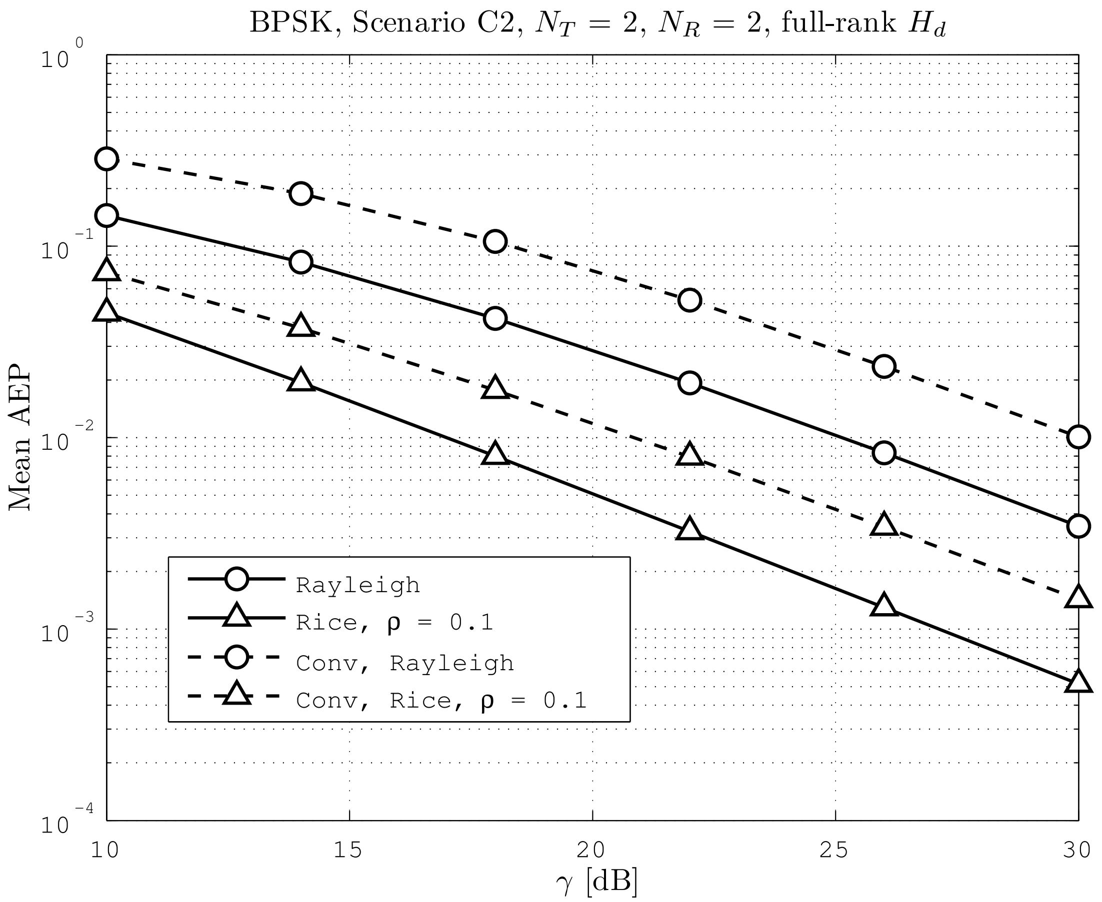
Performance for 2×2 MIMO (Indoor office/Residential, full-rank)



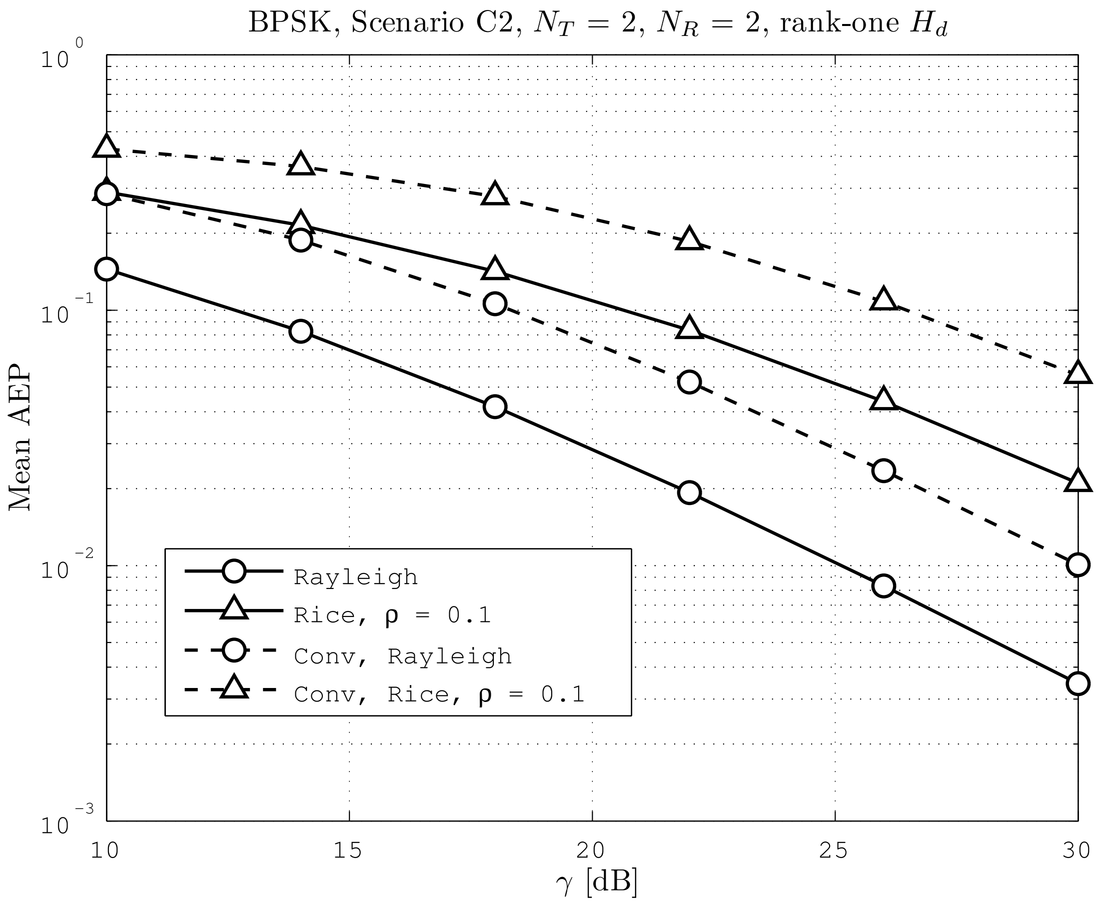
Performance for 2×2 MIMO (Indoor office/Residential, rank-one)



Performance for 2×2 MIMO (Typical urban macrocell, full-rank)



Performance for 2×2 MIMO (Typical urban macrocell, rank-one)



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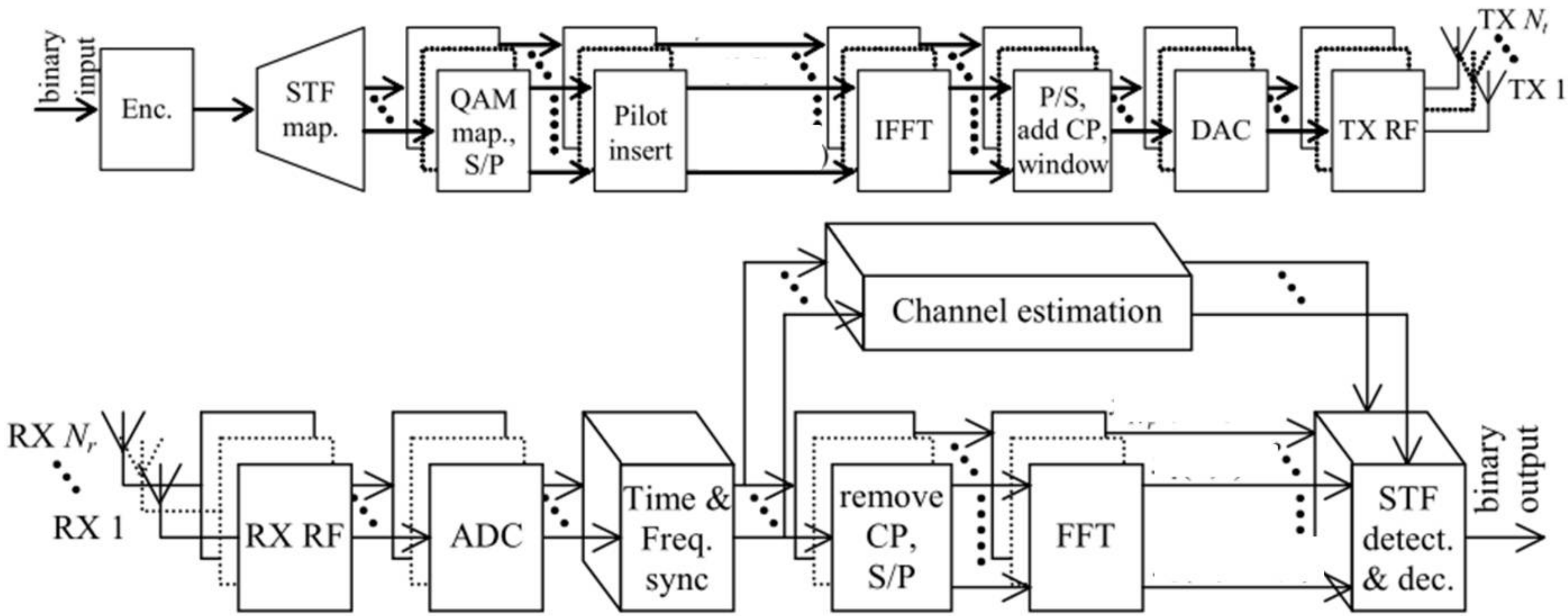
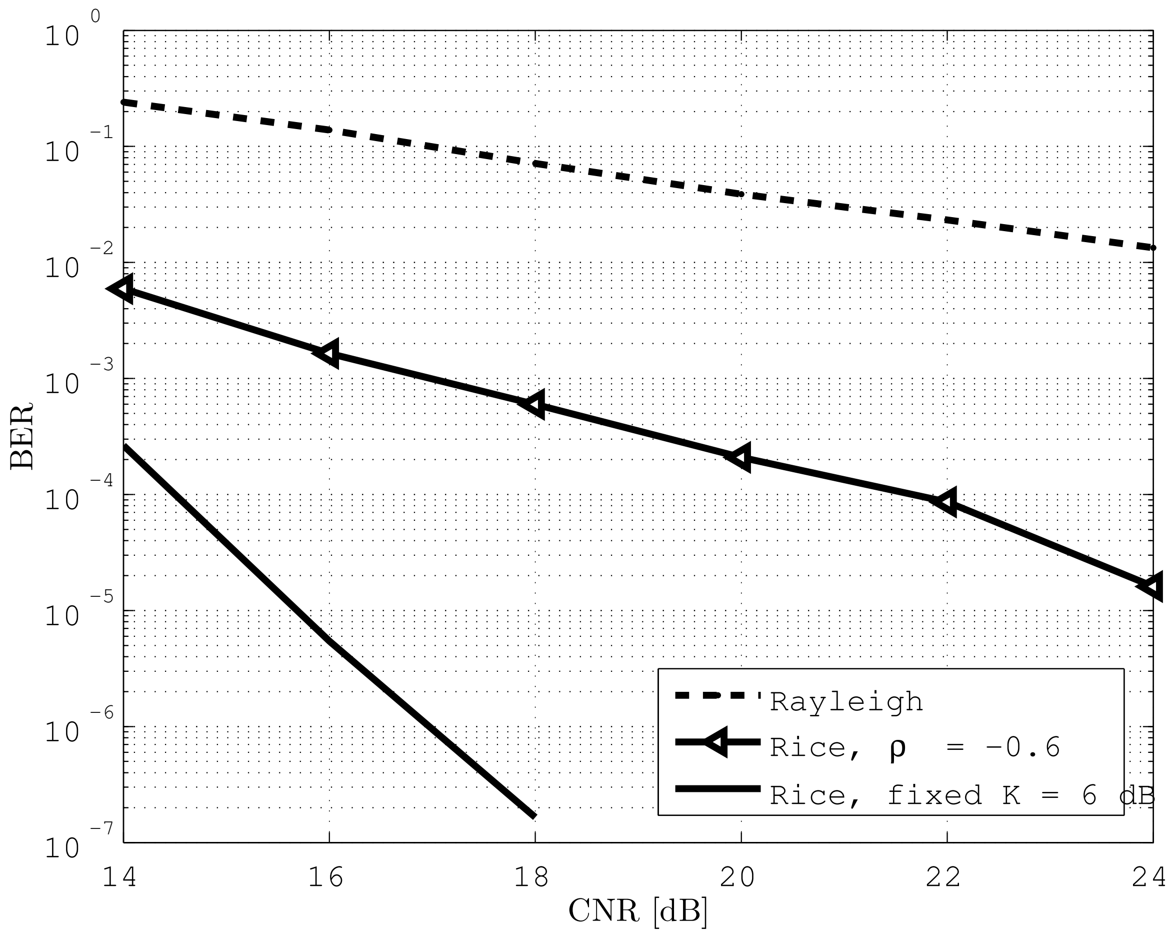
MIMO-OFDM

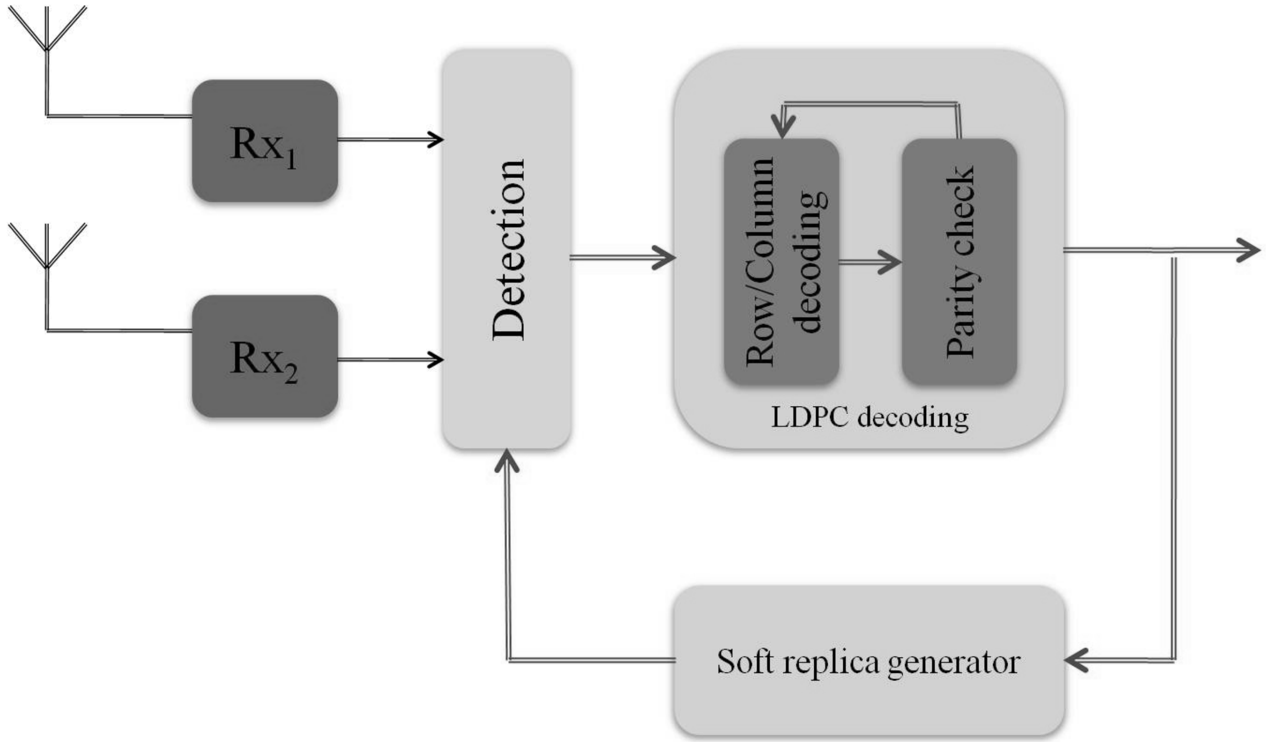


- OFDM: specific orthogonality constraints between multi-carrier ; achieves high spectral efficient
- MIMO-OFDM: Provide basis for next-generation wireless communications systems (Potential application areas–WLANs).

Performance for 4×4 MIMO-OFDM Iterative Receiver (Indoor office/Residential)

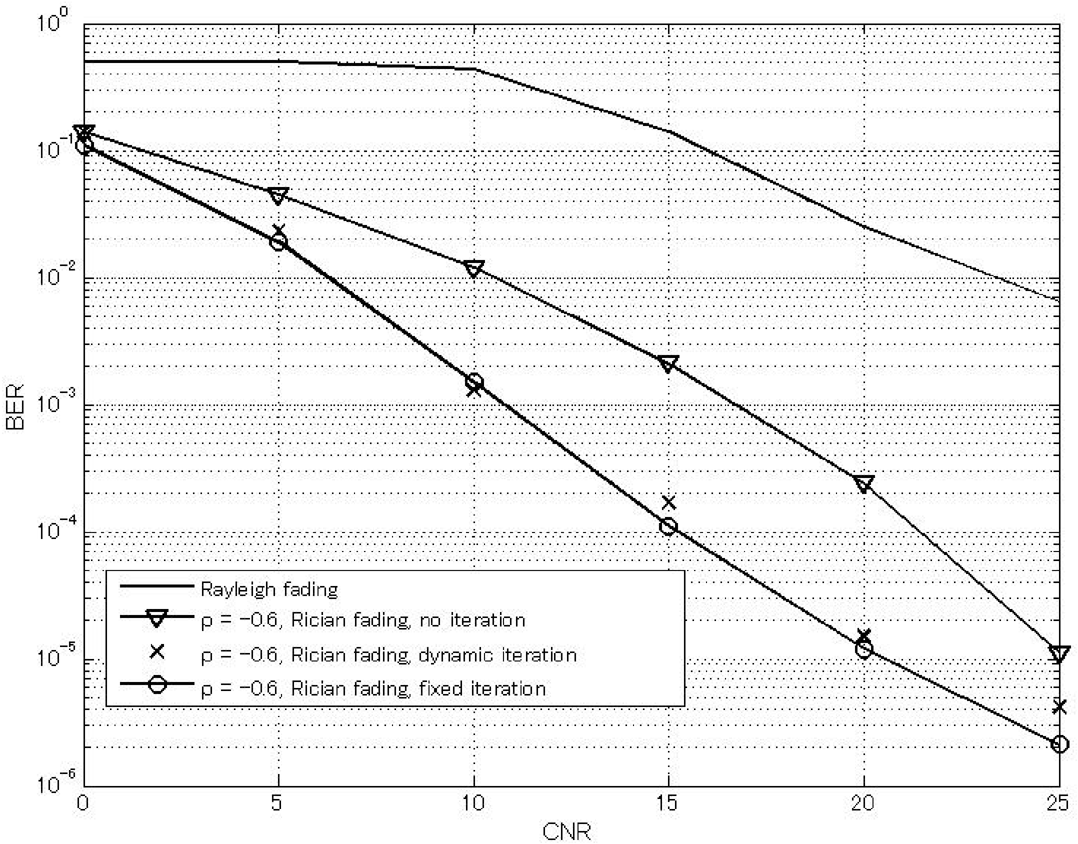


Iterative receiver



- Iterative receiver: Feasible to approach BER performance

Performance for 4×4 MIMO-OFDM Iterative Receiver (Indoor office/Residential)



Future Work – Multi-user MIMO(OFDM)

- Construct multi-user MIMO(OFDM) system by explored knowledge for realistic channel model
- Capture the serious effect of AS and K-factor correlation on the performance indications
- Optimal (mobile) receiver design with obtained channel information
- Feedback complexity reduction with reliability channel conditions information.