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SU-MIMO SVD DigCom System

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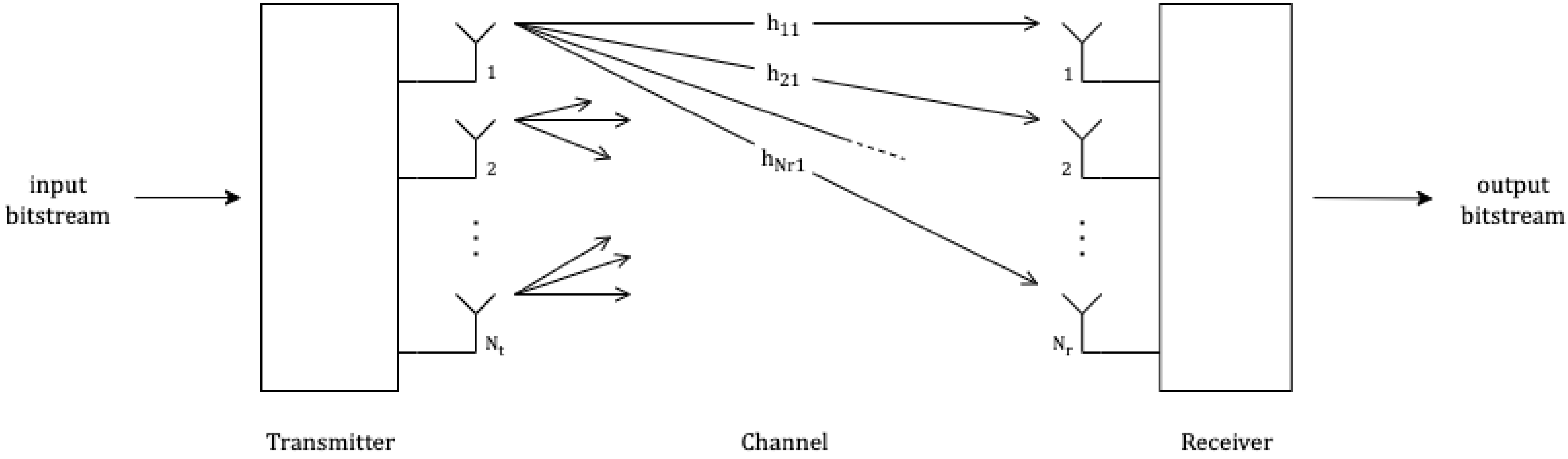
Introduction



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The Channel SVD

A Decomposition into R_H parallel eigenchannels.

- The received signal $\mathbf{y}$ can be written in terms of the transmitted signal $\mathbf{x}$ as:

$$\mathbf{y} = \mathbf{H} \cdot \mathbf{x} + \mathbf{w}$$

- The Singular-Value-Decomposition (SVD) of the channel matrix $\mathbf{H}$:

$$\mathbf{H} = \mathbf{U} \cdot \mathbf{S} \cdot \mathbf{V}^{\mathrm{H}}$$

- Precoding at the transmitter and combining at the receiver:

Precoding: $\mathbf{x} = \mathbf{V} \cdot \tilde{\mathbf{x}}$

Combining: $\tilde{\mathbf{y}} = \mathbf{U}^{\mathbf{H}} \cdot \mathbf{y}$

The Channel SVD

A Decomposition into R_H parallel eigenchannels.

$$\mathbf{y} = \mathbf{H} \cdot \mathbf{x} + \mathbf{w}$$

$$\Leftrightarrow \mathbf{y} = (\mathbf{U} \cdot \mathbf{S} \cdot \mathbf{V}^{\mathrm{H}}) \cdot \mathbf{x} + \mathbf{w}$$

$$\Leftrightarrow \tilde{\mathbf{y}} = \mathbf{U}^{\mathbf{H}} \cdot ((\mathbf{U} \cdot \mathbf{S} \cdot \mathbf{V}^{\mathrm{H}}) \cdot (\mathbf{V} \cdot \tilde{\mathbf{x}}) + \mathbf{w})$$

$$\Leftrightarrow \tilde{\mathbf{y}} = \mathbf{U}^{\mathbf{H}} \cdot \mathbf{U} \cdot \mathbf{S} \cdot \mathbf{V}^{\mathrm{H}} \cdot \mathbf{V} \cdot \tilde{\mathbf{x}} + \mathbf{U}^{\mathbf{H}} \cdot \mathbf{w}$$

$$\Leftrightarrow \tilde{\mathbf{y}} = \mathbf{S} \cdot \tilde{\mathbf{x}} + \mathbf{U}^{\mathbf{H}} \cdot \mathbf{w}$$

$$\boxed{\tilde{\mathbf{y}} = \mathbf{S} \cdot \tilde{\mathbf{x}} + \tilde{\mathbf{w}}}$$

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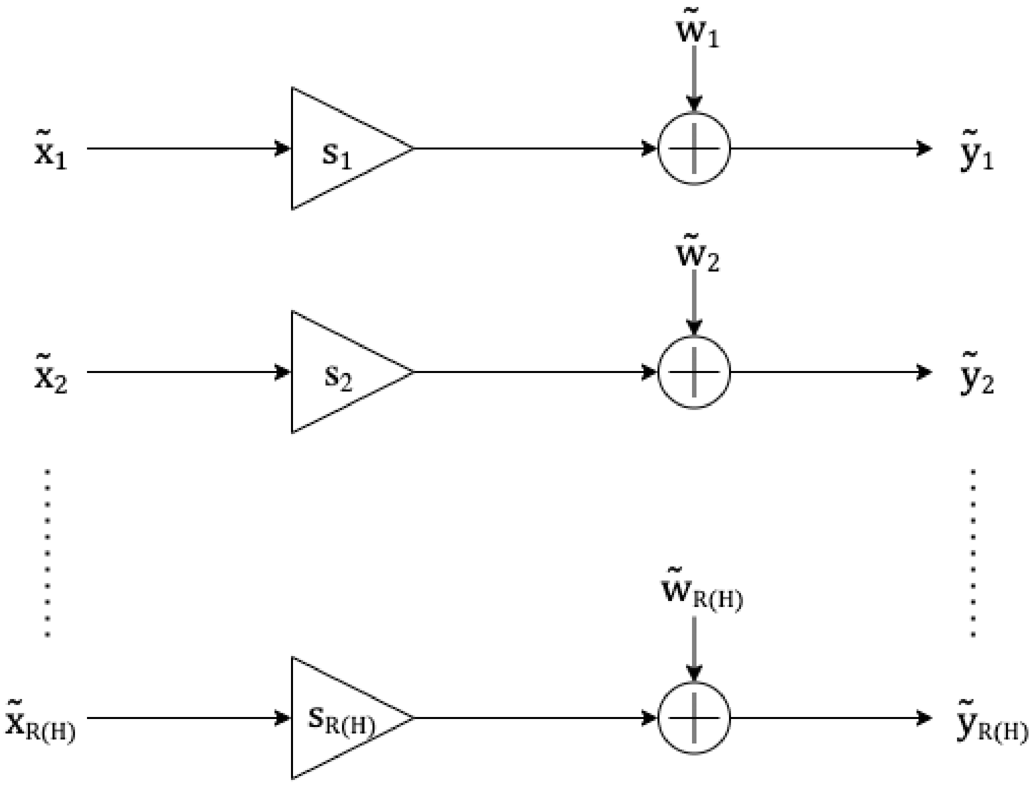
The Channel SVD

A Decomposition into R_H parallel eigenchannels.



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Resource Allocation

How are power and bits allocated across the antennas?

Power Allocation

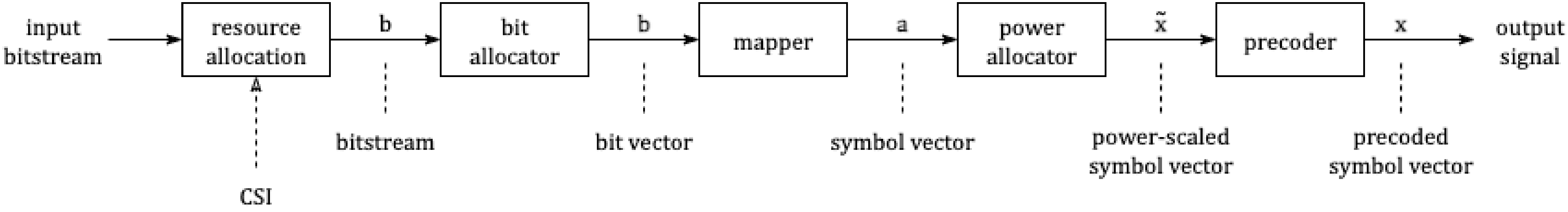
- **Optimal**
  - Waterfilling Algorithm
  - CSI Required
- **Equal**
  - No Waterfilling Algorithm
  - No CSI Required
- **Eigenbeamforming**
  - No Waterfilling Algorithm
  - No CSI Required

Bit Allocation

- **Adaptive**
  - Eigenchannel Capacity Calculation
- **Fixed**
  - No Eigenchannel Capacity Calculation

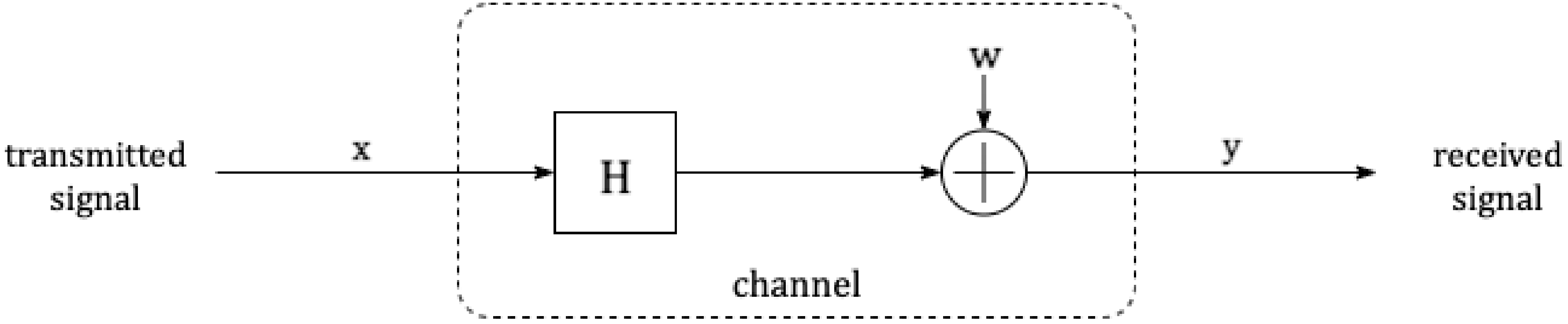
System Design

The Transmitter



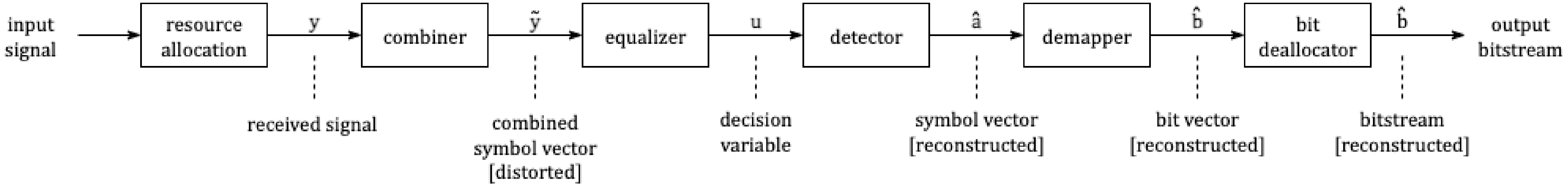
System Design

The Channel

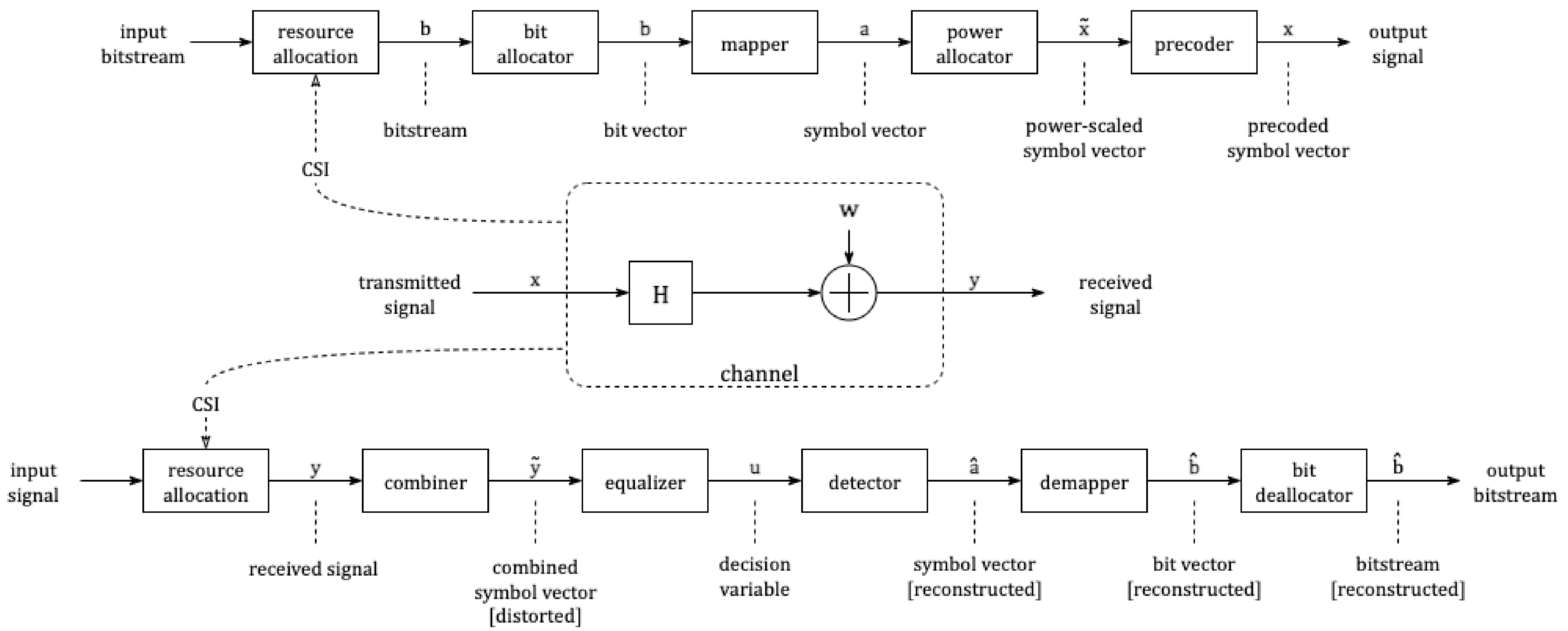


System Design

The Receiver



System Design – Overview



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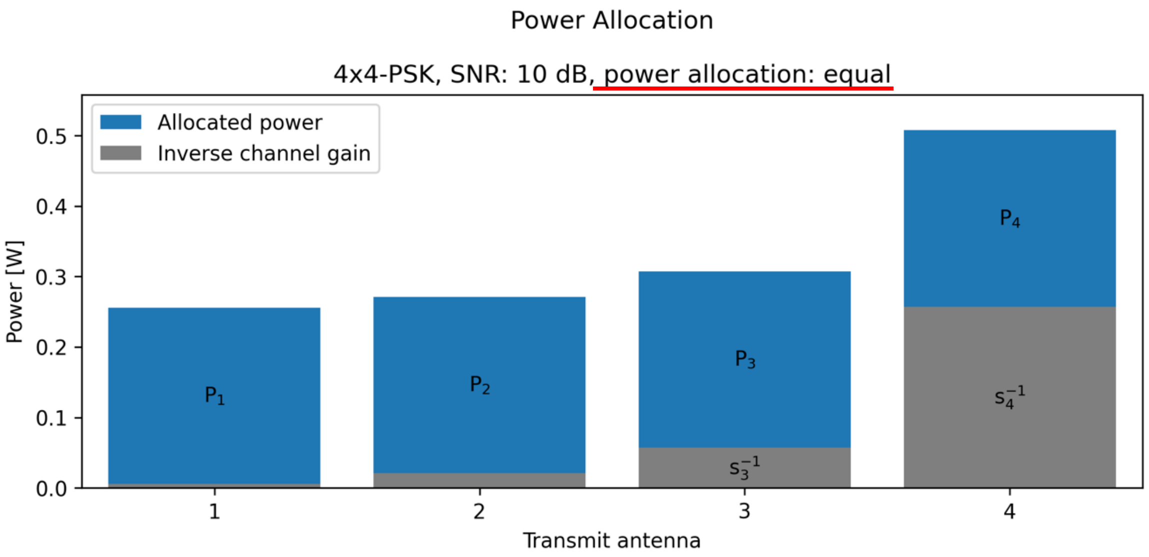
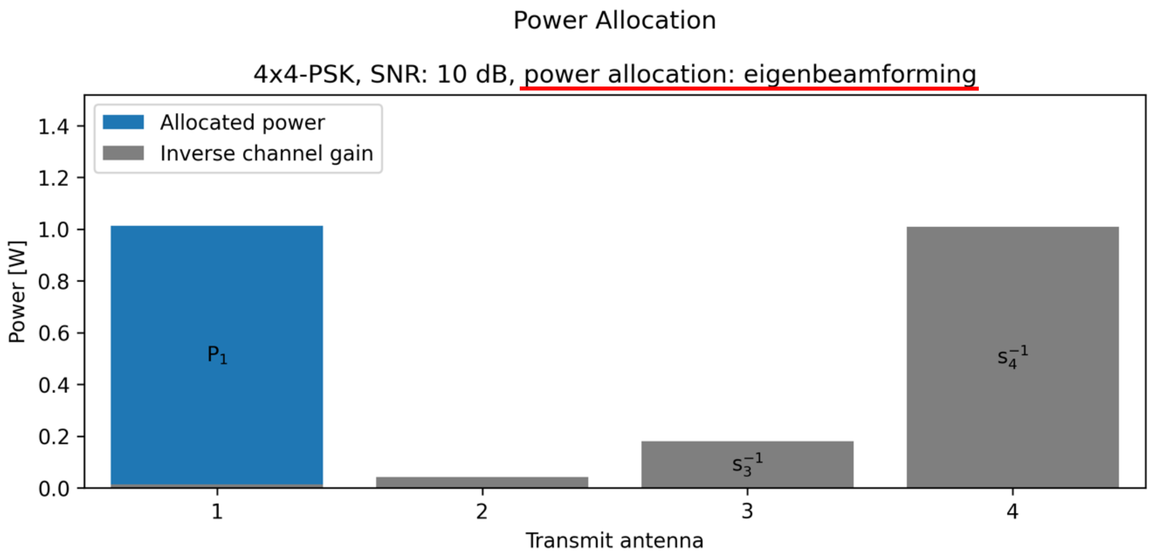
Resource Allocation

Equal Power Allocation & Eigenbeamforming





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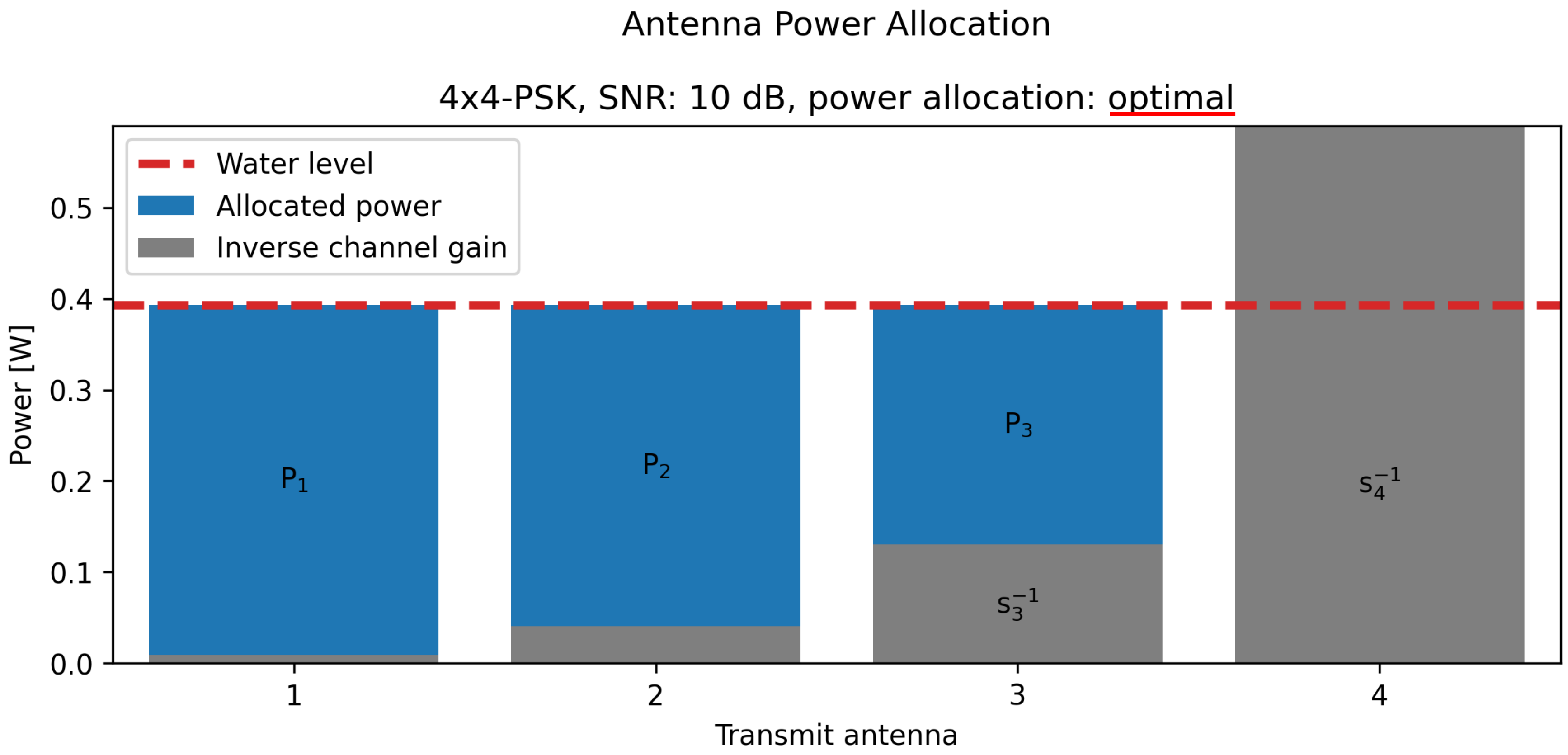
Resource Allocation

Optimal Power Allocation - A Visualisation of the Waterfilling Algorithm



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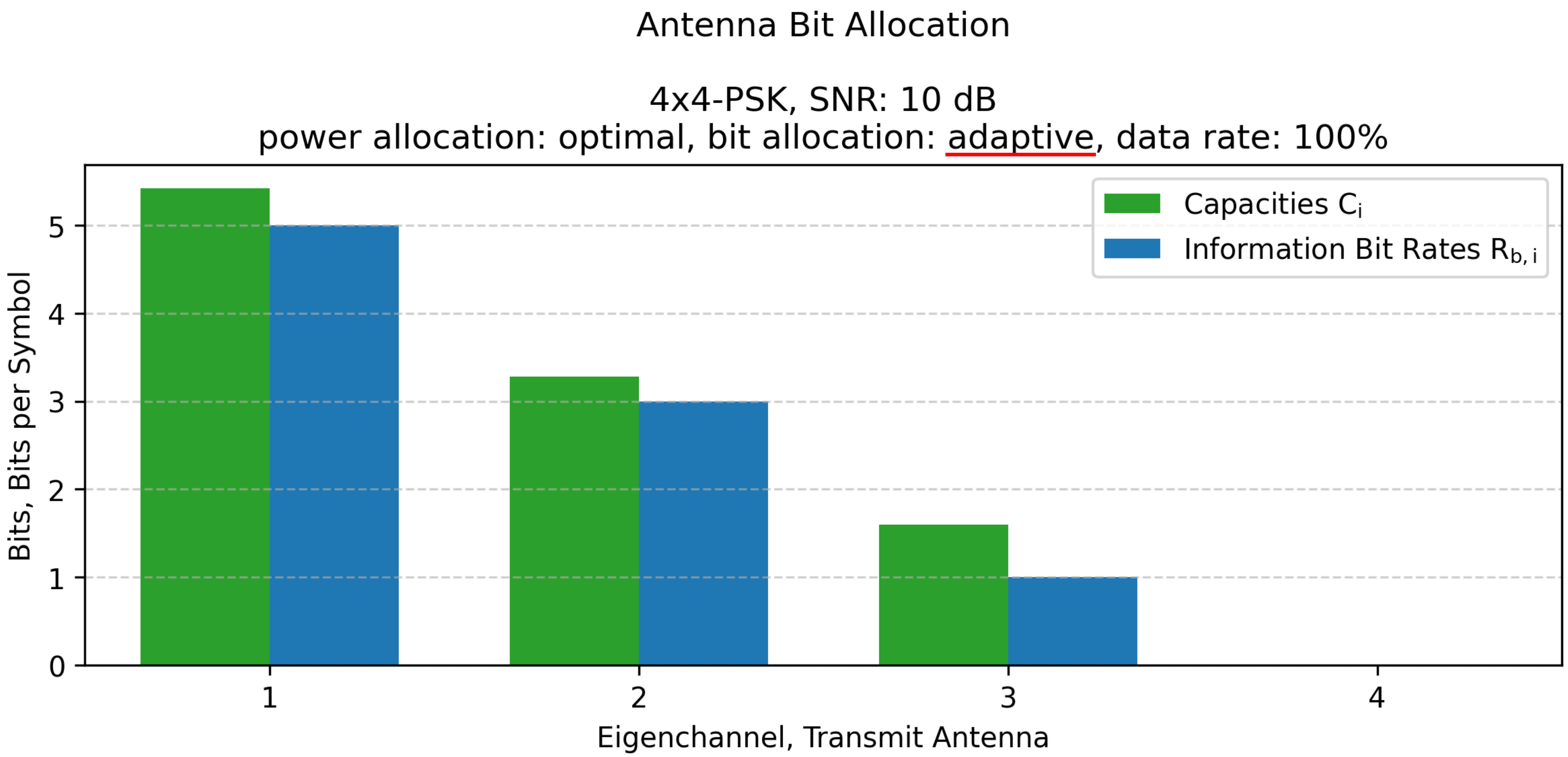
Resource Allocation

Adaptive Bit Allocation - A Visualisation of the Eigenchannel Capacities C_i & Antenna Information Bit Rates $R_{b,i}$



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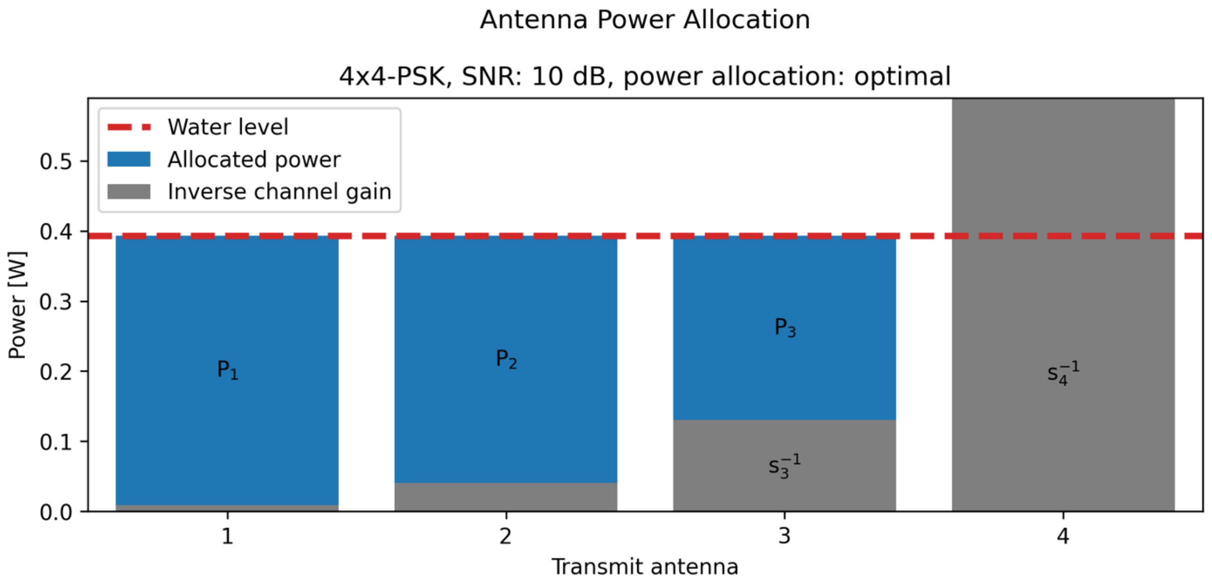
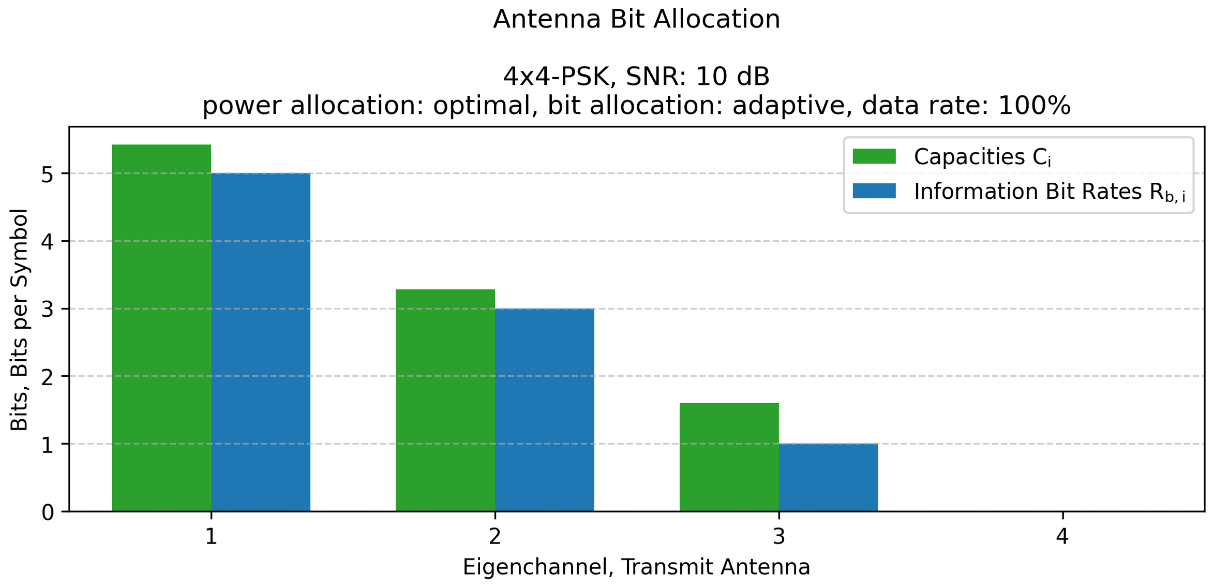
Resource Allocation

Optimal Power Allocation & Adaptive Bit Alocation





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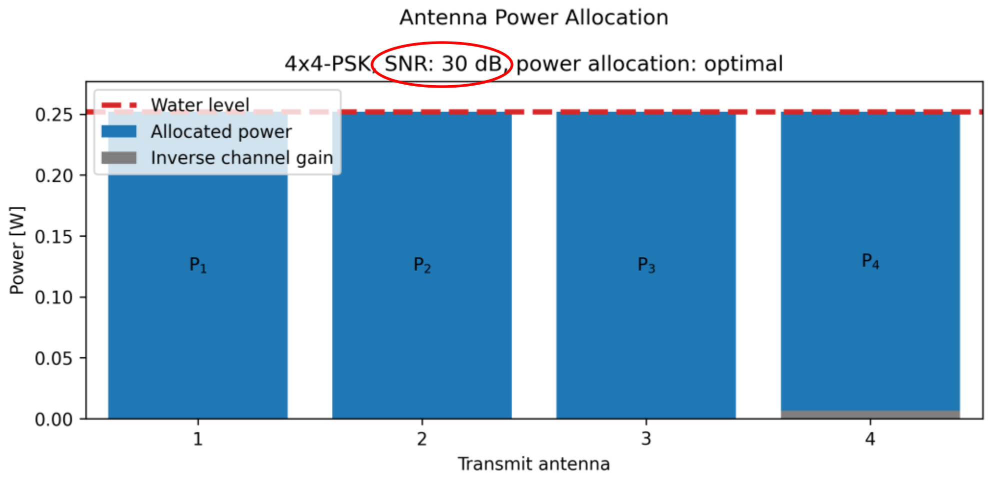
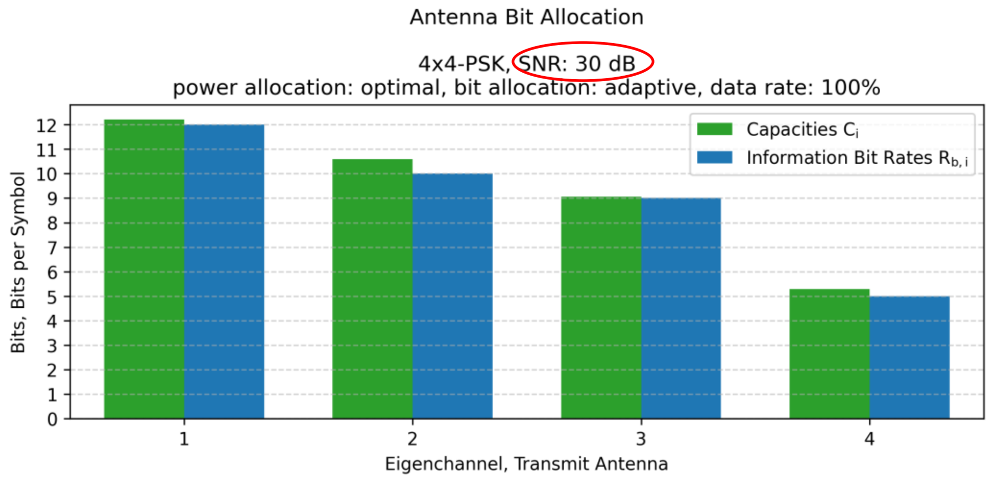
Resource Allocation

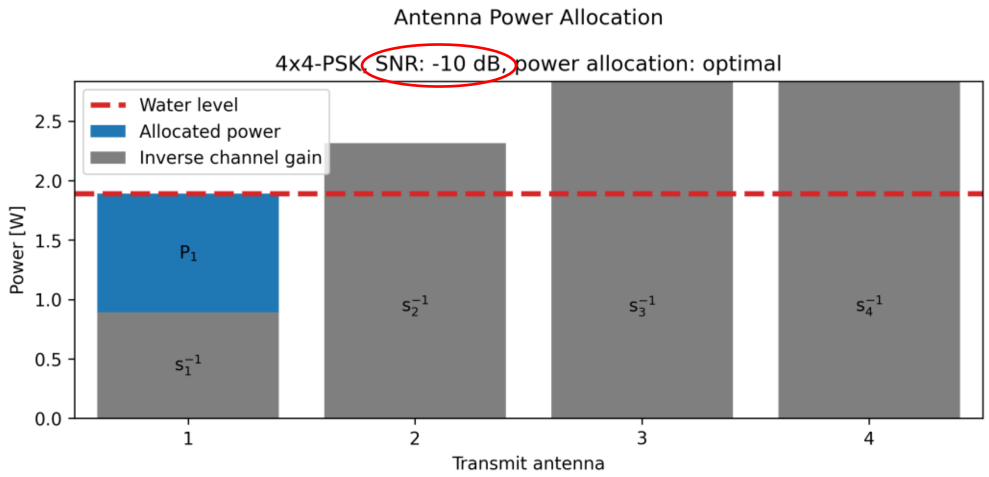
Optimal Resource Allocation at SNR Extremes

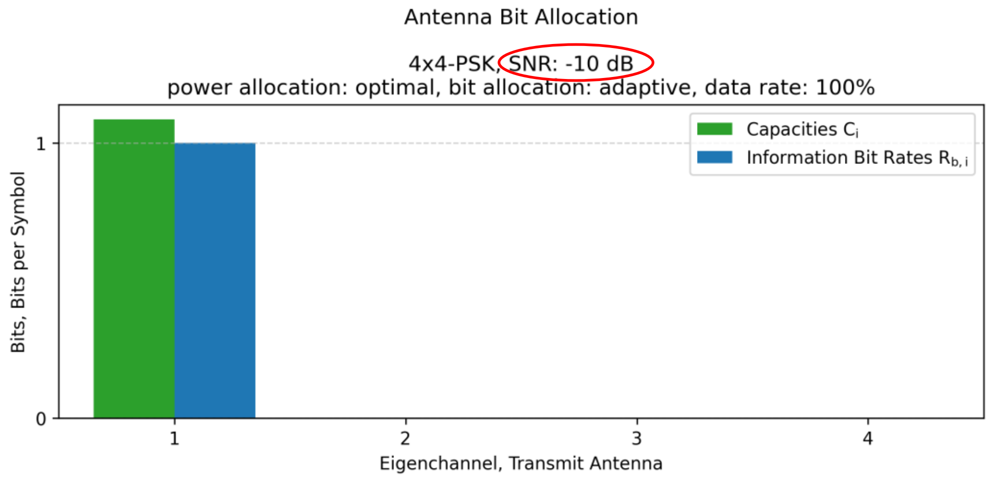
$\text{SNR} = 30$ dB





$\text{SNR} = -10$ dB





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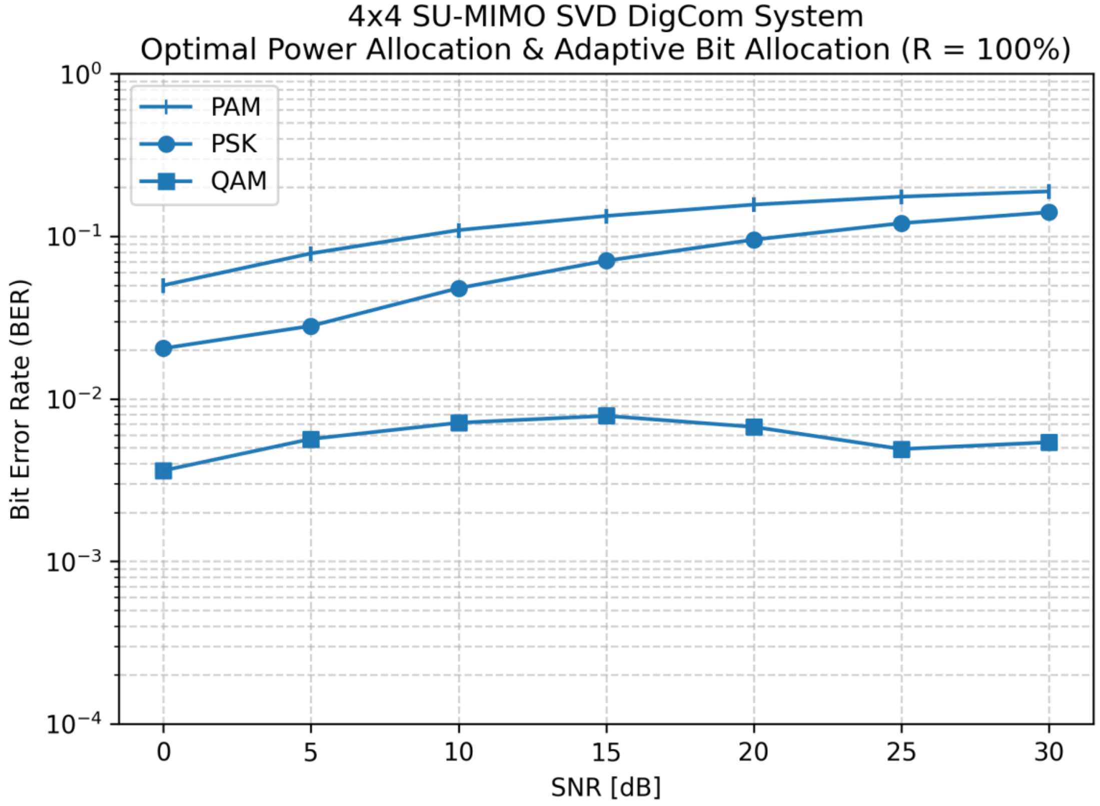
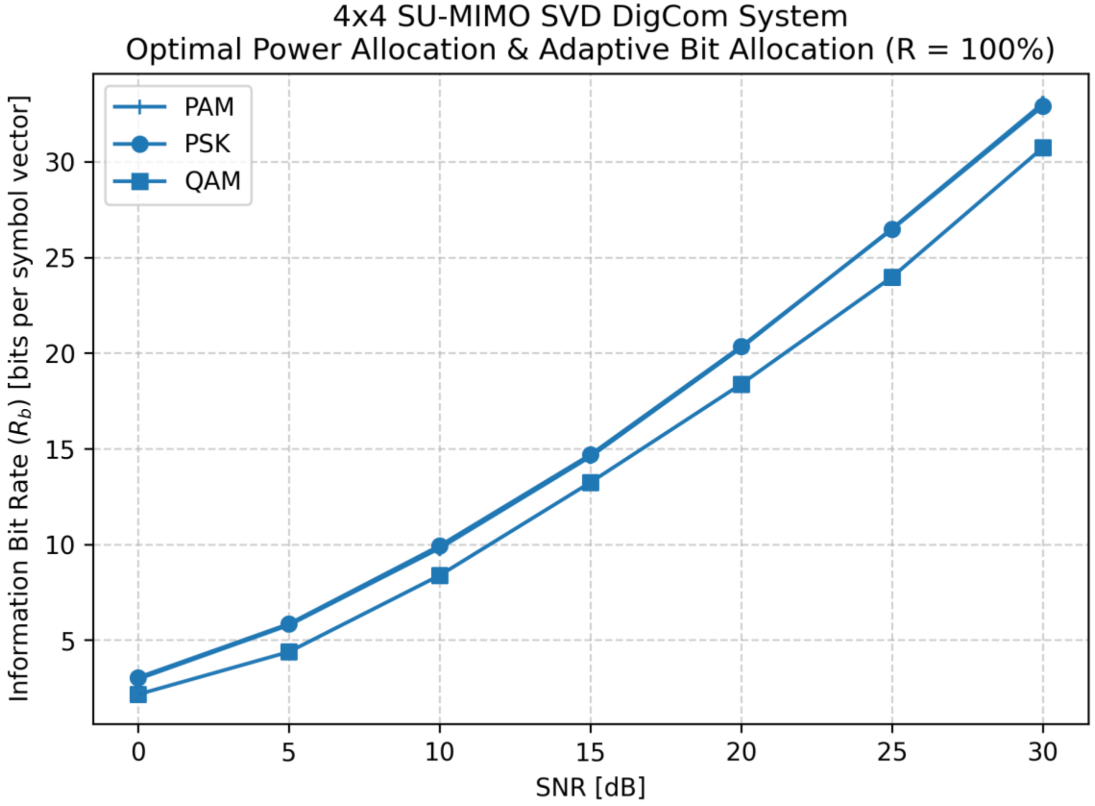
Simulation Results

Optimal Power Allocation & Adaptive Bit Allocation





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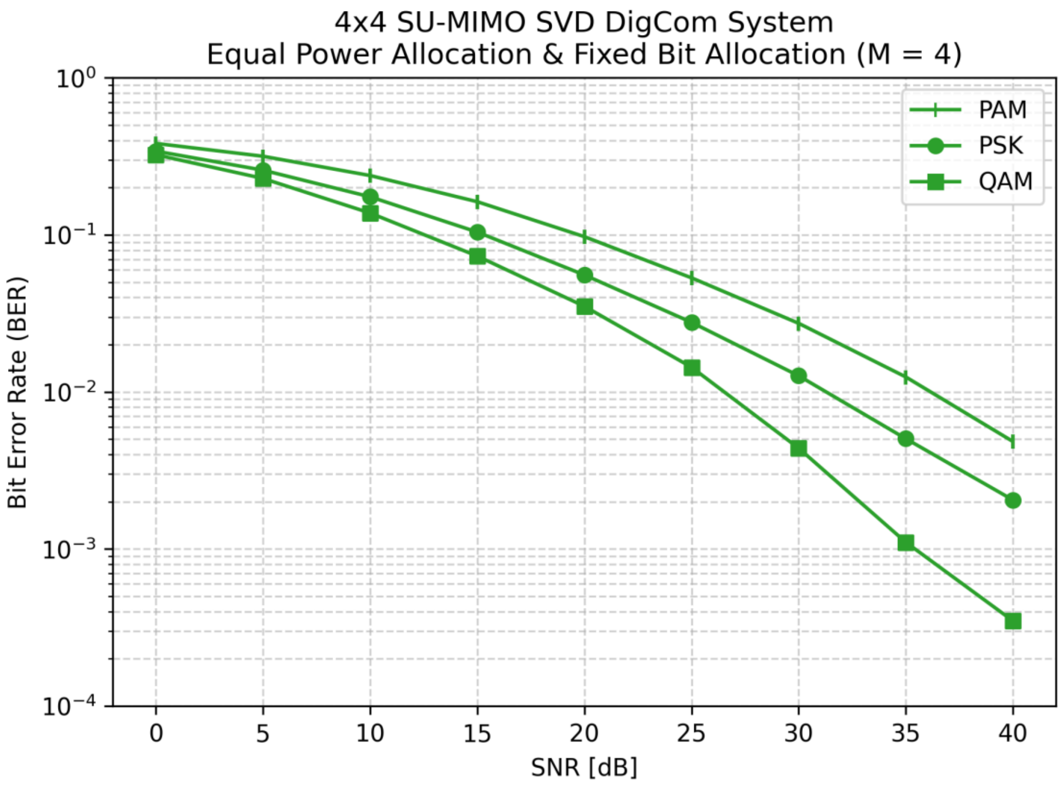
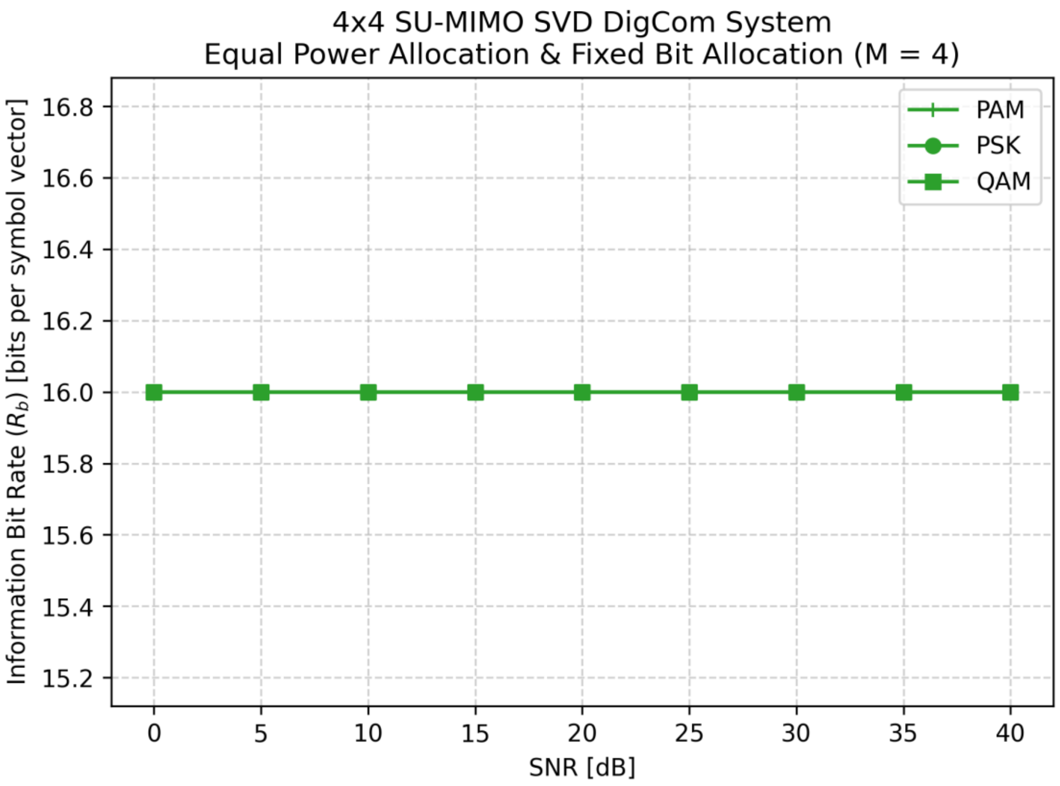
Simulation Results

Equal Power Allocation & Fixed Bit Allocation





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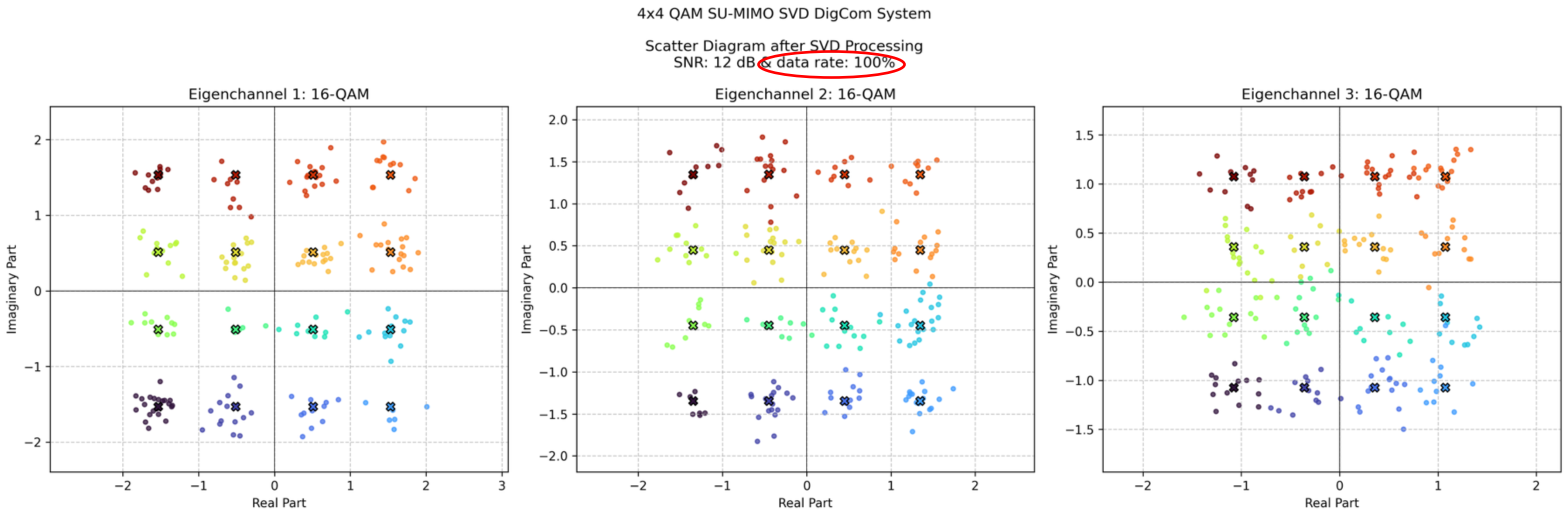
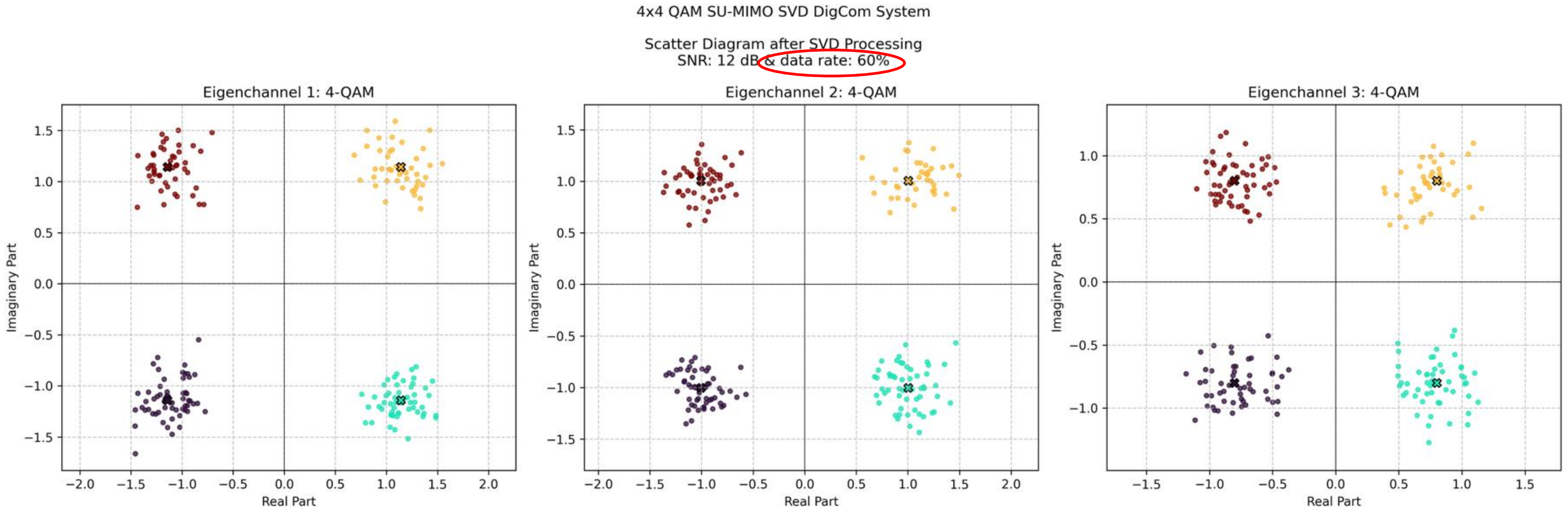
Simulation Results

Impact of **Resource Allocation Strategy**





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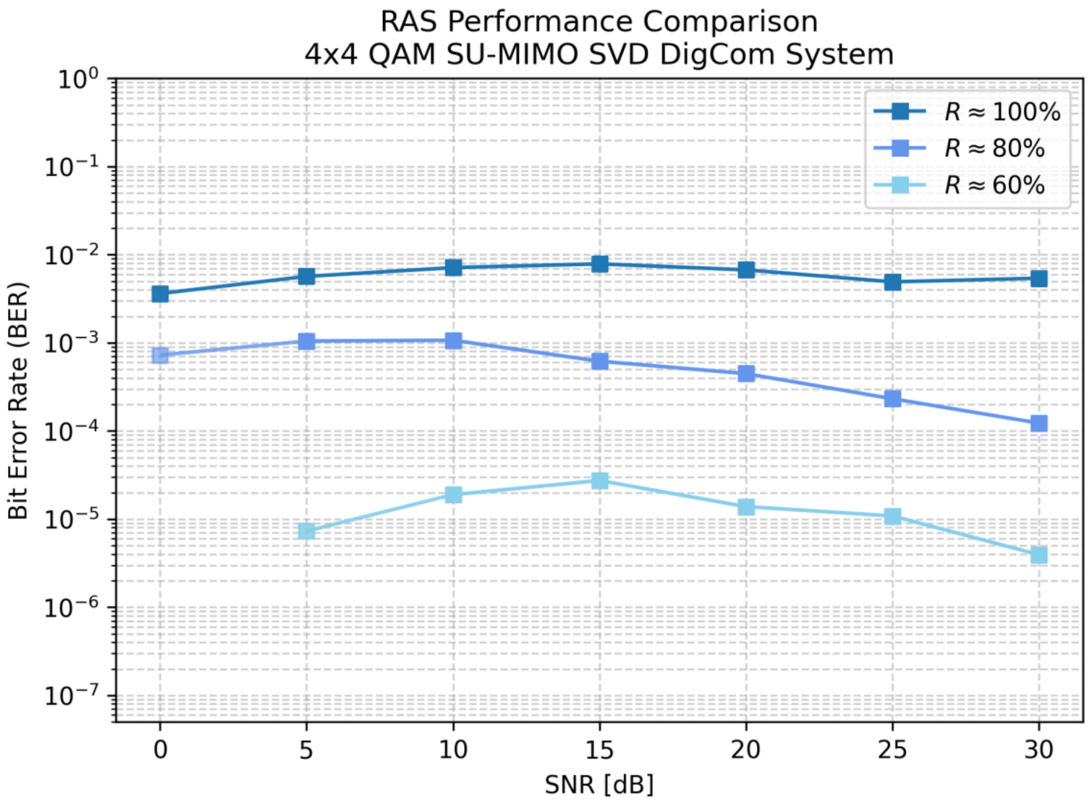
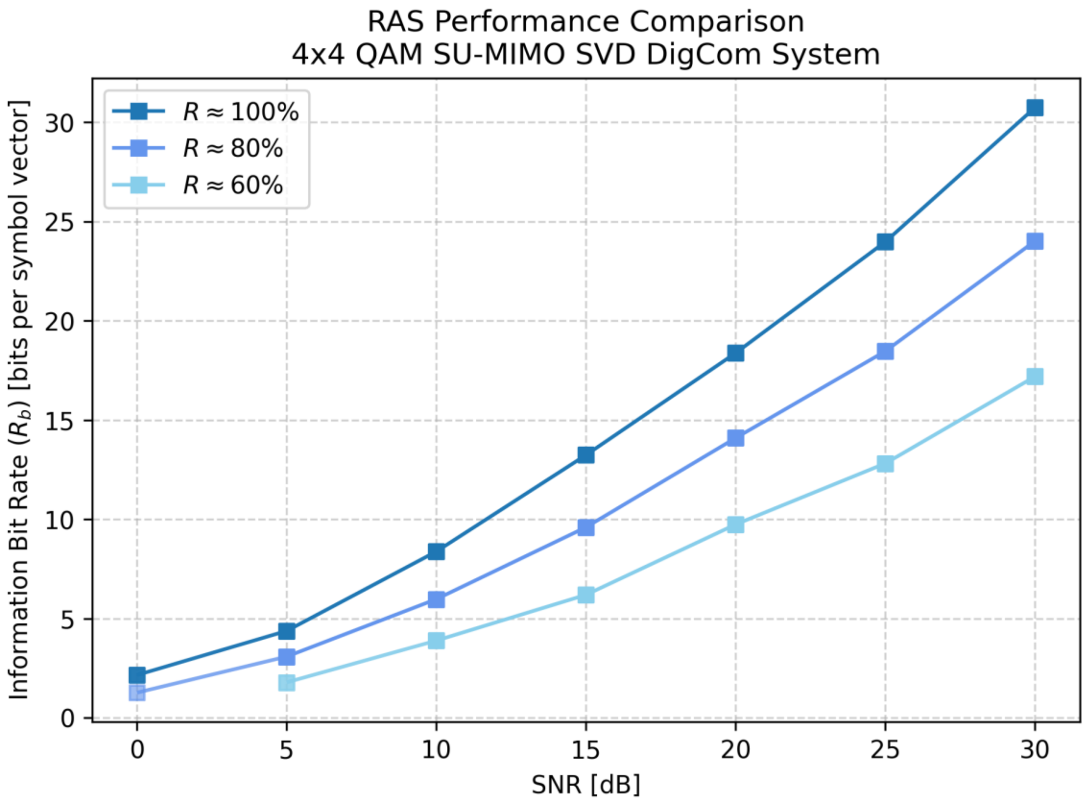
Simulation Results

Impact of **Resource Allocation Strategy** on BER & IBR Performance





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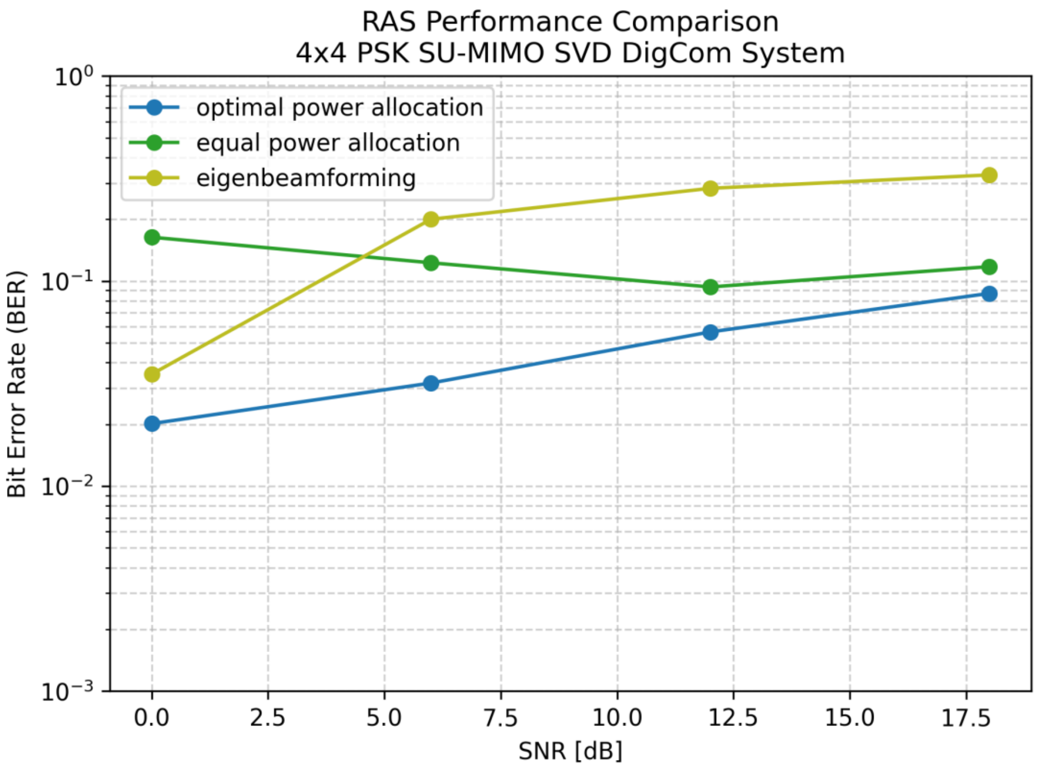
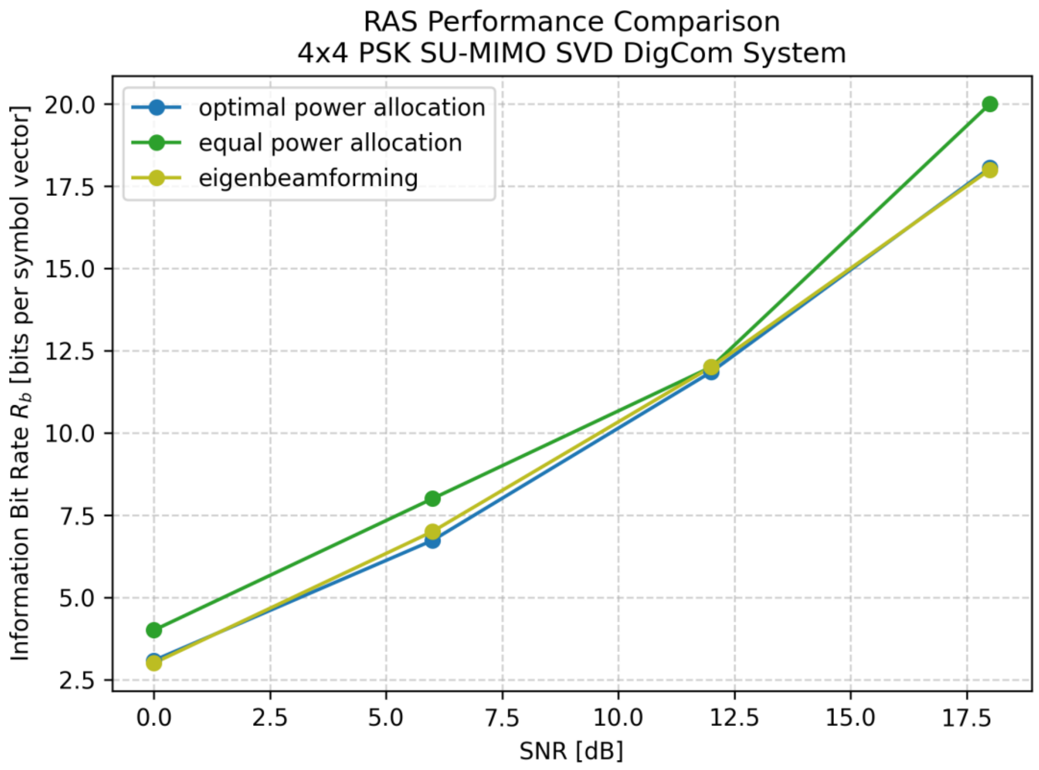
Simulation Results

Impact of **Resource Allocation Strategy** on BER & IBR Performance





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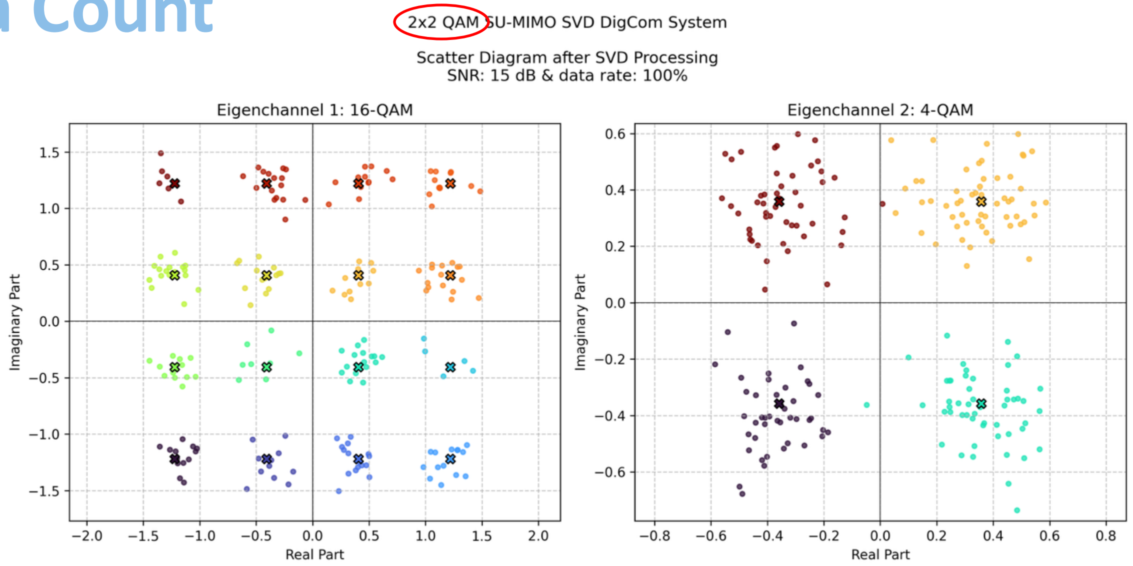
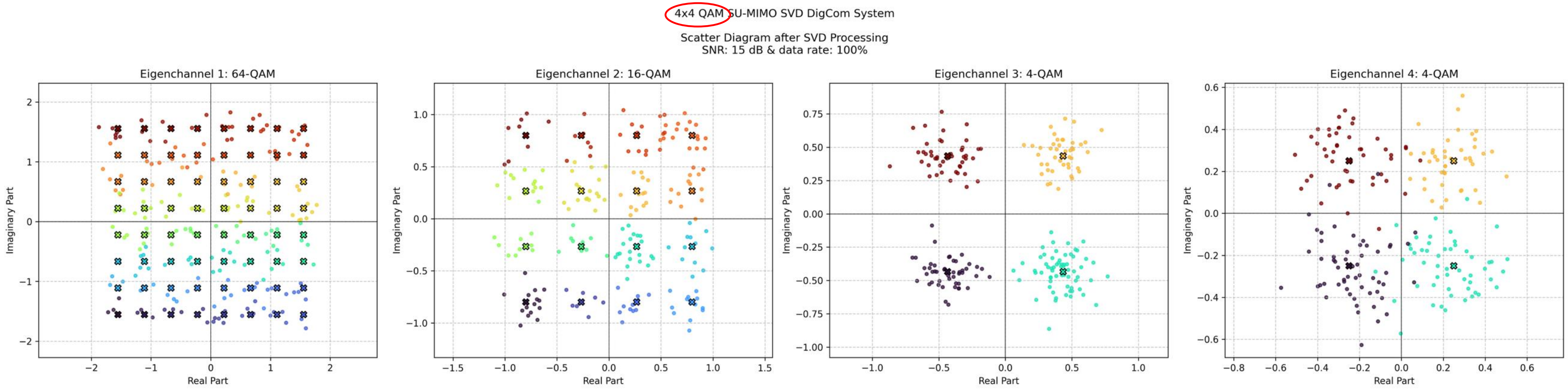
Simulation Results

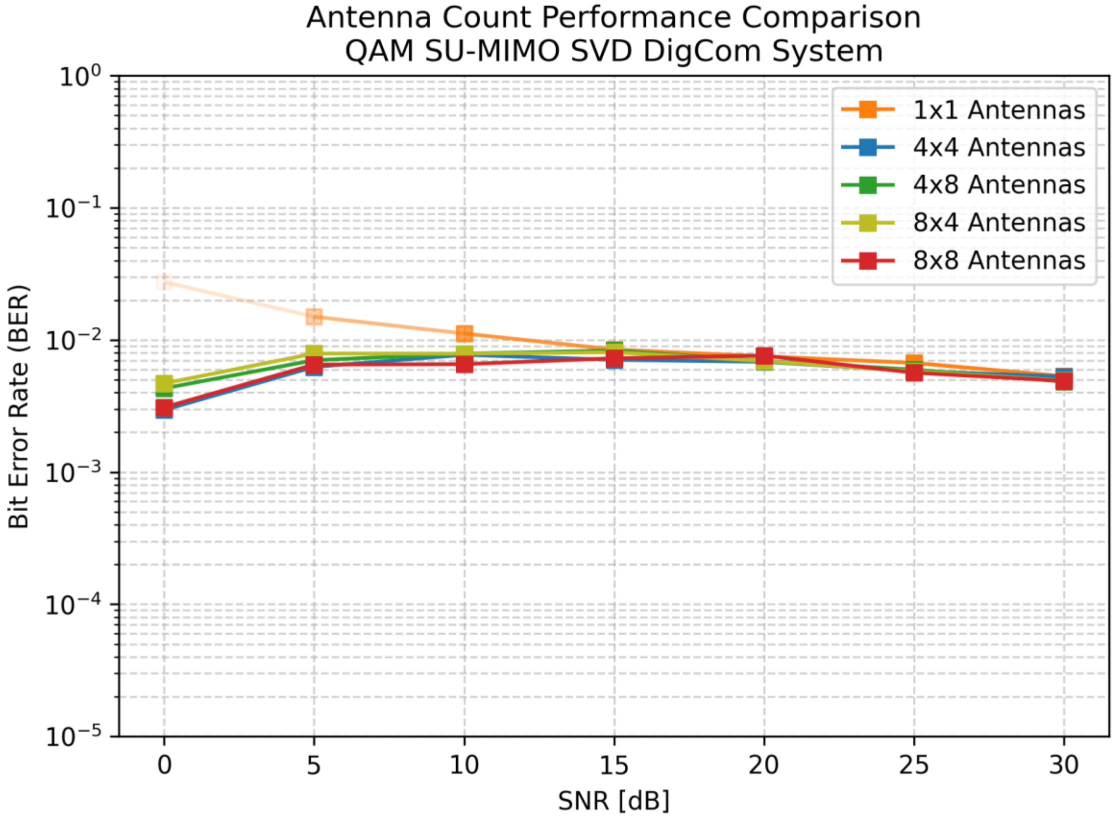
Impact of **Antenna Count**

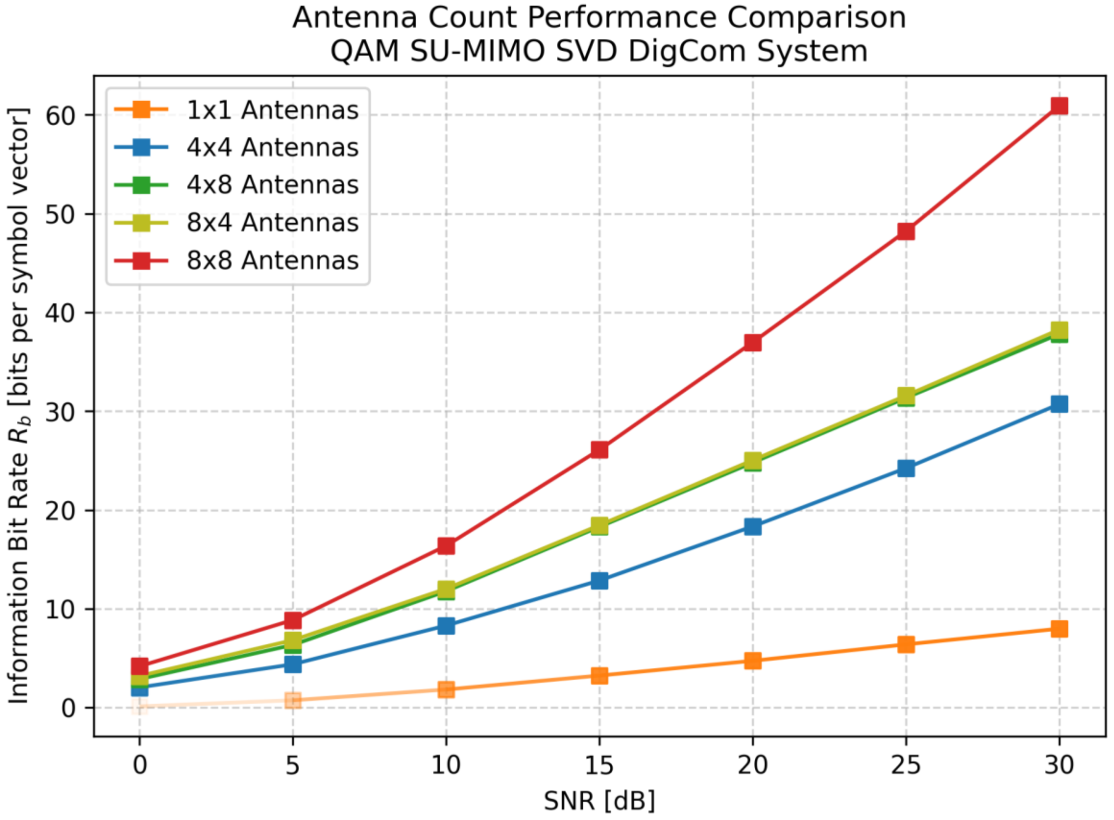




Simulation Results

Impact of **Antenna Count** on BER & IBR Performance





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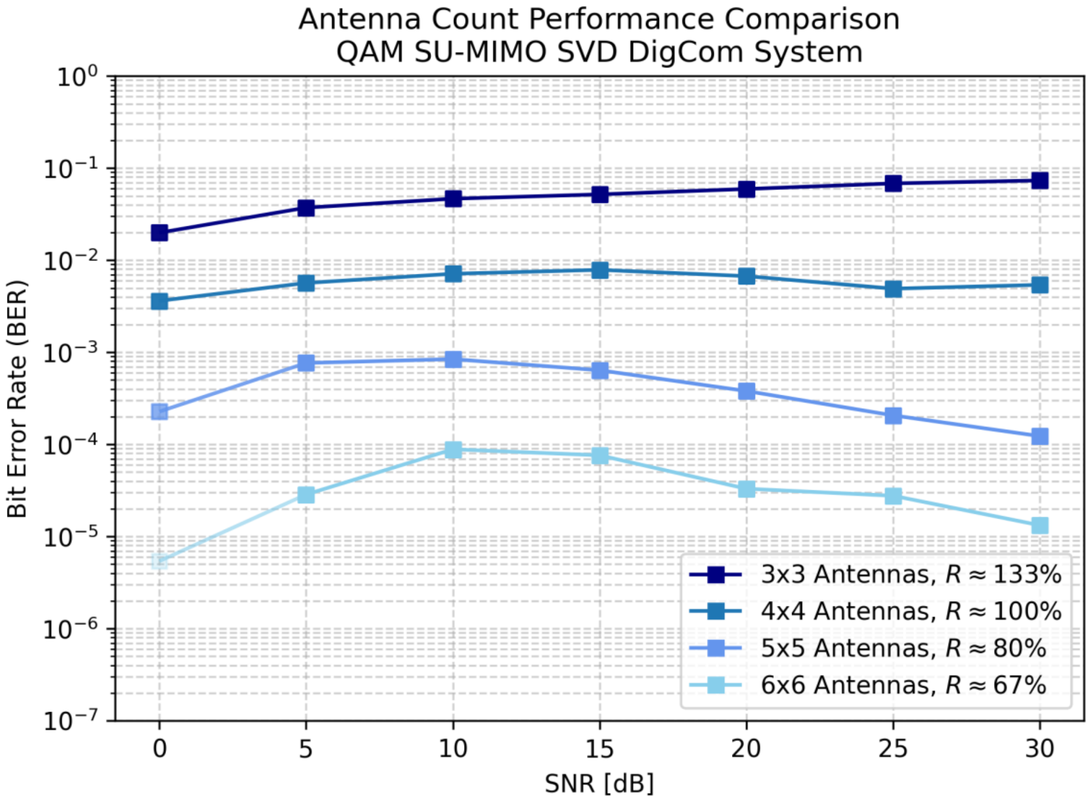
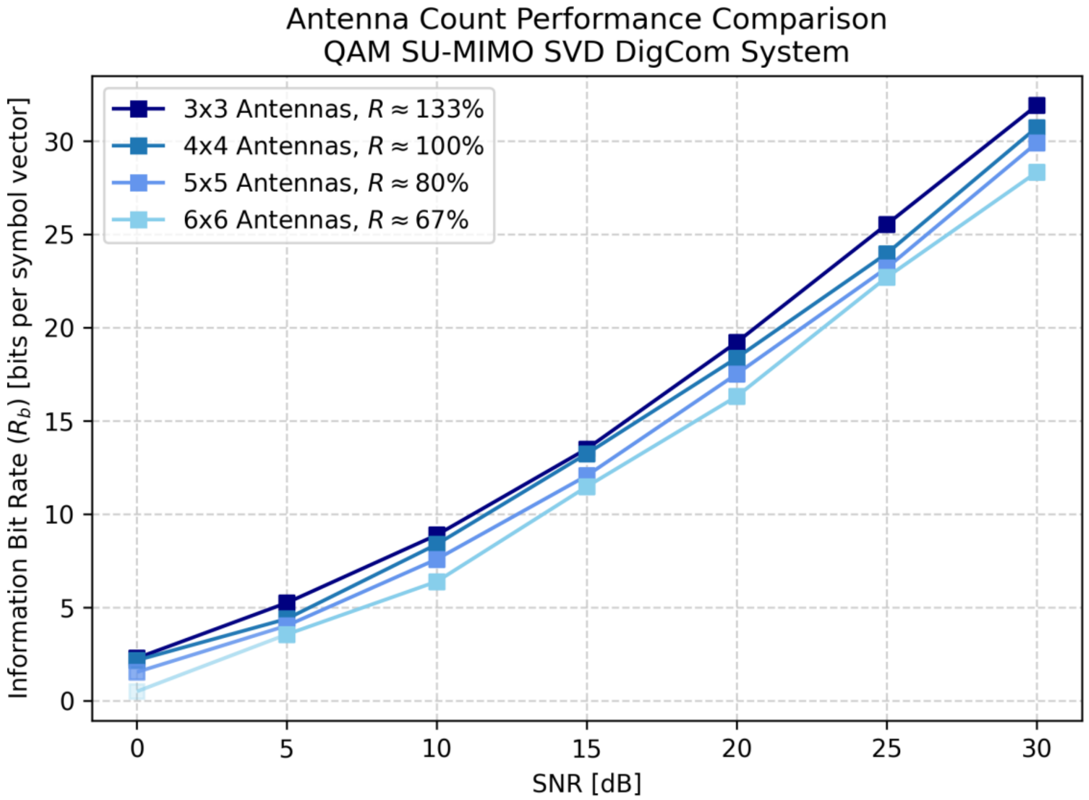
Simulation Results

Impact of **Antenna Count** on BER & IBR Performance





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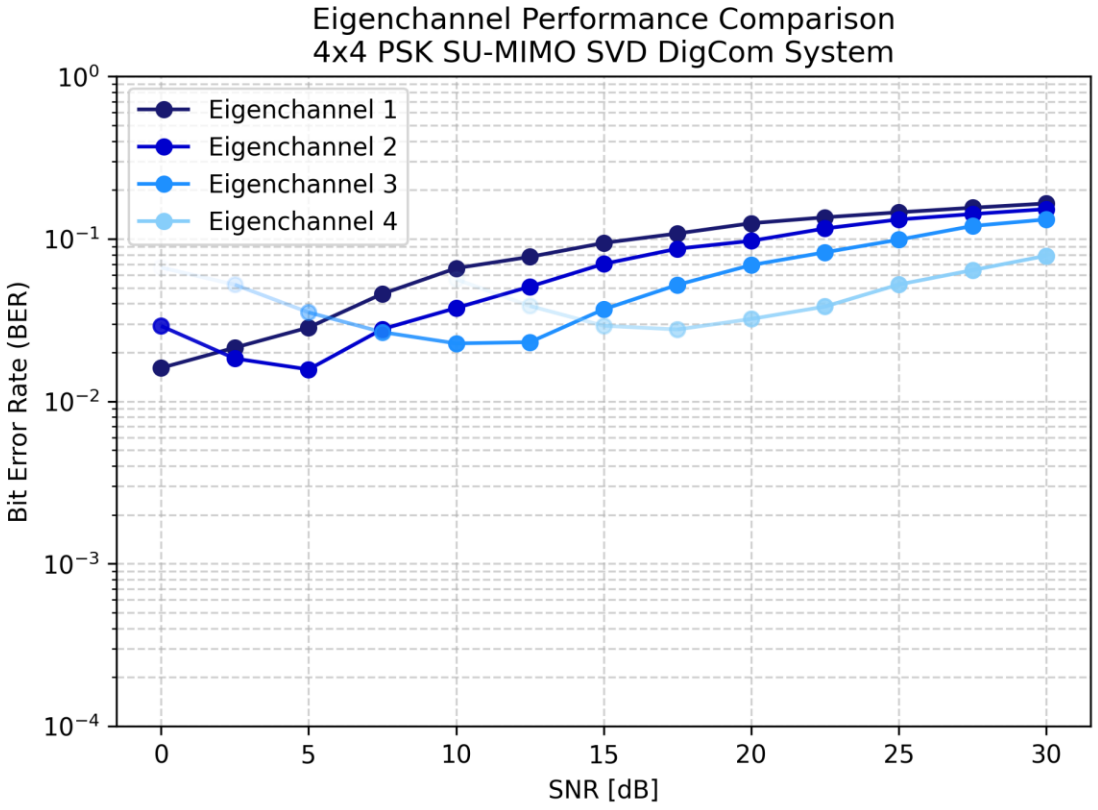
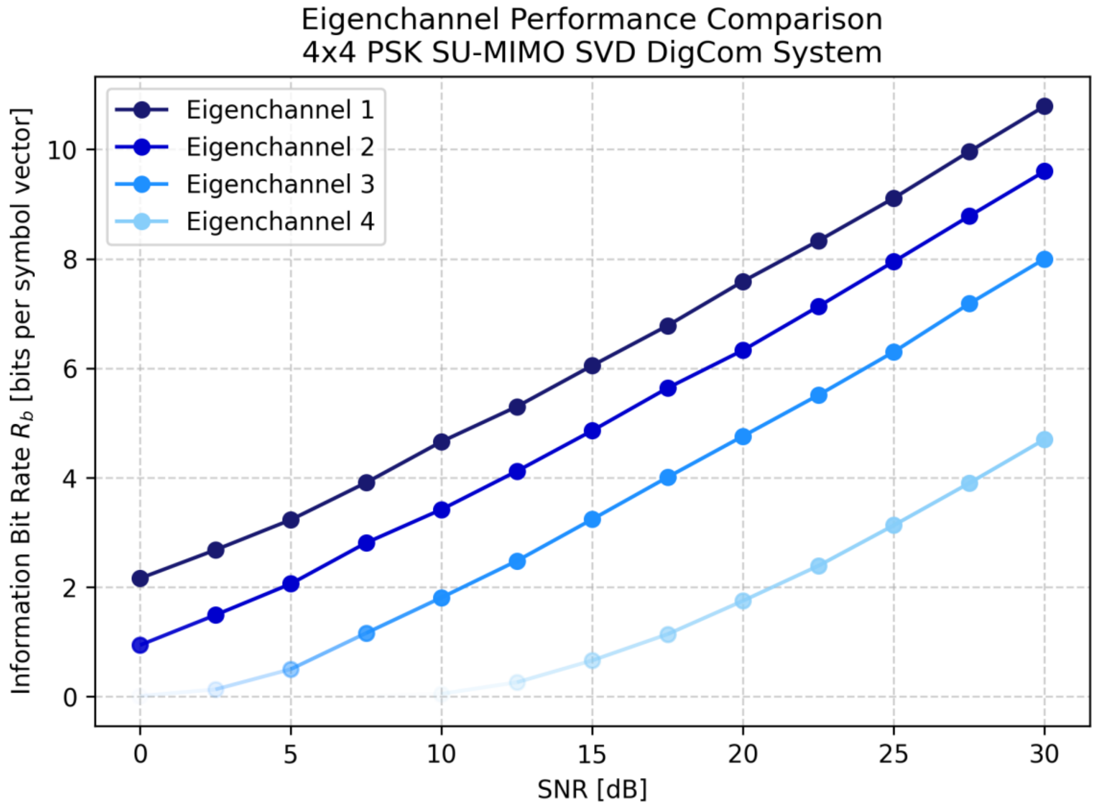
Simulation Results

Comparing BER & IBR Performance across **different eigenchannels**





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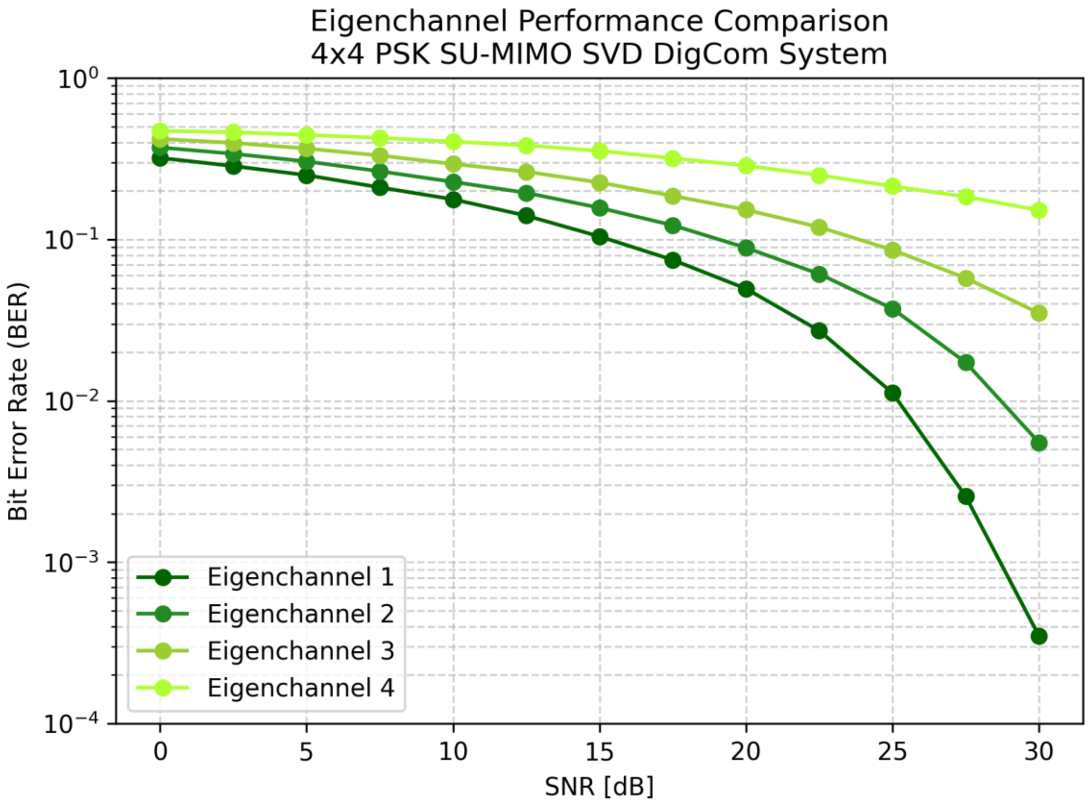
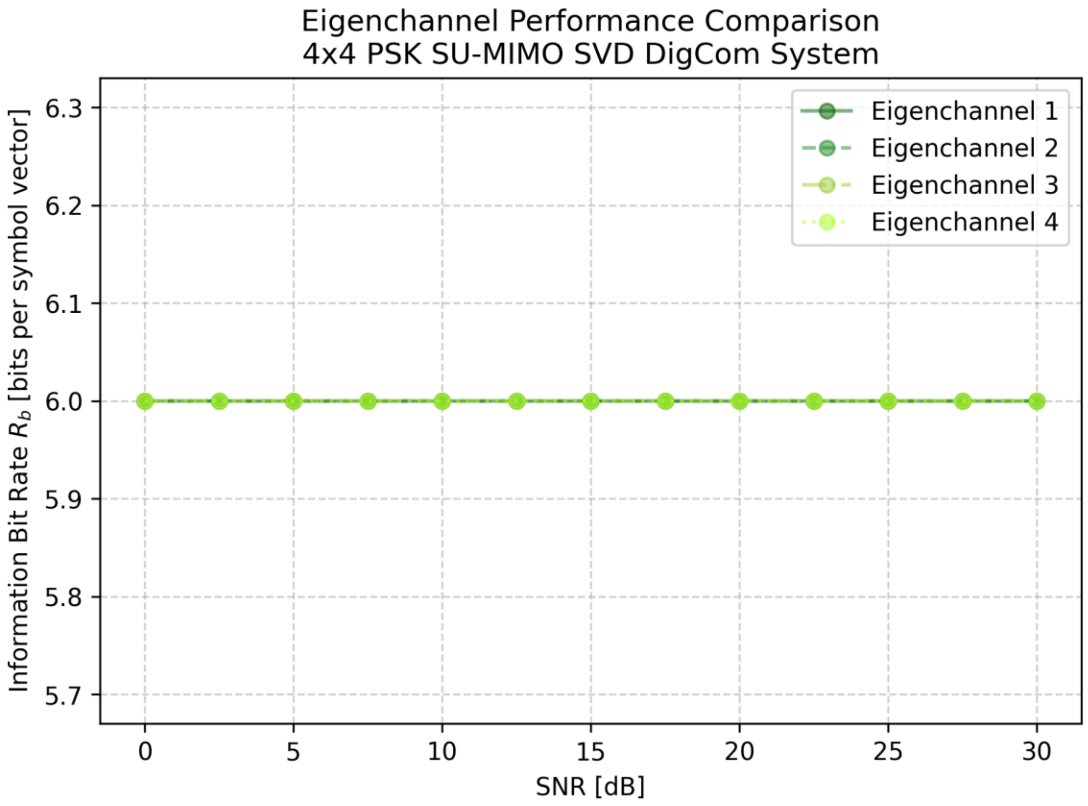
Simulation Results

Comparing BER & IBR Performance across **different eigenchannels**





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Analytical Results

The bit error rate of the system (BER) can be calculated as the weighted average of the bit error rates of each eigenchannel of the system (BER_i):

$$\mathrm{BER} = \frac{1}{R_b} \sum_{i=0}^{\mathrm{R_H}} R_{b,i} \cdot \mathrm{BER}_i$$

The Bit Error Rate of each eigenchannel of the system (BER_i) equals the average amount of bit errors per received data symbol:

$$\mathrm{BER_i} \leq \frac{1}{R_{b,i} \cdot 2^{R_{b,i}}} \sum_{(\hat{\alpha},\alpha)\in\mathcal{C}_i^2} \mathrm{N}(\hat{\alpha},\alpha) \cdot \mathrm{Q}\left(\sqrt{\frac{\mathrm{P_i}\,\sigma_\mathrm{i}^2}{2\mathrm{N_0}}} \cdot |\hat{\alpha} - \alpha|\right)$$

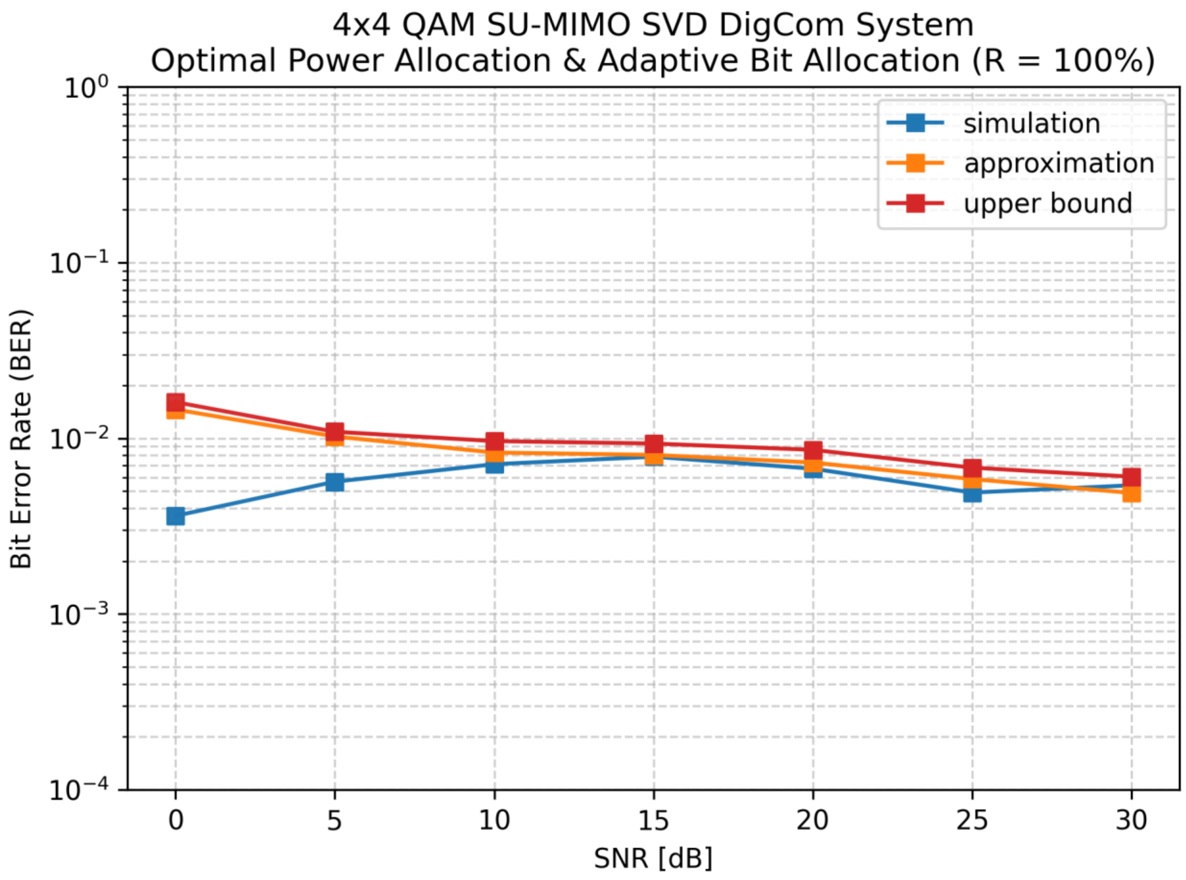
Upper Bound:

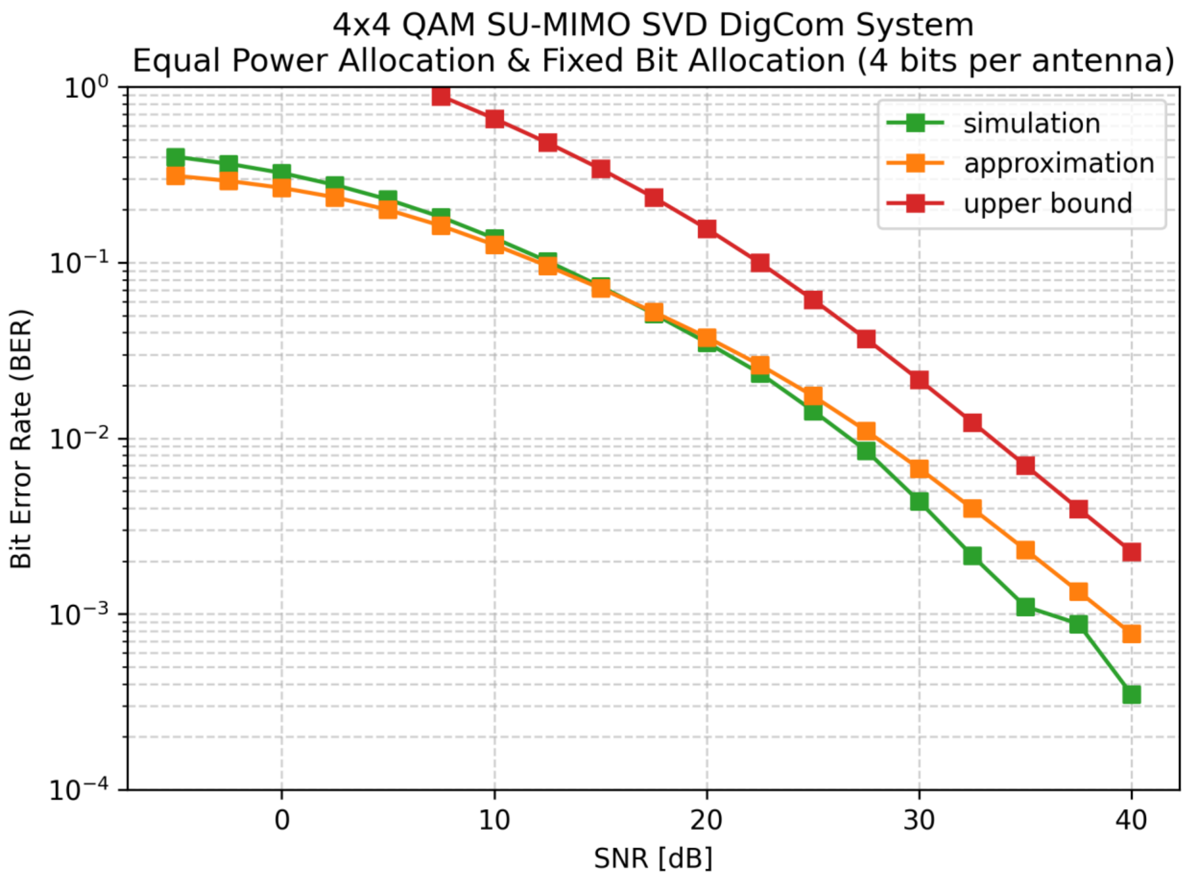
$$\mathrm{BER_i} = \frac{1}{R_{b,i}} \cdot \sum_{(\hat{\alpha},\alpha)\in\mathcal{C}_i^2} \mathrm{N}(\hat{\alpha},\alpha) \cdot \mathrm{P}[\hat{\mathrm{a}}_i = \hat{\alpha} \wedge a_i = \alpha]$$

Approximation:

$$\mathrm{BER_i} \approx \frac{\mathrm{K}}{R_{b,i}} \cdot \mathrm{Q}\left(\sqrt{\frac{\mathrm{P_i}\,\sigma_\mathrm{i}^2}{2\mathrm{N_0}}} \cdot \mathrm{d_{min}}\right)$$

Analytical Results





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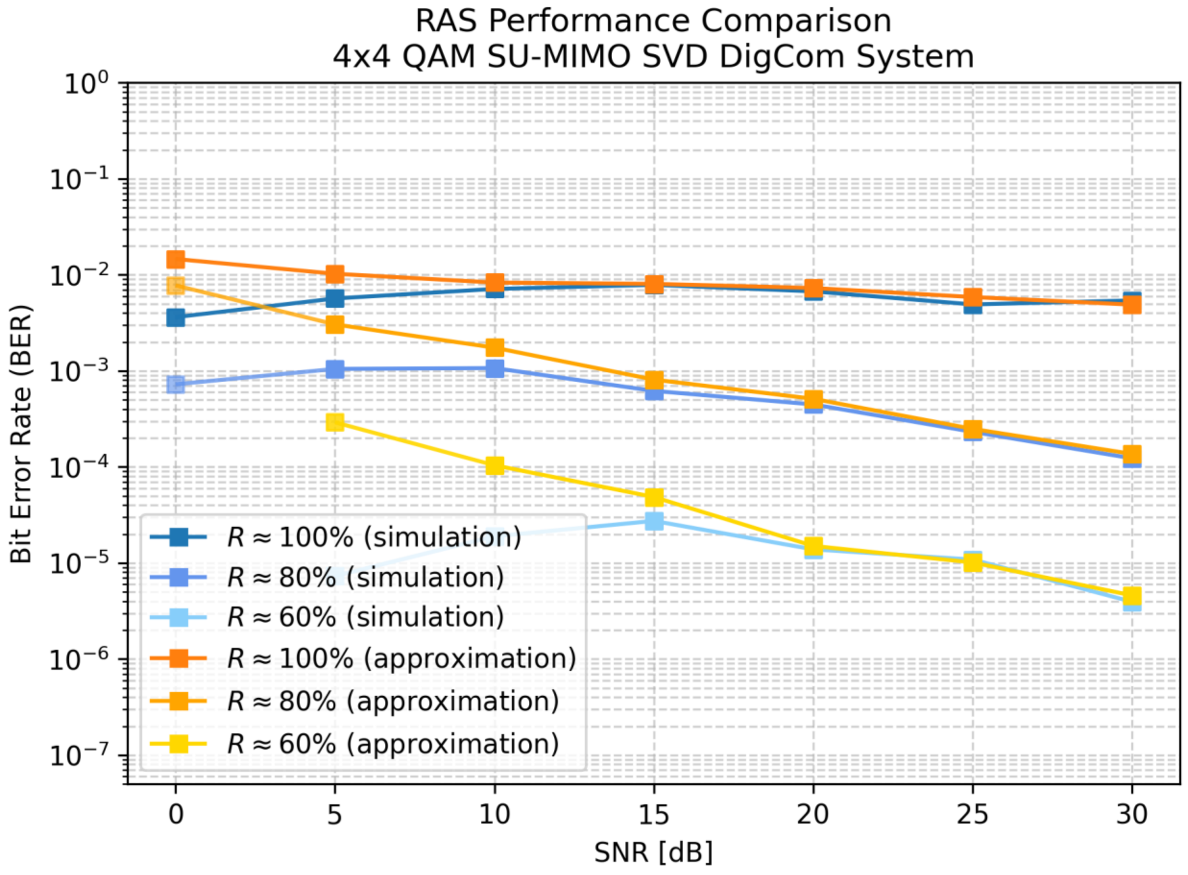
Analytical Results

Different Data Rates



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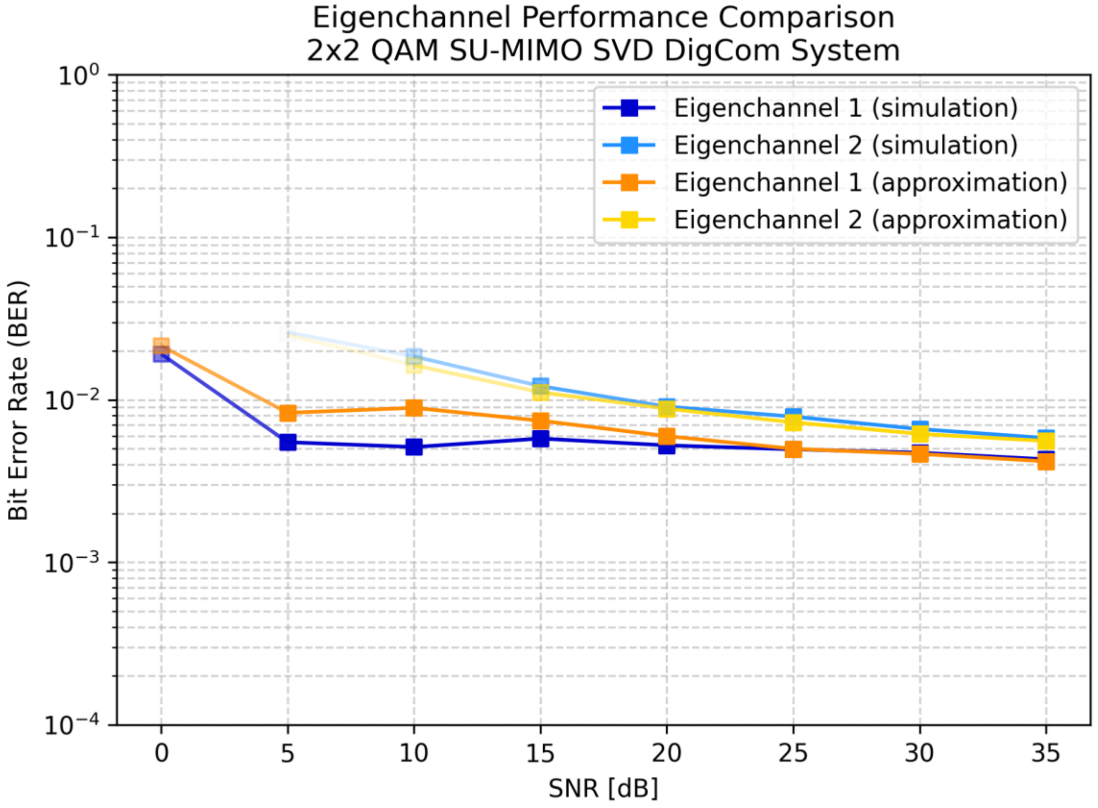
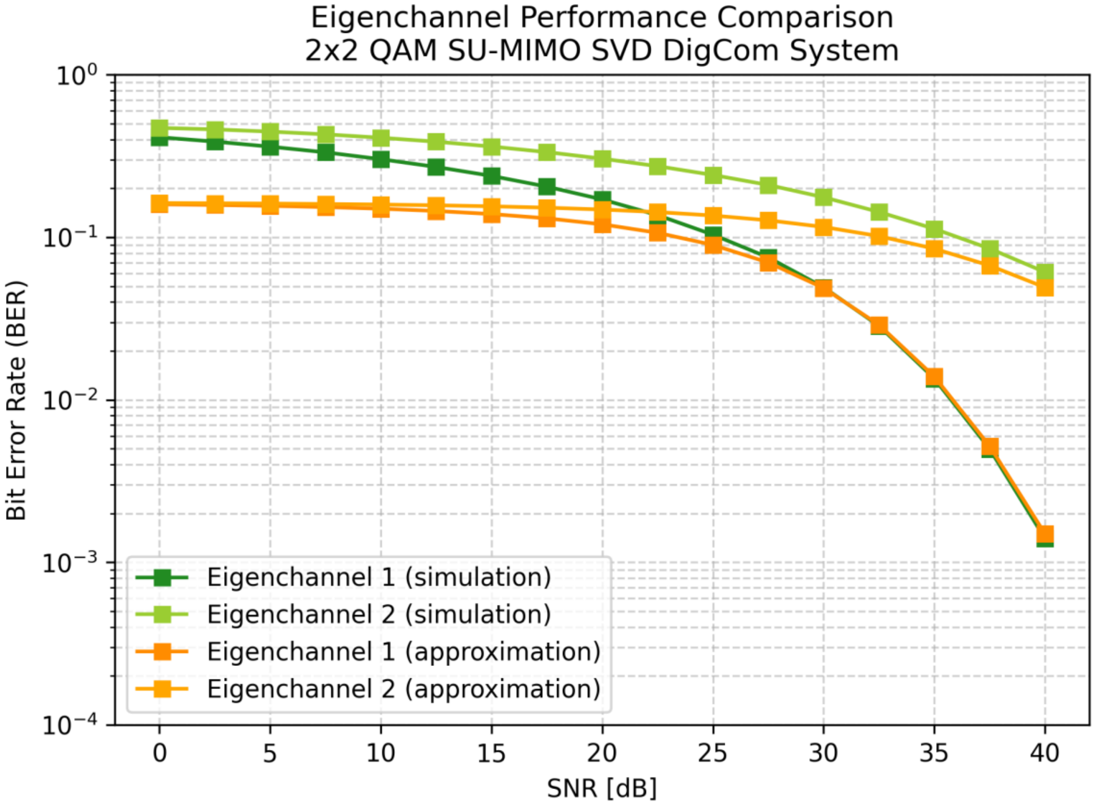
Analytical Results

Different Eigenchannels





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Conclusion

What are the specific **needs** and **restrictions** of your system in terms of **throughtput**, **reliability**, **complexity** and **hardware costs**? In which **environment** will your system be used?

- SNR ↑ ➡ Throughput OR Reliability ↑
- Data Rate ↑ ➡ Throughput ↑ BUT … Reliability ↓
- Antennas ↑ ➡ Throughput OR Reliability ↑ BUT … Complexity AND Hardware Cost ↓
- Use of CSI ➡ Throughput OR Reliability ↑ BUT … Complexity ↓
- …

➡ Choose a system configuration that meets your needs and restrictions!

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Report Presentation: SU-MIMO SVD DigCom System

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