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Transmit Signal Processing for Massive MIMO Systems Using 1-Bit Quantization

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Massive MIMO Systems

+ Large number of antennas at the base station
+ High spectral efficiency
+ High energy efficiency

- Large number of RF chains and DA/AD converters
- High power consumption with high resolution DA/AD converters

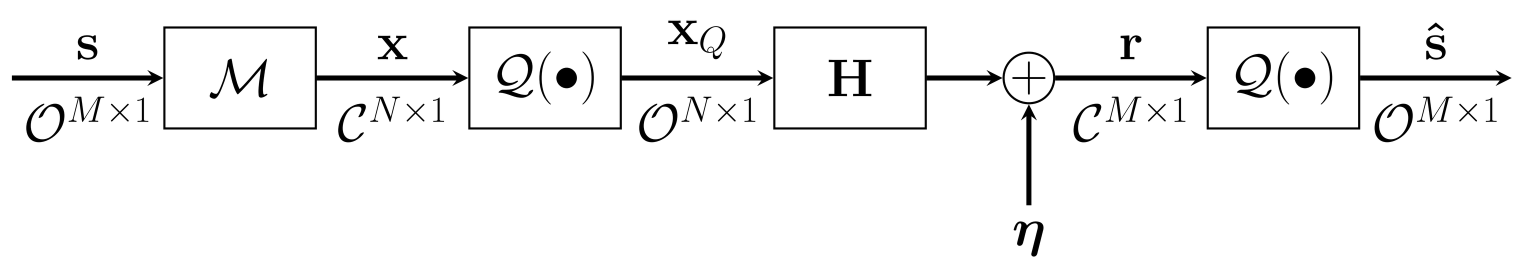
1-Bit Massive MIMO Systems

+ DA/AD converters of 1-bit resolution
+ Reduced power consumption
+ Simplified RF chain

- Performance degradation due to the coarse quantization

Question: How to design precoding techniques to mitigate the multi user interference and the coarse quantization distortions in 1-bit massive MIMO systems?

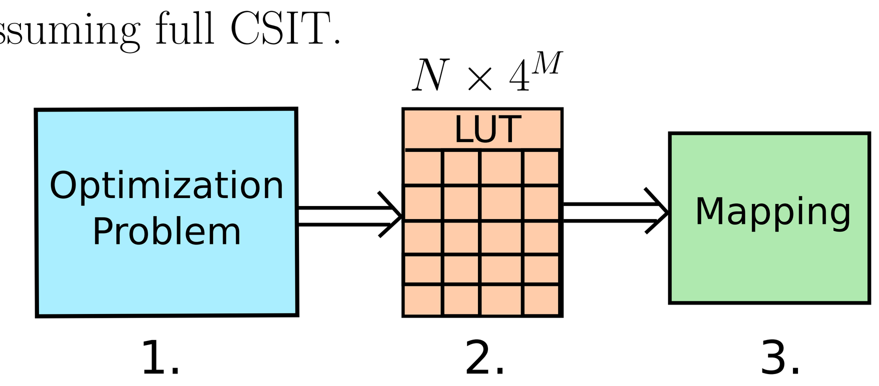
System Model: MU-MISO Downlink



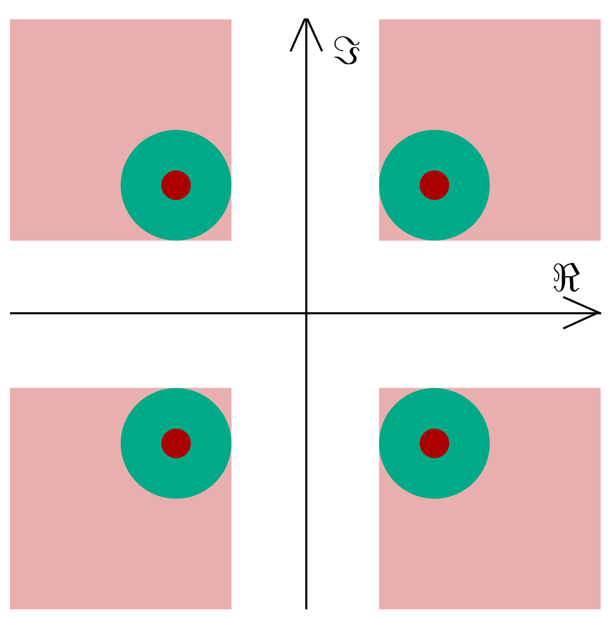
- $\mathcal{O}$ represents the set of QPSK constellation
- N antennas at the base station
- M single-antenna users, where $N >> M$

Mapping: $\mathcal{M}$

Goal: design the transmit vector signal $\mathbf{x}$ for a given input signal vector $\mathbf{s}$ depending on the channel, while assuming full CSIT.

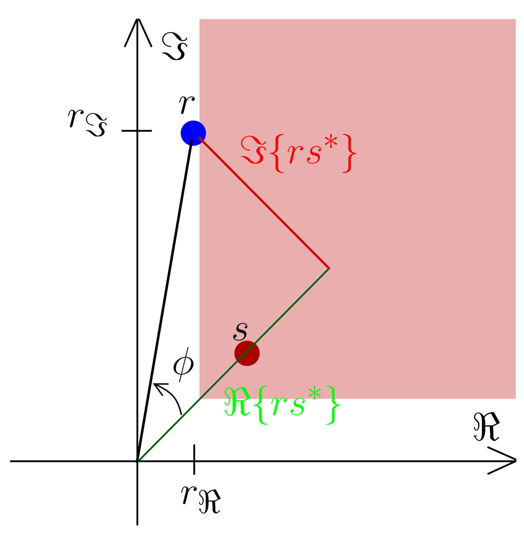


Minimum BER vs. MMSE



- **Minimum BER:** make the received signal belong to the same quadrant as the desired signal and far from the thresholds $\Longrightarrow$ half bounded squares
- **MMSE:** get the received signal as close as possible to the desired signal $\Longrightarrow$ circles around the QPSK points

Problem Formulation



- Single User Scenario

$$\max_{\mathbf{x}} \Re\{(rs^*)^2\} = \max_{\mathbf{x}} |r||s|\cos(2\phi) \text{ s.t. } \mathbf{x} \in \mathcal{O}^N$$

- Multi User Scenario

$$\max_{\mathbf{x}} \Re\{(r_m s_m^*)^2\} = \max_{\mathbf{x}} |r_m||s_m|\cos(2\phi_m), m = 1, 2, ..., M \text{ s.t. } \mathbf{x} \in \mathcal{O}^N$$

Optimization Problem

The M cost functions can be jointly expressed by the following matrix

$$\mathbf{P} = \Re\{\text{diag}\left(\mathbf{r}\mathbf{s}^{\text{H}}\right)^2\}$$

.

The optimization problem is expressed as

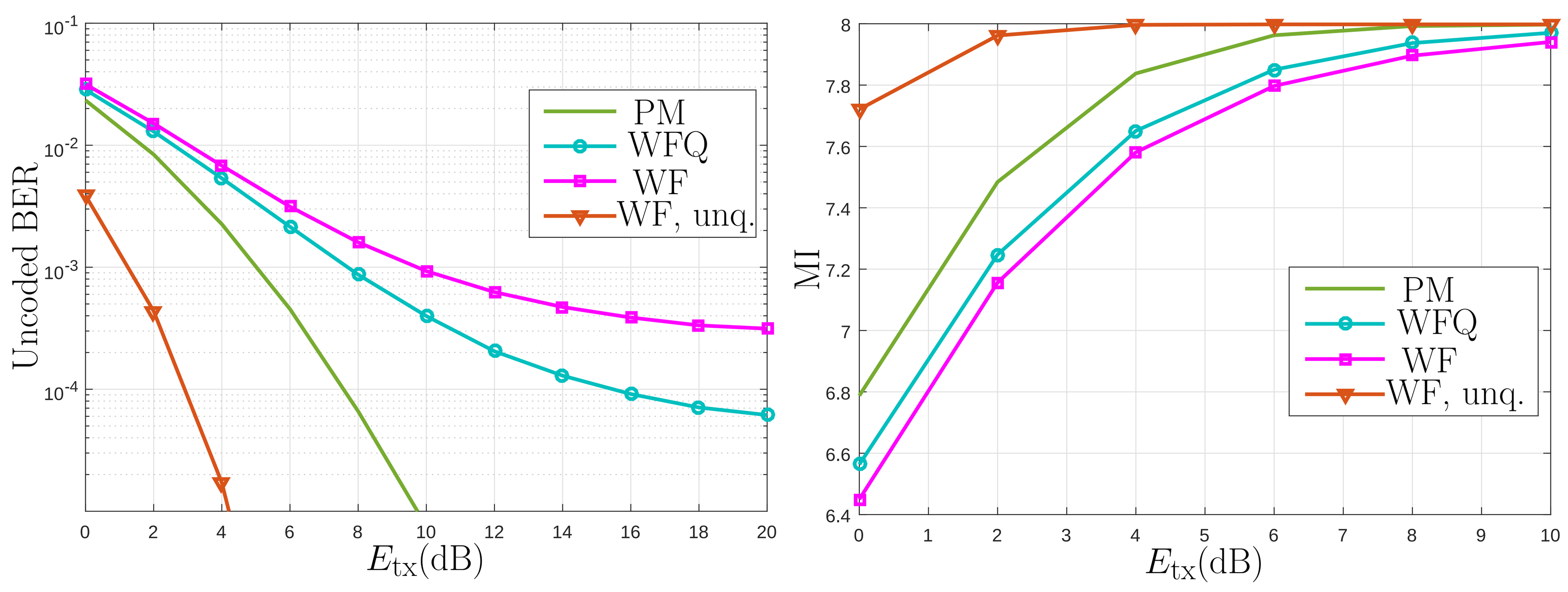
$$\max_{\mathbf{x}'} \det(\mathbf{P}) \text{ s.t. } x'_n \leq 1 \text{ and } -x'_n \leq 1, n = 1, 2, ...2N,$$

$$\text{where } \mathbf{x}' = \begin{bmatrix} \mathbf{x}_{\Re} \\ \mathbf{x}_{\Im} \end{bmatrix}$$

- Constraint relaxation to get a convex optimization problem
- Use the Gradient Projection algorithm to solve the optimization problem

Simulation Results

- $N = 32, M = 4$
- $\mathbf{H}$ with i.i.d. complex-valued entries of zero mean and unit variance: 500 realizations
- 10000 QPSK symbols per channel realization



Conclusion

- Minimum BER precoding significantly improves the performance in terms of uncoded BER and MI.
- The complexity of this method grows exponentilly with the number of users M.

Future Work

- Use of this method to perform spatial coding
- Investigate other non linear precoding techniques such as Thomlinson Harashima precoder