Beamforming Optimization of MIMO Interference Network

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Outline

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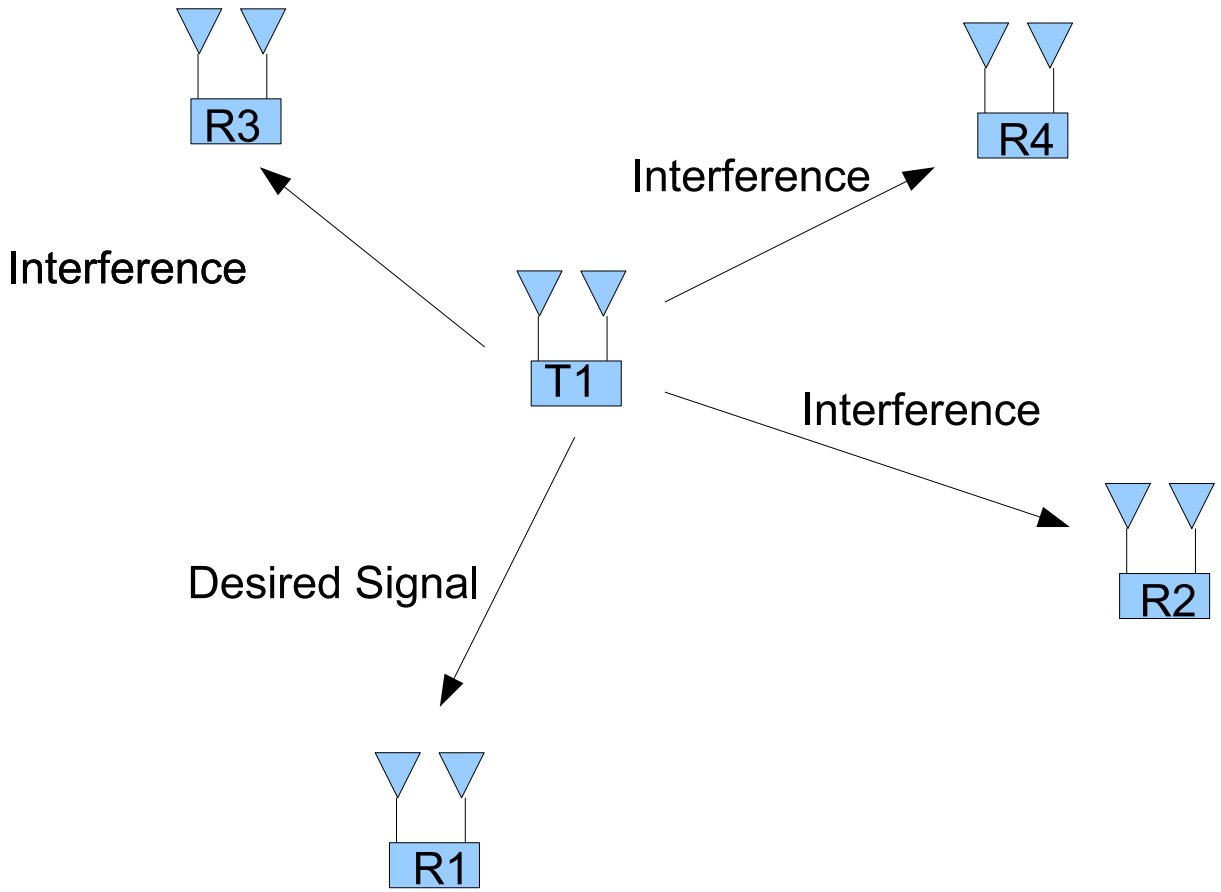
- System Model
- Problem Formulation and Solving Method
- Simulation Example

Background

Compared with single antenna system, the advantage of multiple antenna system

- Increase the data rate of a link through transmitting multiple data stream simultaneously.
- Mitigate interference between links through designing the signal transmitted at different antennas.

System Model



Signal Model

Desired signal

$$\mathbf{y}_1 = \frac{1}{r_{11}^{\alpha}} \mathbf{H}_{11} \sqrt{\mathbf{Q_{11}}} \mathbf{x}_{11} + \mathbf{n} \tag{1}$$

Interference

$$\mathbf{I}_2 = \frac{1}{r_{12}^{\alpha}} \mathbf{H}_{12} \sqrt{\mathbf{Q_{11}}} \mathbf{x}_{11} \tag{2}$$

$$\mathbf{I}_3 = \frac{1}{r_{13}^{\alpha}} \mathbf{H}_{13} \sqrt{\mathbf{Q_{11}}} \mathbf{x}_{11} \tag{3}$$

$$\mathbf{I}_4 = \frac{1}{r_{14}^{\alpha}} \mathbf{H}_{14} \sqrt{\mathbf{Q_{11}}} \mathbf{x}_{11} \tag{4}$$

$$\tag{5}$$

where $\mathbf{H_{1k}} \in \mathbb{C}^{M \times M}$, $\mathbf{x_{11}} \in \mathbb{C}^{M \times 1}$, $\mathbf{n} \in \mathbb{C}^{M \times 1}$, $\mathbf{Q_{11}} \in \mathbb{C}^{M \times M}$, and $\mathbf{Q_{11}} \geq 0$

Signal Model

Power of desired signal

$$\frac{1}{r_{11}^{2\alpha}} E\{(\mathbf{H}_{11}\sqrt{\mathbf{Q_{11}}}\mathbf{x}_{11})(\mathbf{H}_{11}\sqrt{\mathbf{Q_{11}}}\mathbf{x}_{11})^H\} = \frac{1}{r_{11}^{2\alpha}}\mathbf{tr}\left(\mathbf{H}_{11}\mathbf{Q}_{11}\mathbf{H}_{11}^H\right) \quad (6)$$

Power of interference

$$\frac{1}{r_{1k}^{2\alpha}} E\{(\mathbf{H}_{1k}\sqrt{\mathbf{Q_{11}}}\mathbf{x}_{11})(\mathbf{H}_{1k}\sqrt{\mathbf{Q_{11}}}\mathbf{x}_{11})^H\} = \frac{1}{r_{1k}^{2\alpha}}\mathbf{tr}\left(\mathbf{H}_{1k}\mathbf{Q}_{11}\mathbf{H}_{1k}^H\right) \quad (7)$$

Problem Formulation

The optimization problem can be formulated as:

$$\min_{\mathbf{Q}_{11},t} \quad \max_{k=2,3,4} \quad \frac{1}{r_{1k}^{2\alpha}} \mathbf{tr}\left(\mathbf{H}_{1k}\mathbf{Q}_{11}\mathbf{H}_{1k}^{H}\right)$$

$$\text{subject to} \quad \mathbf{tr}\left(\mathbf{H}_{11}\mathbf{Q}_{11}\mathbf{H}_{11}^{H}\right) = P_t,$$

$$\frac{1}{r_{11}^{2\alpha}} \mathbf{tr}(\mathbf{Q}_{11}) \leq P_{max},$$

$$\mathbf{Q}_{11} \geq 0.$$

Problem Formulation

Through introducing an auxiliary variable t ($t \geq 0$), the problem can be reformulated as:

$$\min_{\mathbf{Q}_{11}, t} \quad t$$

$$\text{subject to} \quad \frac{1}{r_{1k}^{2\alpha}} \mathbf{tr}(\mathbf{H}_{1k} \mathbf{Q}_{11} \mathbf{H}_{1k}^H) \leq t, \quad k = 2, 3, 4$$

$$\frac{1}{r_{11}^{2\alpha}} \mathbf{tr}(\mathbf{H}_{11} \mathbf{Q}_{11} \mathbf{H}_{11}^H) = P_t,$$

$$\mathbf{tr}(\mathbf{Q}_{11}) \leq P_{max},$$

$$\mathbf{Q}_{11} \geq 0.$$

SDP Problem

$$\mathbf{X}_{11} = \begin{bmatrix} t & \cdots & \cdots & \cdots \\ \cdots & \mathrm{diag}\{t - \frac{1}{r_{1k}^{2\alpha}}\mathbf{tr}(\bar{\mathbf{H}}_{1k}\bar{\mathbf{Q}}_{11}\bar{\mathbf{H}}_{1k}^{T})\} & \cdots & \\ \cdots & \cdots & P_{max} - \frac{1}{2}\mathbf{tr}\left(\bar{\mathbf{Q}}_{11}\right) & \cdots \\ \vdots & \vdots & \vdots & \bar{\mathbf{Q}}_{11} \end{bmatrix},$$

$$\mathbf{A}_{11} = \begin{bmatrix} 0 & \cdots & \cdots & \cdots \\ \cdots & 0 & \cdots & \cdots \\ \cdots & \cdots & 0 & \cdots \\ \vdots & \vdots & \vdots & \frac{1}{r_{11}^{2\alpha}}\bar{\mathbf{H}}_{11}^{T}\bar{\mathbf{H}}_{11} \end{bmatrix},$$

$$\mathbf{B}_{11} = \begin{bmatrix} 1 & \cdots & \cdots & \cdots \\ \cdots & 0 & \cdots & \cdots \\ \cdots & \cdots & 0 & \cdots \\ \vdots & \vdots & \vdots & 0 \end{bmatrix},$$

SDP Problem

$$\begin{aligned} \min_{\mathbf{X}_{11}} \quad & \mathbf{tr}\left(\mathbf{B}_{11}\mathbf{X}_{11}\right) \\ \text{subject to} \quad & \mathbf{tr}\left(\mathbf{A}_{11}\mathbf{X}_{11}\right) = P_t, \\ & \mathbf{X}_{11} \succeq 0. \end{aligned}$$

Simulation Example

Number of nodes: 5
Distance: $r_{11} = 10m, r_{12} = 15m$, $r_{13} = 25m$, $r_{14} = 30m$
Maximum Transmission Power: 40dB, Pathloss factor: $\alpha = 1$
Antanna number: $M = 4$
QoS requirement: $P_t = 10$
Channel realization: 1000

Simulation Example

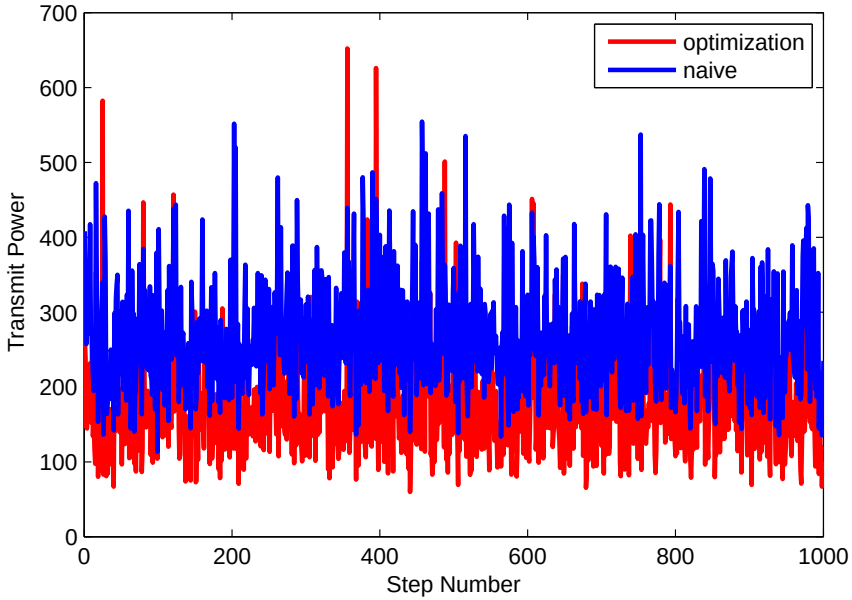


Figure 2: average transmit power of T1: 265 (naive), 176(optimization)

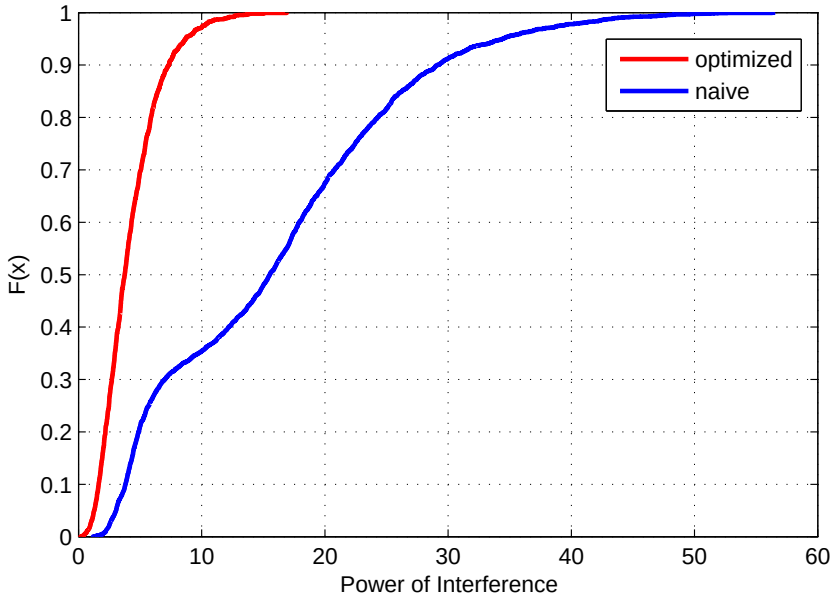


Figure 3: average interference power to R2, R3, R4: 15.8(naive), 4.2(optimization)

Thanks for your attention!