INTERFERENCE ALIGNMENT PERFORMANCE ON MIMO X CHANNELS WITH IMPERFECT CHANNEL ESTIMATION

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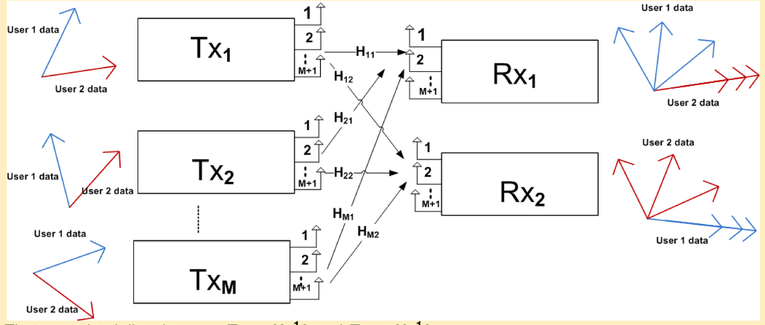
Abstract

Interference alignment (IA) can achieve the optimal degrees of freedom in interference-limited wireless systems. Popular IA schemes assume perfect global knowledge of the MIMO channels at all transmitters and receivers. In this paper, we investigate the error rate performance of interference alignment in MIMO $M \times 2$ X-channel systems at practical signal to noise ratios. Through theoretical analysis and Monte Carlo simulations, we analyze the effect of imperfect channel estimation at the receiver and transmitter on the bit error rate performance of zero-forcing interference alignment.

System Model

- IA model



The transmitted directions are $\boldsymbol{T_{i1} = H_{i2}^{-1} I_2}$ and $\boldsymbol{T_{i2} = H_{i1}^{-1} I_1}$.

- CSI model

The channel matrix $\boldsymbol{H_{ij}}$ is estimated at the transmitters or receivers as $\widehat{\boldsymbol{H}}_{ij}$.
It can be expressed as :

$$\widehat{\boldsymbol{H}}_{ij} = \boldsymbol{H_{ij}} + \boldsymbol{e}\Omega_{ij}. \tag{1}$$

The CE error $\boldsymbol{e\Omega_{ij}}$ is independent of $\boldsymbol{H_{ij}}$ and the elements of Ω_{ij} are assumed to be i.i.d complex Gaussian of zero mean and unit variance.

Perfect CSI

BER performance of the $\boldsymbol{M \times 2}$ IA system using $\boldsymbol{K}$-PSK modulation can be approximated as:

$$\boldsymbol{BER}_{K-\text{PSK}} \approx \frac{1}{\max(\log_2 K, 2)} \sum_{i=1}^{\min(2,\lceil K/4 \rceil)} (1 - \mu_i) \tag{2}$$

$$\text{where } \mu_i = \sqrt{\frac{\gamma_s \sin^2((2i-1)\pi/K)}{1 + \gamma_s \sin^2((2i-1)\pi/K)}},$$

and γ_s is the effective symbol SNR gain. For the special case of no CE error then

$$\gamma_s = \frac{E_s}{N_0}. \tag{3}$$

With accurate CSI knowledge, perfect IA achieves single user performance.

IMPERFECT CSI AT THE RECEIVER ONLY

We analyze the case when the 2 receivers have imperfect CSI while the $\boldsymbol{M}$ transmitters have perfect CSI. In this case, the effective symbol SNR gain (2)) is

$$\gamma_s = \frac{E_s}{\mathrm{E}[\widehat{\mathbf{n}}_i \widehat{\mathbf{n}}_j^H]_{i,i}}, \tag{4}$$

for $i = 1, 2, \cdots, M$, where $\boldsymbol{X}_{i,i}$ is the ith diagonal element of $\boldsymbol{X}$.
Generally, when *only* $\boldsymbol{V}$ *out of* $\boldsymbol{M}$ transmitters are sending data then

$$\gamma_s \approx \frac{E_s/N_0}{1 + e_r^2(V+1)(M+1)E_s/N_0} \tag{5}$$

$$= \frac{E_s/N_0}{1 + e_r^2(M+1)^2 E_s/N_0}\Bigg|_{V=M}. \tag{6}$$

At infinite bit SNR, the error floor due to inter-stream interference is given by

$$\gamma_s^{\infty} \approx \frac{1}{e_t^2(M+1)^2}. \tag{7}$$

IMPERFECT CSI AT THE TRANSMITTER ONLY

The effective symbol SNR gain in case all the $\boldsymbol{M}$ transmitters are active can be expressed as

$$\gamma_s \approx \frac{E_s/N_0}{1 + e_t^2(M+1)^2 E_s/N_0}. \tag{8}$$

At infinite bit SNR, the error floor due to inter-stream interference is given by

$$\gamma_s^{\infty} \approx \frac{1}{e_t^2(M+1)^2}. \tag{9}$$

IMPERFECT CSI AT THE RECEIVER AND TRANSMITTER

When $\boldsymbol{V}$ transmitters are active, the effective SNR gain is

$$\gamma_s \approx \frac{E_s/N_0}{1 + (e_r^2 + e_t^2)(V+1)(M+1)E_s/N_0}, \tag{10}$$

and the error floor due to residual inteference after ZF is

$$\gamma_s^{\infty} \approx \frac{1}{(e_r^2 + e_t^2)(V+1)(M+1)}. \tag{11}$$

SIMULATION RESULTS