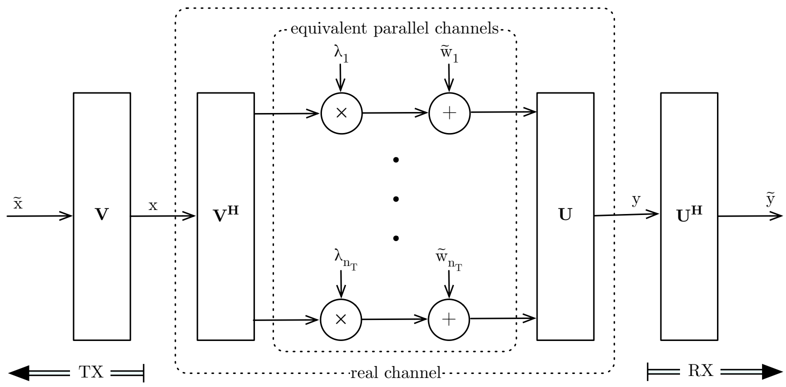
Receivers for wireless communications II	**Short Assignment** 5
Spring Semester 2013	Out: 2013-04-26
Telecommunications Circuits Laboratory	Due: 2013-05-03
EPF Lausanne	*Revision* : 1.0

Introduction

In class we have seen how a MIMO channel can be converted into a set of independent SISO channels using singular value decomposition (SVD). We will now examine this transformation in a MATLAB environment.

Scenario

Consider the MIMO transmission scenario shown below, with n_T transmit and n_R receive antennae. Assume that the channel is stable (i.e. $\boldsymbol{H}$ does not change) over the entire block length of L symbols. We would like to achieve virtual transmission of each symbol in $\widetilde{\boldsymbol{x}}$ over an independent eigenmode of the channel.



Exercises

Task 1

Assuming $n_T = n_R = 4$ and high SNR ($\sigma_n^2 = 0.01$), reproduce the system shown above by completing the 4 missing lines of code in `mimoSimulator.m`.
What relationship can you observe between the transmitted $\widetilde{\boldsymbol{x}}$ and received $\widetilde{\boldsymbol{y}}$ given the singular values (eigenmodes) in $\boldsymbol{S}$? Notice that the singular values are given in descending order.
Now lower the SNR by setting $\sigma_n^2 = 0.5$ and simulate the transmission of 10^4 symbols over each eigenchannel by setting L. Execute the following to calculate the BER on each channel

```
>> sum(xb~=yb,2)./L
```

What can you conclude about the reliability of each channel, given that σ_n^2 applies equally to all of them?

Task 2

Now examine some asymmetric cases $n_T \gtrless n_R$, e.g. $[n_T, n_R] = [5,3]$ and $[3,5]$. What happens to $\widetilde{\boldsymbol{x}}$ in the case $n_T > n_R$? And to $\widetilde{\boldsymbol{y}}$ when $n_T < n_R$? How many equivalent channels can we theoretically use?

Hint: this number, r, has to do with the channel (and the matrix $\boldsymbol{H}$) and is only bounded by n_T and n_R.

Task 3

This task is completely unrelated to Tasks 1 and 2. As we have seen in the lecture, assuming a channel matrix $\boldsymbol{H}$ with i.i.d elements $h_{ij} \in \mathcal{CN}(0,1)$, fully known at the receiver, then the optimal covariance matrix for the transmitted signal is $\boldsymbol{K}_x = (P'/n_T)\boldsymbol{I}_{n_T}$. In this case, the achievable capacity is given by

$$C = E\left[\log_2 \det\left(\boldsymbol{I}_{n_T} + \frac{\text{SNR}}{n_T}\boldsymbol{S}^2\right)\right]$$

where $\boldsymbol{S}$ contains only diagonal entries, which are the ordered singular values of $\boldsymbol{H}$.

We would now like to examine via simulation the increase in capacity with the number of antennae, as a function of SNR. We will only consider symmetric MIMO scenarios, where $n_T = n_R$. A starting script is given in `capacityWithAntennae.m`. Complete this script, to produce a graphic with three curves, for the MIMO 2×2, 3×3, and 4×4 configurations, taking the expectation above over 10^4 channel realizations. What happens to the capacity as the number of antennae increases?

Hand In Instructions

You can submit your solutions (2 Matlab scripts and a short report) online on to the moodle website of the lecture until 03.05.2013.