Report MIMO Project

# The Channel

## The Tab Model

We can model a wireless channel as a complex number which is changing in time. Here we ignore that the complex data symbol is modulated and then mapped to a carrier frequency and that the channel itself is a real function. And only use the complex Channel representation:

// complex channel representation

## SISO

The well know channel model of a wireless communication System is that we have one antenna on each side – receiver and transmitter. This creates a Channel like //y=h\*x+n, where one symbol is transmitted per time slot, modulated by the channel and noise added.

## MIMO

Over the last decade much research was done on MIMO (Multiple Input Multiple Output) channels. The base idea is to increase the throughput with special diversity in contrast to only frequency and time diversity of our well known typical SISO (Single Input Single Output) channel.

// formula SISO

The special diversity as the name MIMO already suggest is achieved by using multiple Antennas on both receiver and transmitter side of the channel, which alters our channel form a single Tab //h per time to a Matrix //H.

// formula MIMO Channel

In a sufficient strong Fading environment and with sufficient antenna separation this Matrix is an all Random //H element of C, NxM Matrix.

# CSI

The question now is, is it possible to increase the Throughput of this channel with knowledge of the channel Matrix //H. and to investigate this we use following Channel Representation and we are fully aware of its implications and imperfections.

## An Optimal Solution

In a single user MIMO systems we have the ability to fully diagonalizable the channel by using the SVD of H:

// SVD

Now we can use this information and change our transmitter and receiver as follows:

// Channel diagonalisation

Now we have created min(N,M) diagonal channels, the remaning question is how to distribute the transmit power over the antennas to maximize the throughput. The solution is called water filling:

Waterfilling compares the channel eigenfalues of each channel and fills up the channels until the whole power budget is spent.

// img of water filling

//description of water level

# Multiuser Case

Since Water Filling diagonalizese the channel it does not matter what kind of decoder is used on the receiver side, the streams are already independent. But Waterfilling is only feasible in a single user case due to the fact that inter antenna data coordination is needed. So in a multi user scenario we need other methods to decode the channel.

We use two well-known Receiver structures:

1. Linear MMSE Receiver  
   //formula
2. V-BLAST MMSE or MMSE with SIC  
   //formula (algorithm)  
   the SIC receivers try to diagonalize the channel on the receiver side.

Generally speaking the SIC receivers provide better Throughput but are more complicated to implement, and harder to adapt.

## Optimizing the Throughput of V-Blast

[Jindal]

The Paper proposes an algorithm which optimizes the throughput with an SIC receiver, the papers goal is to solve the problem of beam forming in a Broadcast or Downlink Channel, so exactly the opposite direction than we are discussing in this report. But as //paper has described there is a duality of these two channels and we are able to use the optimized results of the MAC to optimize the BC. So his work is using this duality to solve the easer problem of the MAC and then transform it back to the BC problem, so his work is highly relevant to us.

// Duality description

// abstract of Jindal

// Jindal algorithm

## Comparison

Numerical Gradient Search function

We implemented a numerical gradient search for the SIC receiver to compare to the Jindal algorithm in terms of throughput maximization. We do not compare it in terms of complexitiy or speed of convergence.

Convergence is guaranteed for the numerical Gradient based on the work of //paper. And the Jindal himself adds the proof of convergence to in his paper.

# Linear MMSE

From there we started to investigate the LMMSE receiver.

//theory

// formulas

## Optimizing

The drawback of this decoder is his very high channel dependency. // problems

Fodor describes an algorithm in his //paper to optimize the throughput of an typical Cellular Network Channel, but to improve stability and feasibility of his algorithm he sacrifices accuracy and chooses to use a very week constraint. Which leads to unusable results in comparison to an easy numerical Gradient search of the same Optimum.

## Numerical Gradient

So we will only look at the numerical Gradient for Optimizing the LMMSE receiver. As shown in // Figure there is some pretty big improvement over just equal power distribution, but even for high SNR cases at least one channel is closed, which means that at least one user is not allowed to send any data.