UPPSALA UNIVERSITET

CHALMERS

Wireless IP Project

OFDM channel estimation with emphasis on the uplink

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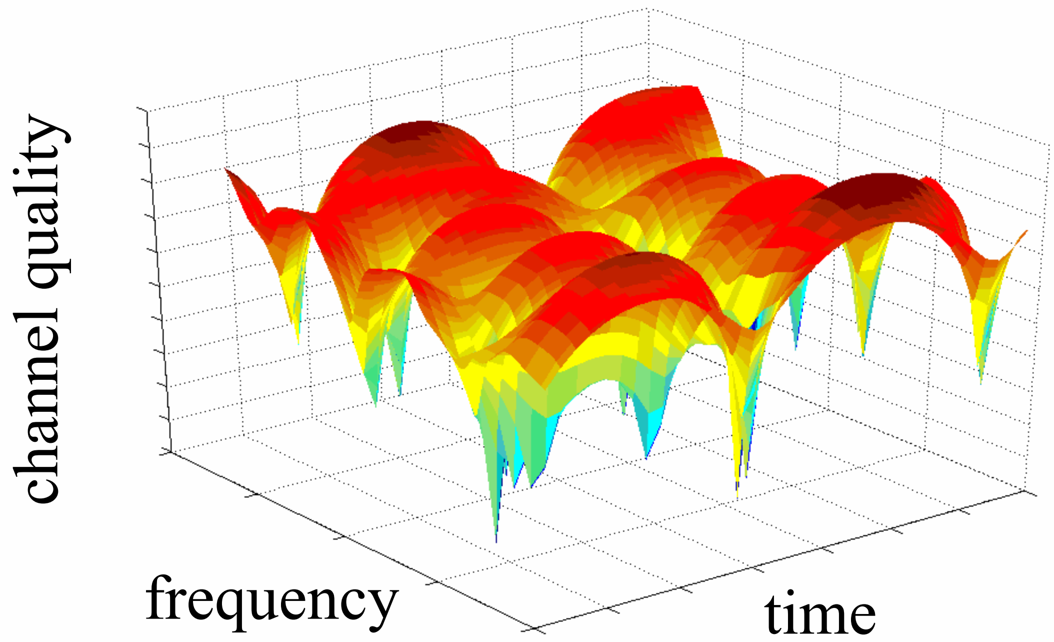
Channels fade in time and frequency



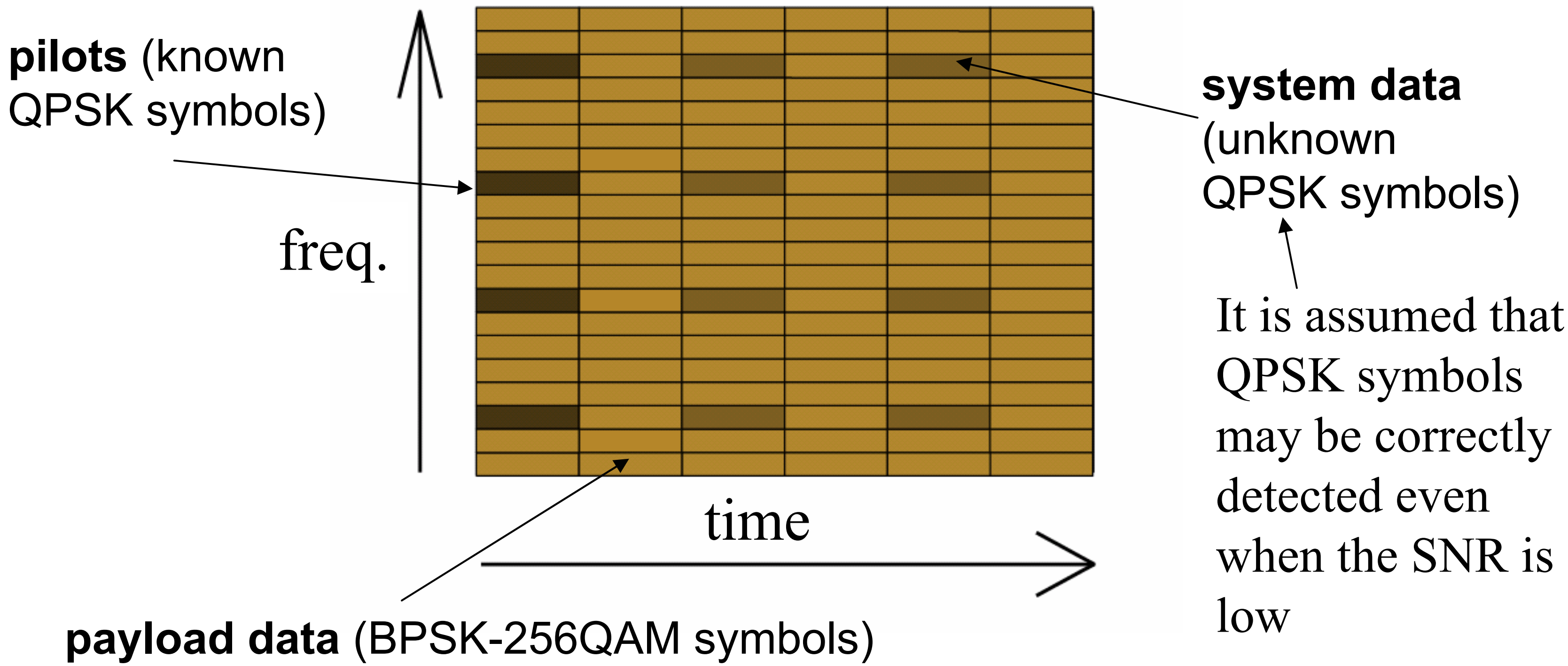
We need to estimate/predict the channel in order to :
- retrieve payload data
- allow for optimal scheduling

Adapting to the short-term fading

Our system allocates time/frequency resources based on channel quality, which enables multiuser diversity gains.

- At time t, the quality (SINR) of the fading channel at time t+L must be predicted, for all resources. This is done for each terminal over a large bandwidth.
- A scheduler at the base station allocates resources based on the qualities signalled by the terminals

The least unit for user resource allocation is called a bin



- Use pilots and system data to estimate the channels at these 12 locations/bin
- To retrieve payload data, fit a smooth surface to the rest of the bin.

Modelling the complex channel on one subcarrier (tap)

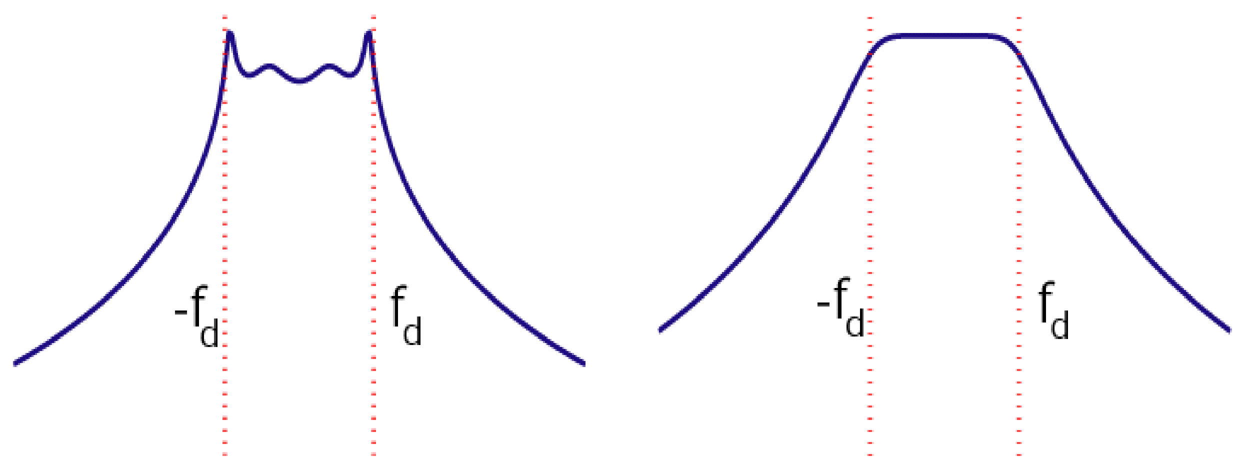
$$x_{n,t+1} = \underbrace{\begin{bmatrix} -d_1 & 1 & & \\ -d_2 & & 1 & \\ -d_3 & & & 1 \\ -d_4 & & & \end{bmatrix}}_{F_{tap}} x_{n,t} + \underbrace{\begin{bmatrix} c_1 \\ c_2 \\ c_3 \\ c_4 \end{bmatrix}}_{G_{tap}} e_{n,t}$$

$$h_{n,t} = \underbrace{\begin{bmatrix} 1 & 0 & 0 & 0 \end{bmatrix}}_{H_{tap}} x_{n,t}$$

The time correlation is described by the $d_1..d_4, c_1..c_4$ parameters (4^{th} order AR model)

Time correlation

Doppler spectra for the two different fading models



Jakes statistics *Robust statistics*

Either of these is approximated with a 4th order AR model.

Modelling parallel taps on adjacent subcarriers

$$\begin{bmatrix} x_{1,t+1} \\ x_{2,t+1} \\ x_{3,t+1} \\ x_{4,t+1} \end{bmatrix} = \underbrace{\begin{bmatrix} F_{tap} & & & \\ & F_{tap} & & \\ & & F_{tap} & \\ & & & F_{tap} \end{bmatrix}}_{F_{user}} \begin{bmatrix} x_{1,t} \\ x_{2,t} \\ x_{3,t} \\ x_{4,t} \end{bmatrix} + \underbrace{\begin{bmatrix} G_{tap} & & & \\ & G_{tap} & & \\ & & G_{tap} & \\ & & & G_{tap} \end{bmatrix}}_{G_{user}} \begin{bmatrix} e_{1,t} \\ e_{2,t} \\ e_{3,t} \\ e_{4,t} \end{bmatrix}$$

$$\begin{bmatrix} h_{1,t} \\ h_{2,t} \\ h_{3,t} \\ h_{4,t} \end{bmatrix} = \underbrace{\begin{bmatrix} H_{tap} & & & \\ & H_{tap} & & \\ & & H_{tap} & \\ & & & H_{tap} \end{bmatrix}}_{H_{user}} \begin{bmatrix} x_{1,t} \\ x_{2,t} \\ x_{3,t} \\ x_{4,t} \end{bmatrix}$$

$$R_e = E\left(\begin{bmatrix} e_1 \\ e_2 \\ e_3 \\ e_4 \end{bmatrix} \begin{bmatrix} e_1 \\ e_2 \\ e_3 \\ e_4 \end{bmatrix}^* \right)$$

describes the frequency correlation.

A state space representation for the downlink channel

N parallel tracked subchannels :

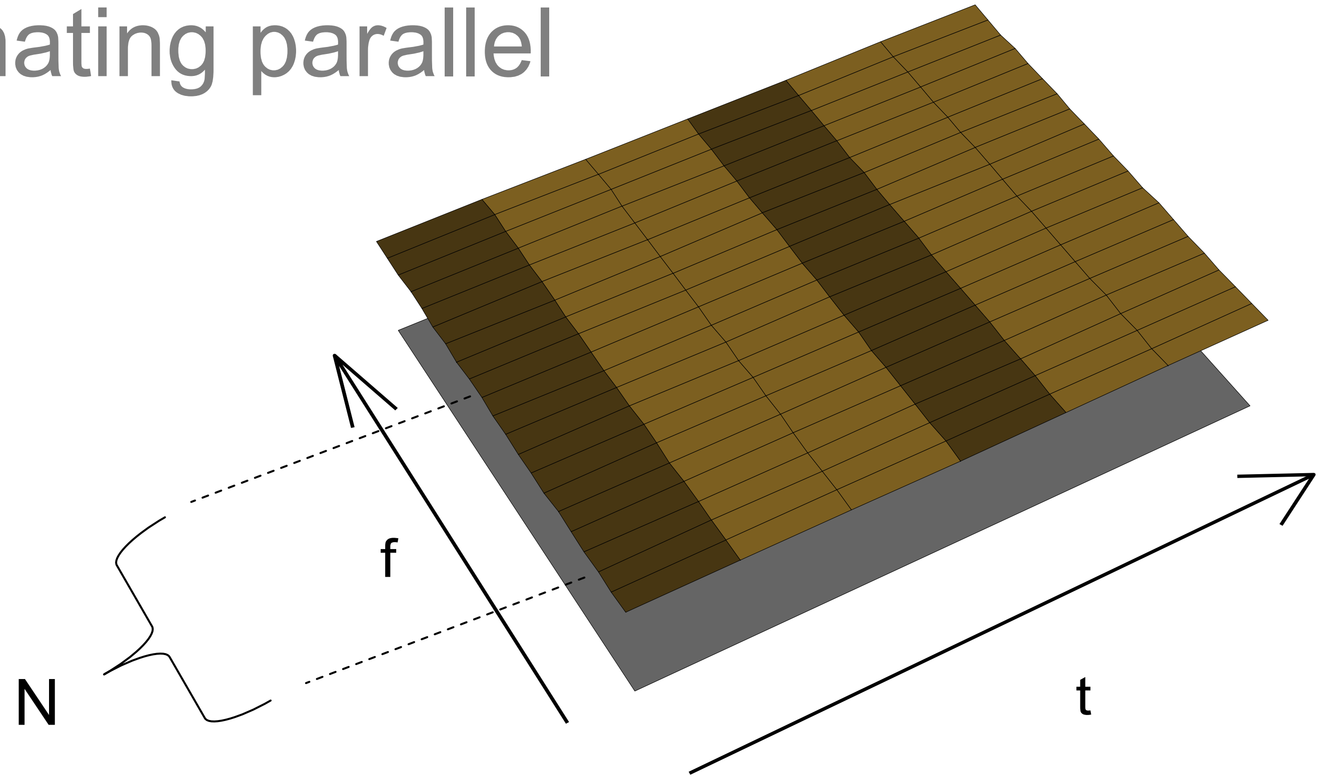
$$\begin{aligned} x_{t+1} &= F_{user} x_t + G_{user} e_t \\ h_t &= H_{user} x_t \\ y_t &= \phi_t^* h_t + v_t \end{aligned} \quad \text{, where } \phi_t^* = \begin{pmatrix} s_1 & & \\ & \ddots & \\ & & s_N \end{pmatrix}$$

The Kalman filter produces both $\hat{h}_{t|t}$, $\hat{h}_{t+1|t}$ and $\hat{h}_{t+L|t}$

ϕ_t^* is known when $s_1..s_N$ are pilots. When $s_1..s_N$ are downlink data (unknown) we need to use estimated values :

$$\hat{s}_{n,t} = \text{detectQPSK}(y_{n,t}/\hat{h}_{n,t|t-1})$$

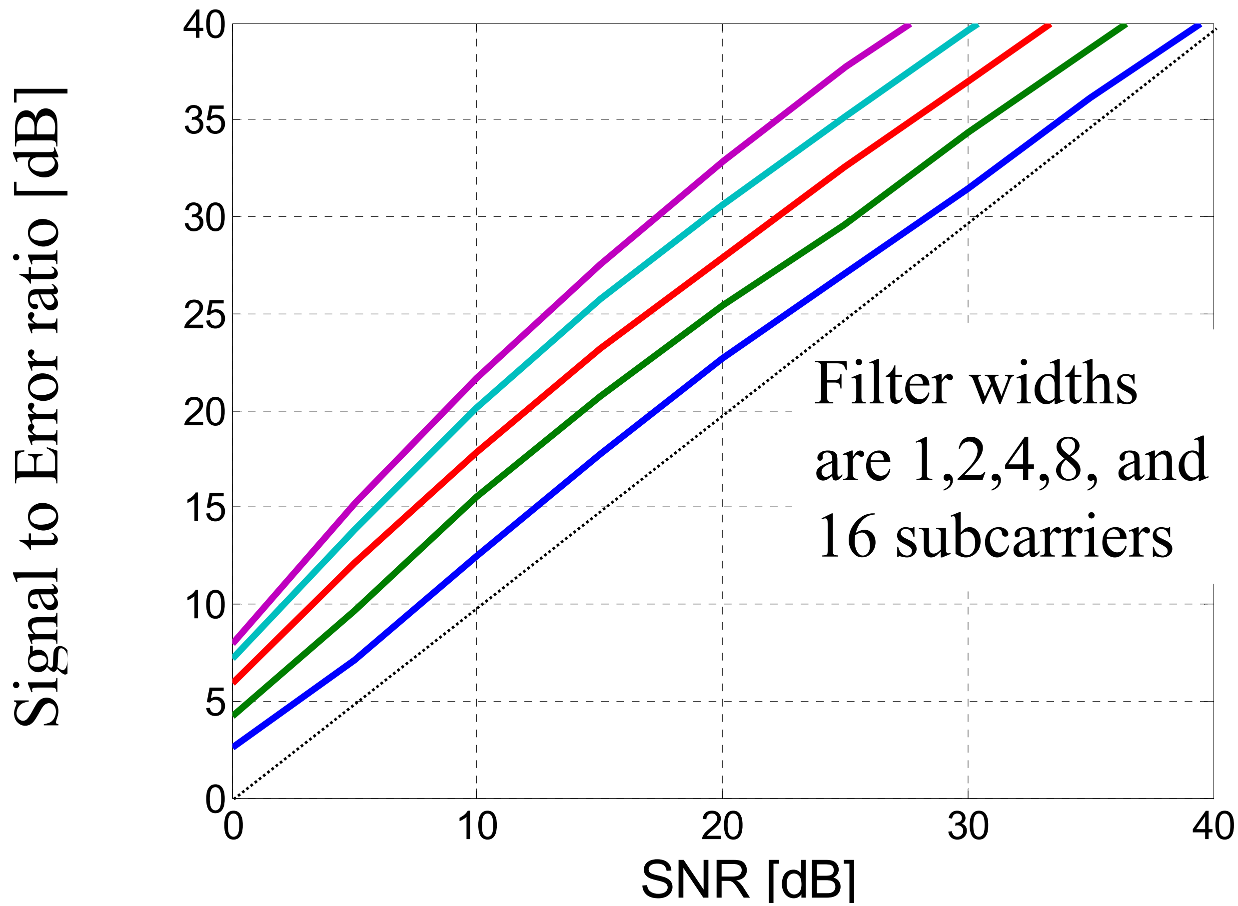
Estimating parallel taps



Increasing N :

- Increasing filter performance (more frequency correlation is taken into account.
- Increasing computational load on the estimator.

The benefits of increased filter width



The investigated channel is flat fading. Doubling the filter width leads to a 3 dB increase in performance

What about the uplink?

- The downlink enables each user to estimate its own channel. For the uplink, the basestation needs to estimate several channels – one for each user.
- We investigate one method of doing this : let all users share the same resource. Users not scheduled for traffic only send pilots. The base station then operates on a superposition of signals (overlapping pilots)

Modelling the superposition

Several users (U) share the same resource.

$$X_{t+1} = \underbrace{\begin{bmatrix} F_{user} & & & \\ & F_{user} & & \\ & & F_{user} & \\ & & & F_{user} \end{bmatrix}}_{F} X_t + \underbrace{\begin{bmatrix} G_{user} & & & \\ & G_{user} & & \\ & & G_{user} & \\ & & & G_{user} \end{bmatrix}}_{G} e_t$$

$$h_t = \underbrace{\begin{bmatrix} H_{user} & & & \\ & H_{user} & & \\ & & H_{user} & \\ & & & H_{user} \end{bmatrix}}_{H} X_t$$

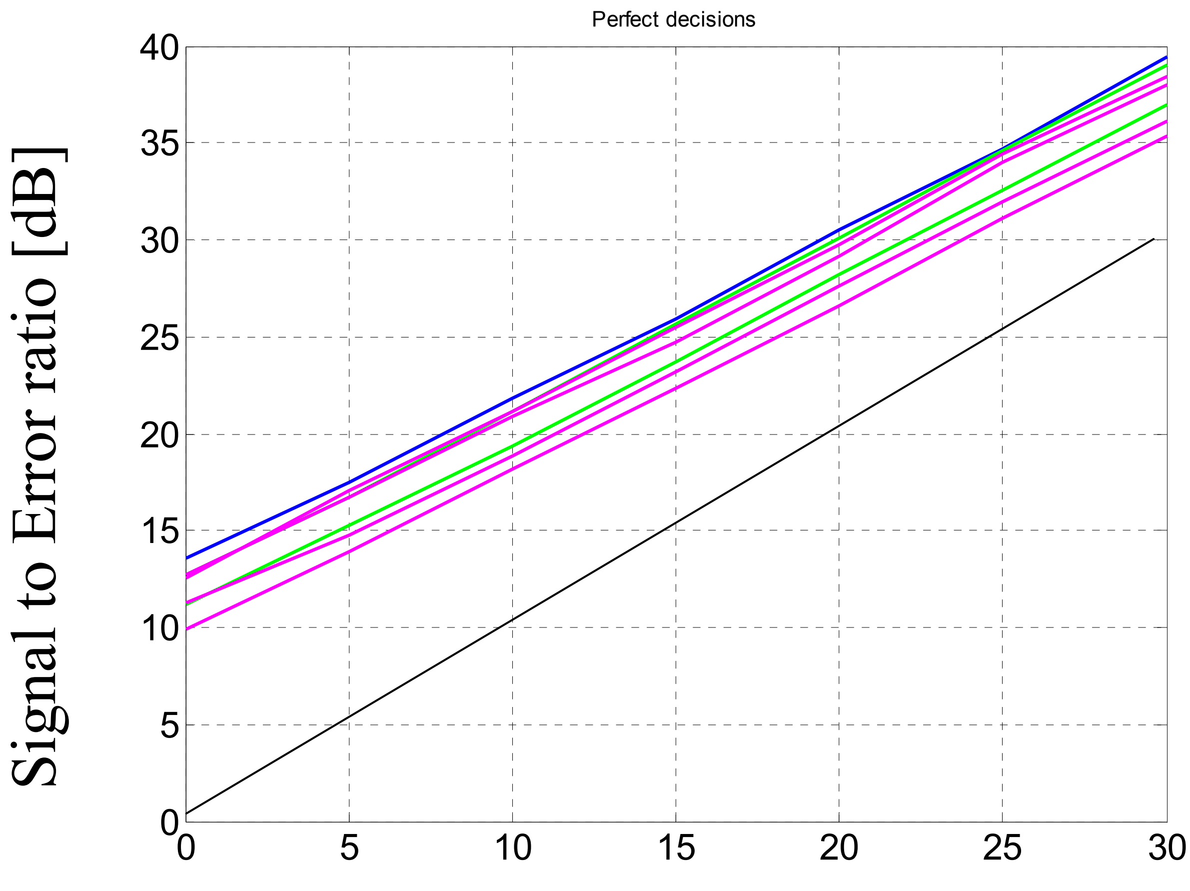
h_t contains all N taps for all U users.

$$y_t = \underbrace{\begin{pmatrix} s_{1,1} & & & s_{1,U} & \\ & \ddots & \dots & & \ddots \\ & s_{N,1} & & & s_{N,U} \end{pmatrix}}_{\phi_t^*} h_t + v_t$$

Note that y_t still only holds N values (N subchannels)

Performance for many users

Assume unknown QPSK symbols are correctly detected



Blue : 1 user

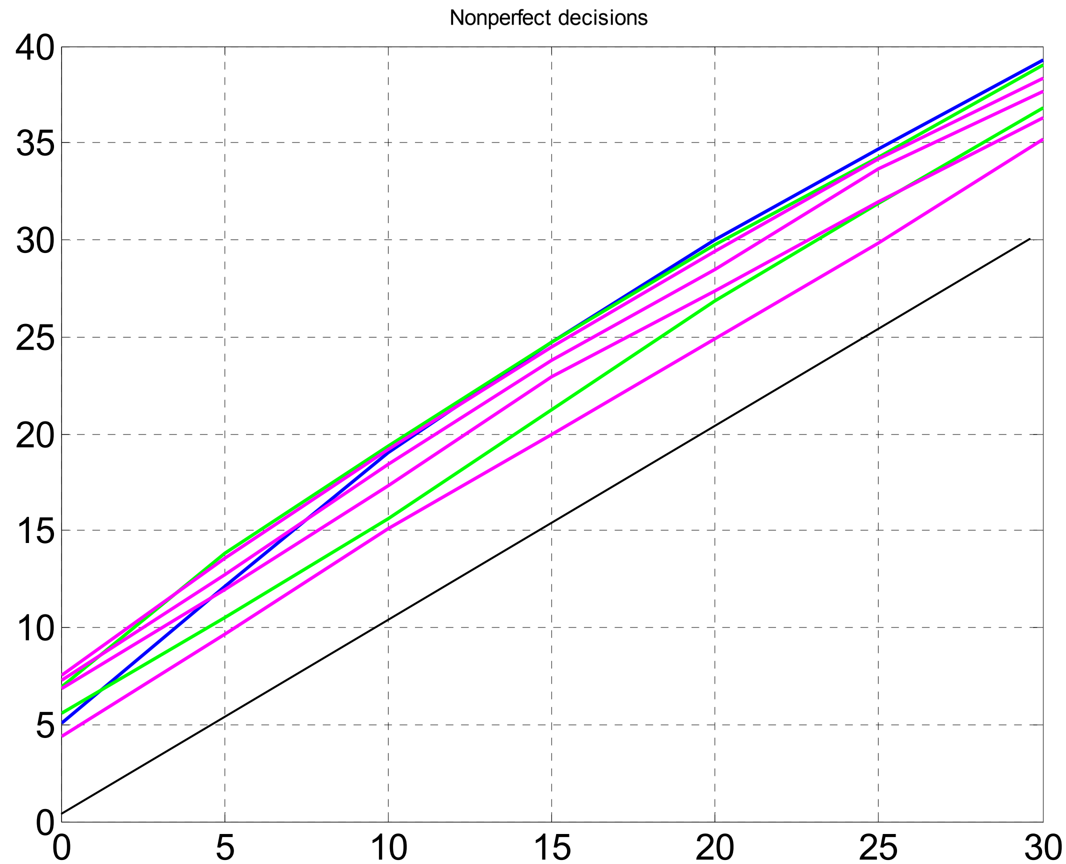
Green : 2 users

Purple : 4 users

Number of users < filter width ⇒ Little or no loss

Performance for many users

Unknown QPSK symbols are estimated based on estimates of the channel state.



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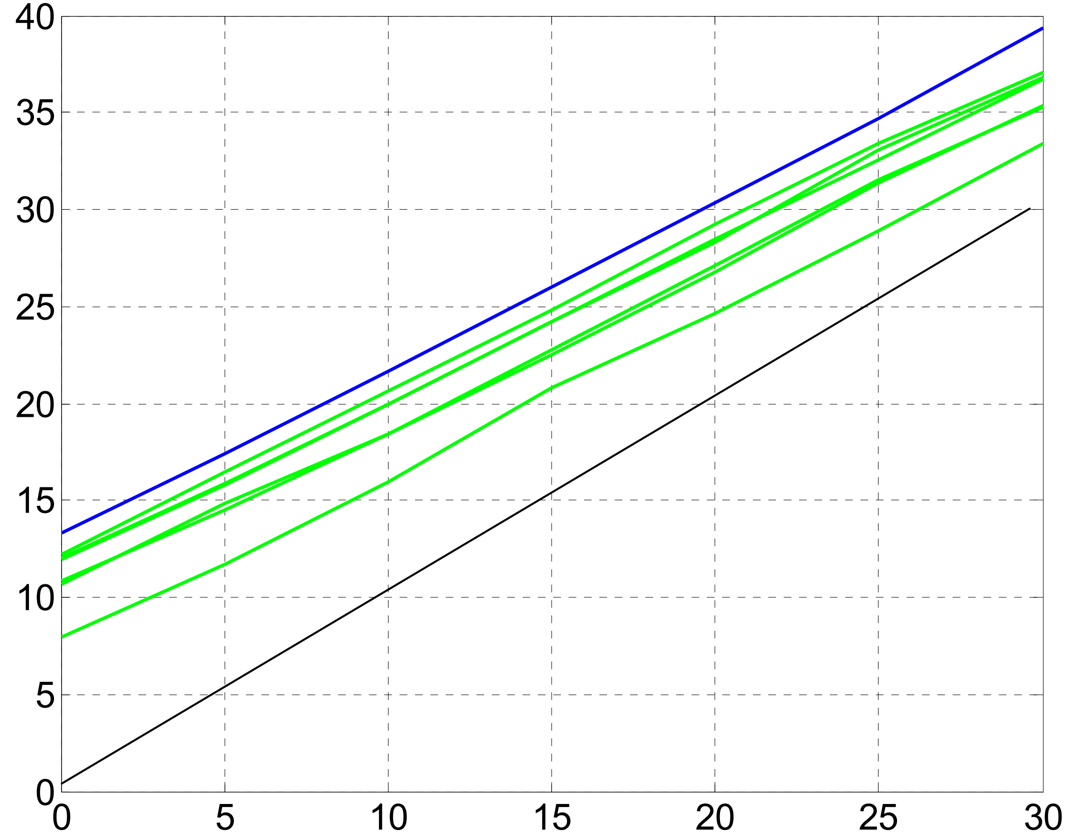

Blue : 1 user

Green : 6 users

⇒ **Good results even when number of users > filter width**

Performance for many users

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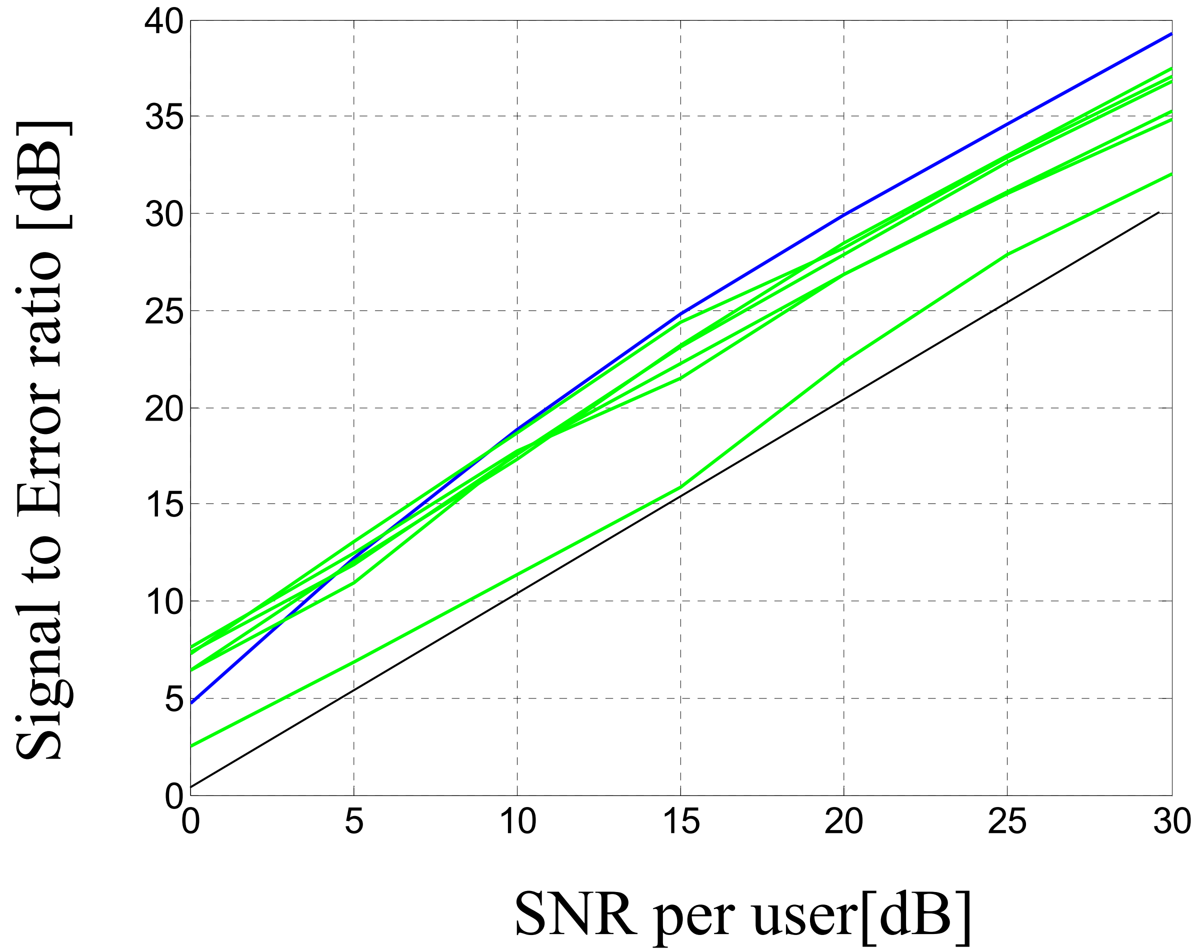

Blue : 1 user

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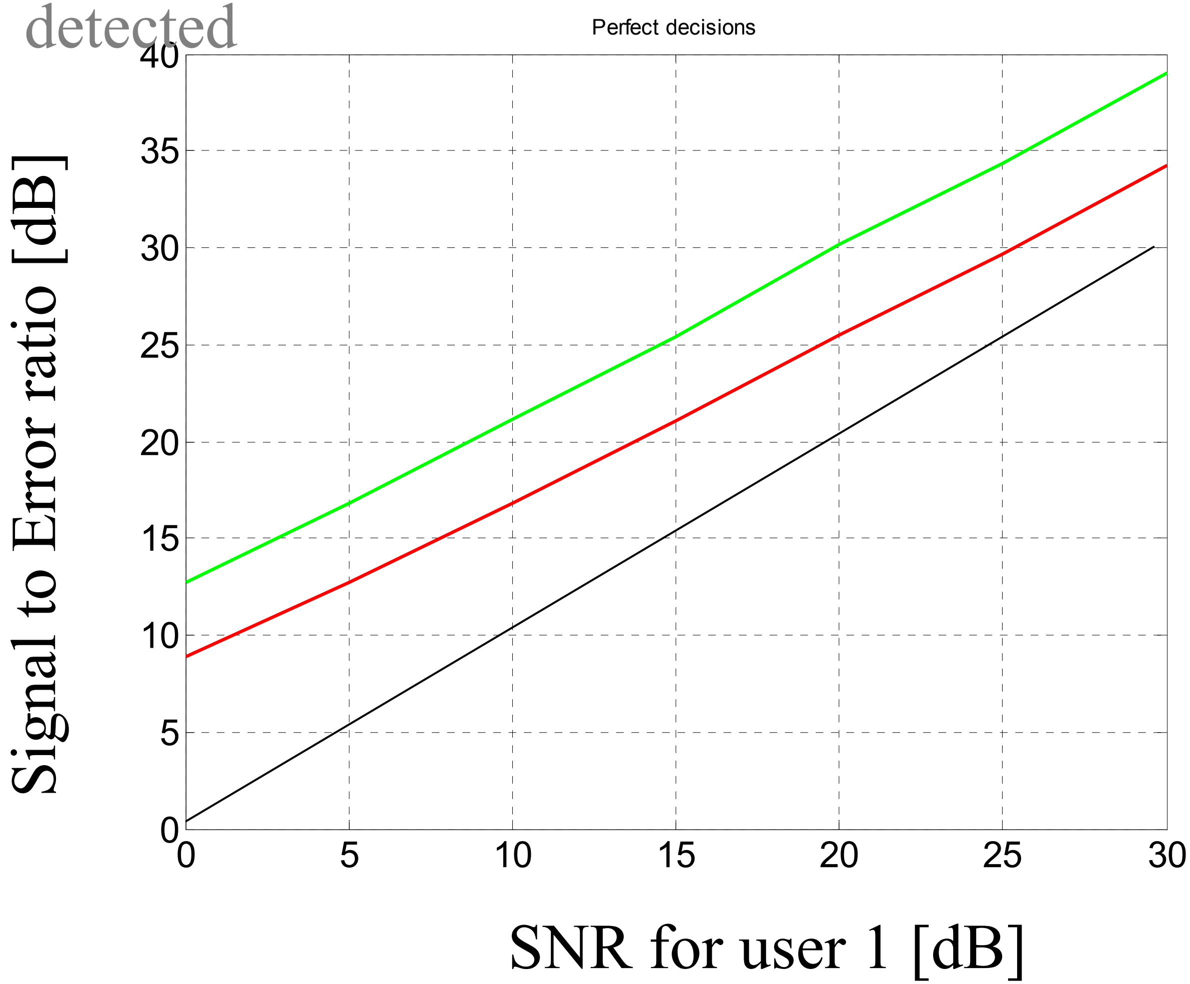
⇒ **Good results even when number of users > filter width**

Performance for two users with different SNRs

Assume unknown QPSK symbols are correctly detected



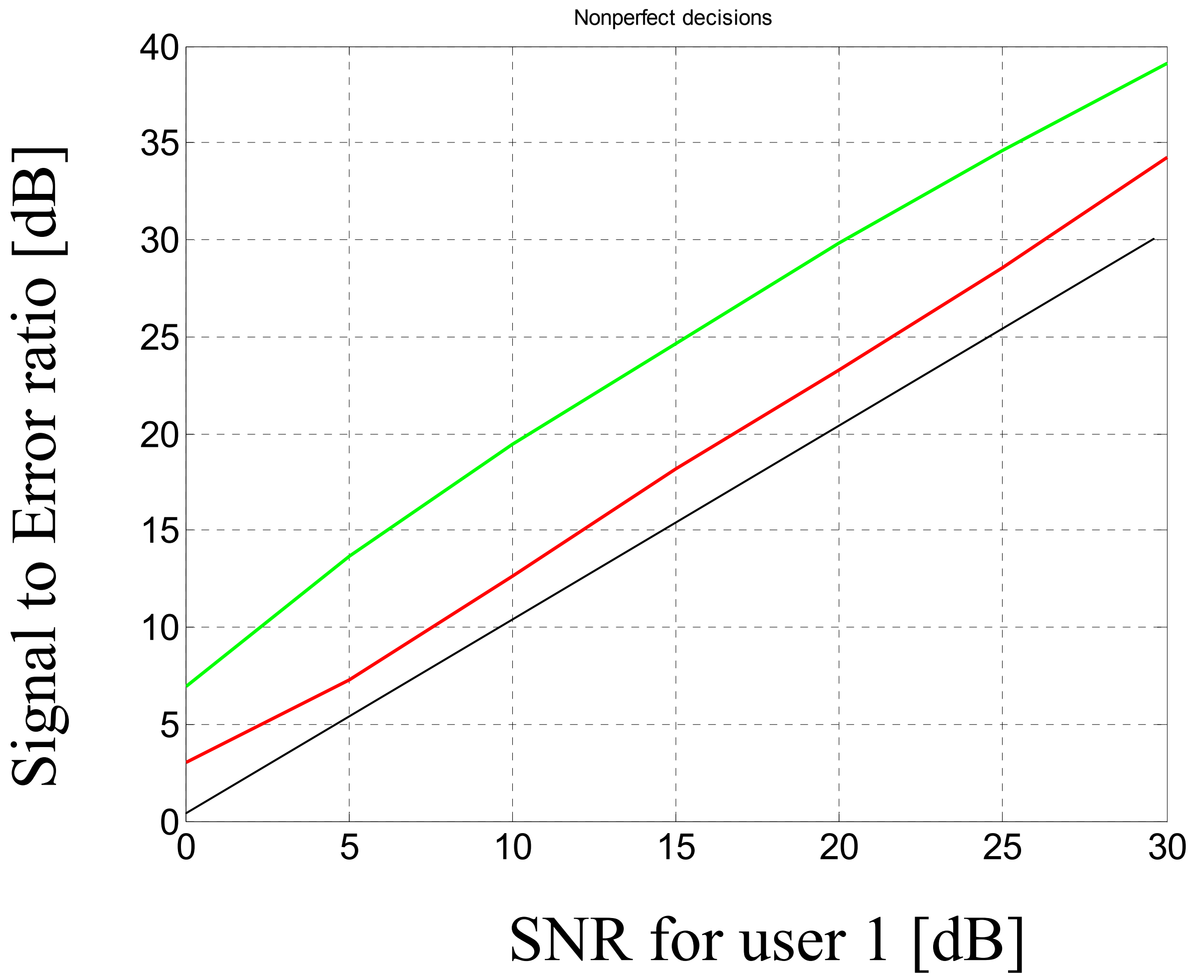
Green : User 1

Red : User 2

The SNR for user 2 is 3 dB below the SNR for user 1

Performance for two users with different SNRs

Unknown QPSK symbols are estimated based on estimates of the channel state.



Green : User 1

Red : User 2

The SNR for user 2 is 3 dB below the SNR for user 1

Conclusions

- The results show that this choice of design for the uplink is likely to work.
- In reality, different users will have different SNRs and channels won't be flat fading. This will put harder strain on the filter and the effects of it needs to be investigated