Technical University of Denmark

DTU

Comparative analysis of equalization methods for SC-FDMA

Dogadaev, Anton Konstantinovich; Kozlov, Alexander; Ukhanova, Ann

Link back to DTU Orbit

DTU Library
Technical Information Center of Denmark

Comparative Analysis of Equalization Methods for SC-FDMA

Anton Dogadaev, Alexander Kozlov and Ann Ukhanova

Saint-Petersburg State University of Aerospace Instrumentation,
Technical University of Denmark

November 11, 2010

Scope of work

Range of application:

- Wireless telecommunication network based on the 3GPP LTE standard

Task definition:

- Development of a simulation model for signal transmission in the LTE Uplink
- Implementation of equalization algorithms for this model
- Performance analysis of the considered equalization techniques
- Optimization of parameters of these schemes

SC-FDMA transmission scheme (LTE Uplink)
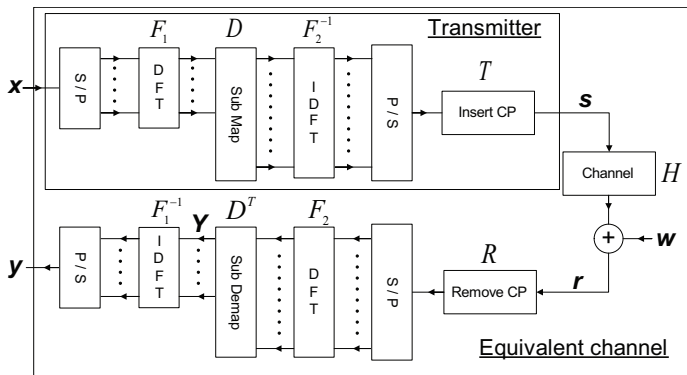
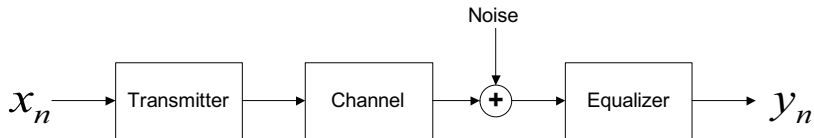Equation of the equivalent channel:

$$y = F_1^{-1} D^T F_2 \left(RHT \right) F_2^{-1} D F_1 x + w',$$

where w' is the noise in the equivalent channel

Equalization task

The main goal of equalization is to compensate the transmitted signal distortion, caused by the channel.

- ▶ Equalization performance may be significantly improved using error correcting decoder output $\widehat{s}_n$:
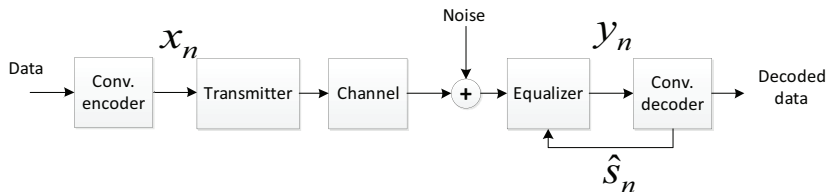
SC-FDMA linear equalization

Vector $\{G_{LE,1} \ldots G_{LE,M}\}$ denotes frequency domain coefficients used for adjustment of channel effects
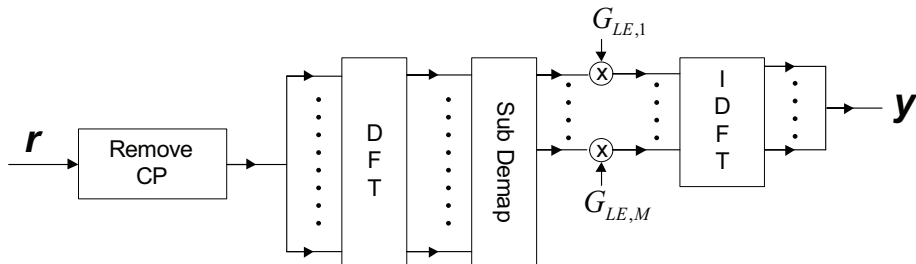
SC-FDMA DFE equalization

SC-FDMA turbo equalization

Log likelihood ratio (LLR):

$$L(b_{k,j}) = \log \frac{P\left(b_{k,j=1}\right)}{P\left(b_{k,j=0}\right)}$$

SC-FDMA turbo equalization

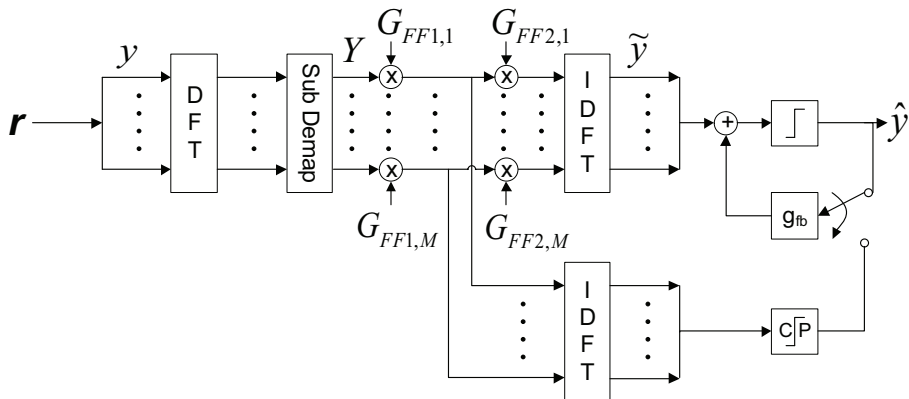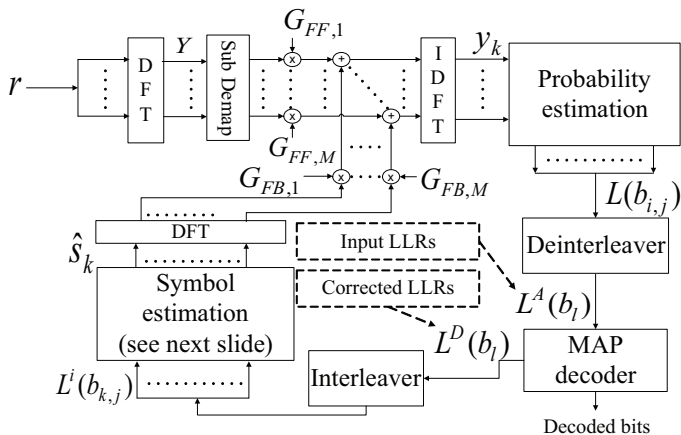Probabilities of all the coded bits are calculated as LLRs on each step of the algorithm:

$$L(b_{k,j}) \approx \min_{\epsilon_k^i : b_{k,j}=0} \epsilon_k^i - \min_{\epsilon_k^i : b_{k,j}=1} \epsilon_k^i,$$

where ϵ_k^i denotes the squared Euclidian distance of the equalizer output to constellation point

Estimation of the transmitted symbol vector:

$$\widehat{s}_k = E\left(\underline{s_k^i}\right) = \sum_{i=1}^{M} s^i P_a\left(\underline{s_k^i}\right),$$

where M is the size of the constellation diagram,
$P_a\left(\underline{s_k^i}\right)$ determines the probability of the kth symbol in the transmitted vector to be the ith point of constellation

Derivation of the equalizers FF and FB coefficients
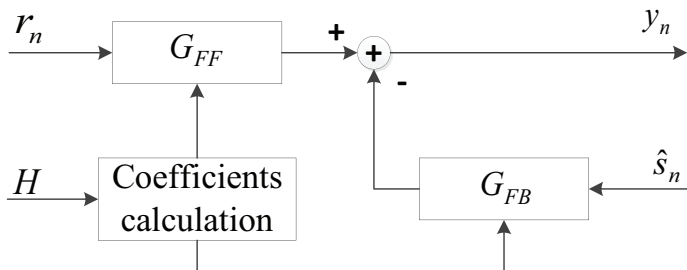
Coefficients of all the filters are derived using Minimum Mean Square optimization (MMSE) based on the known channel behavior

Channel model with Rayleigh fading

The frequency-selective channel with Doppler spread was modeled as tapped delay line where taps are independent Rayleigh fading simulators:

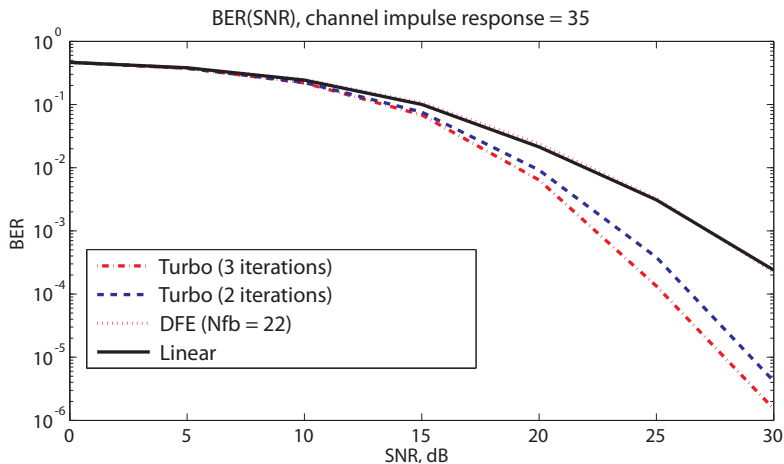$$h(t, \tau) = \sum_{i=1}^{N} c_i(t) \delta(\tau - \tau_i)$$

Tap coefficients with number of scatterers M are defined as follows:

$$c_i(t) = \frac{\sigma_i}{\sqrt{M}} \sum_{k=1}^{M} A_k e^{2j\pi f_{dk} t}$$

where f_{dk} is Doppler shift of kth scatterer, σ_i^2 is average power of the taps with exponential distribution, and $A_k = N\left(0, \frac{1}{2}\right) + jN\left(0, \frac{1}{2}\right)$

Experimental results

For the error probability 10^{-3} the advantage of application of turbo equalization is up to 3 dB

BER(SNR), channel impulse response = 35

Legend:
- Turbo (3 iterations)
- Turbo (2 iterations)
- DFE (Nfb = 22)
- Linear

Conclusion

- The simulation model of the SC-FDMA transmission was developed and tested for the given equalization schemes

- Turbo equalization has better performance in comparison with linear and DFE techniques and allows to achieve performance advantage up to 3 dB for bit error probability 10^{-3}

- 2-3 iterations of turbo equalization are enough to get significant performance increase in the SC-FDMA system

- Turbo equalization may face error propagation problem as well as DFE

Any questions?