3G Evolution

Chapter: 5

Wider-band single-carrier transmission

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Outline

- Why wider-band single carrier transmission?
- Equalization against radio- channel frequency selectivity
  - Time domain linear equalization
  - Frequency domain equalization
  - Other equalizer strategies
- Uplink FDMA with flexible bandwidth assignment
- DFT- spread OFDM
  - Basic principles
  - DFTS-OFDM receiver
  - User multiplexing with DFTS-OFDM
  - Distributed DFTS-OFDM

Why wider-band single carrier transmission

- OFDM

  Advantages:
  - Provides overal very high transmission bandwidth.
  - Robust to signal corruption due to radio channel frequency selectivity.

  Drawbacks:
  - Large variations in the instantaneous power of transmitted signal.
    - Reduced power amplifier efficiency
    - High power amplifier cost
    - Critical for uplink
  - Some methods to reduce this power variations discussed in chapter 4.
    - Limitations on the amount of reduction in these variations.
    - Significant computational complexity and/or reduced link performance.

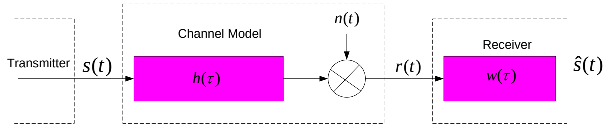
- wider-band single carrier transmission as an alternative for multicarrier transmission especially for Uplink.

Equalization against radio- channel frequency selectivity

- Equalization: main method to handle signal corruption due to radio channel frequency selectivity
- Time domain linear equalization
  - Rake receiver in DS-CDMA
    - Channel mached filtering with filter response as the complex conjugate of the time reversed channel impulse response.
    - Also called Maximum Ratio Combining (MRC)

$$w(\tau) = h^*(-\tau)$$

    - Maximizes post filter signal to noise ratio
    - No compensation for radio channel frequency selectivity



Time domain linear equalization

- Zero Forcing (ZF) equalizer:
- Select the receiver filter to fully compensate for the radio channel frequency selectivity.

$$h(\tau) \otimes w(\tau) = 1$$

- $\otimes$ Denotes linear convolution.
- Suppression of any signal corruption caused by radio channel frequency selectivity.
- Large or potentially very large increase in noise level after equalization.
- Overal degradation of the link performance.
- Especially for channel with large variations in frequency response.

MMSE Equalization

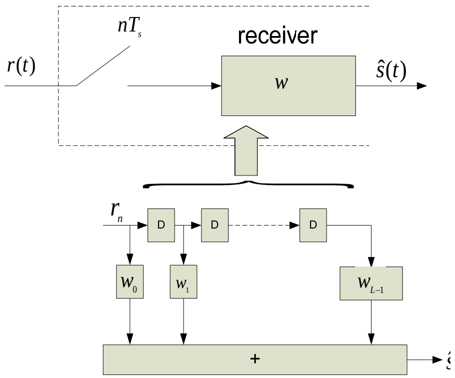
- Time domain linear equalization
  - MMSE Equalization
    - A trade-off between signal corruption due to radio channel frequency selectivity and noise/ interference.

$$\varepsilon = E\left\{\left|\hat{s}(t) - s(t)\right|^2\right\}$$

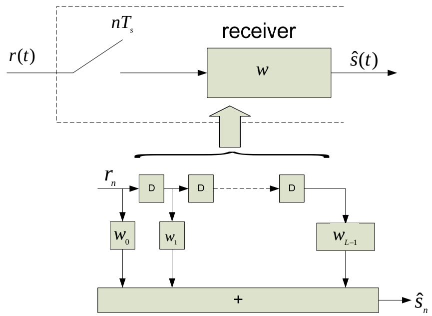
    - Select a filter to minimize the mean squared error between the equalizer output and the transmitted signal.
  - Linear equalization implemented as time discrete FIR filter.

Time domain linear equalization

- Complexity of such time discrete equalizer grows relatively rapidly with bandwidth of the sigal to be equalized:
- More wide band signal is subject to relatively more radio channel selectivity
- Requires the equalizer to have a larger span to be able to compensate it.

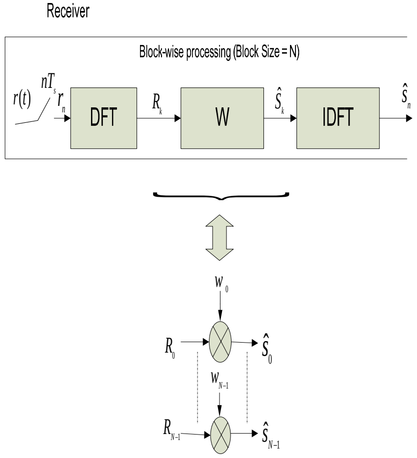


- More wideband signal leads to a correspondingly higher sampling rate for the received signal. Filter processing shall run with higher sampling rates.
- High complexity in the equalization and also calculating the inverse of channel output autocorrelation matrix.



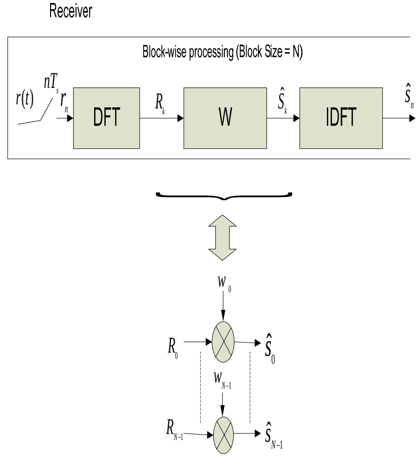
Frequency domain equalization

- Reduce complexity of equalization.
- Carried out block wise in block size N.
- Equalization as frequency domain filtering.
- Block size N preferably selected as $N = 2^n$ for some integer n to allow for computational efficient radix-2 FFT/IFFT implementation of DFT/IDFT.
- For channels with extensive frequency selectivity frequency domain equalization is less complex.



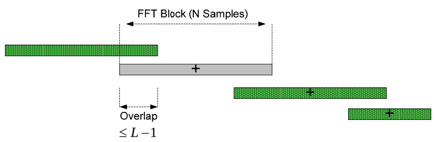
Frequency domain equalization

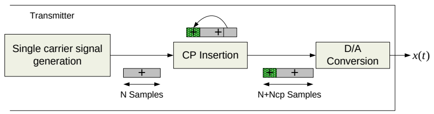
- Time domain filtering implements a time discrete linear convolution.
- Frequency domain filtering corresponds to circular convolution in the time domain.
- First L-1 samples at the output of the frequency domain equalizer will not be identical to the corresponding output of the time domain equalizer.



Frequency domain equalization

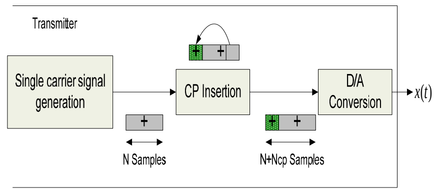
- Overlap of at least L-1 samples.
- Discard first L-1 samples at output of the frequency domain equalizer as they are also provided as the last part of the previously received / equalized block.
- Computational overhead or higher receiver complexity.
- Cyclic prefix insertion.





Frequency domain equalization

- Cyclic prefix → channel will seem to the receiver as circular convolution over a receiver processing block of size N.
- Frequency domain taps can be calculated directly.
- Estimate of MMSE equalizer in frequency domain.
- Overhead in power and bandwidth.
- Less overhead→ increase block size : channel shall be constant in duration of a block size ; upper limit for the block size



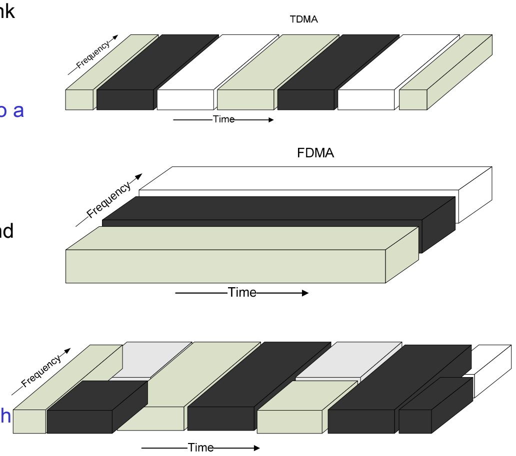
$$W_K = \frac{H_K^*}{|H_K|^2 + N_0}$$

Other equalizer strategies

- Decision feedback equalization (DFE)
  - Previously detected symbols are fed back and used to cancel the contribution of the corresponding transmitted symbols to the overal signal corruption. Used in combination with time domain linear filtering. Also used in combination with frequency domain linear equalization.
- Minimum Likelihood (ML) Detection or Maximum Likelihood Sequence Estimator (MLSE)
  - Uses the entire received signal to decide on the most likely transmitted sequence, taking into account the impact of time dispersion on the signal.
  - Viterbi Algorithm
  - Used widely in 2G but too complex for 3G evolution (much wider transmission bandwidth, much more channel frequency selectivity, much higher sampling rate)

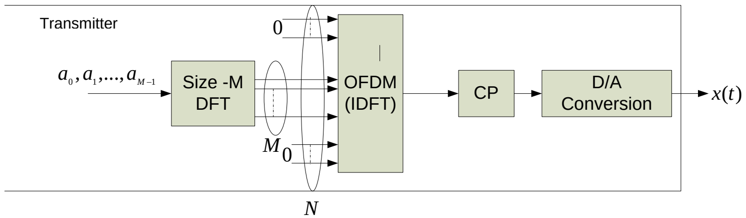
Uplink FDMA with flexible bandwidth assignment

- Share uplink radio resource using plink intra-cell multiple access scheme.
- High rate packet data transmission→ Assign the entire system bandwidth to a terminal.
- Burstiness of most packet data services→ in most cases mobile terminals do not have anything to send in uplink. TDMA required.
- Just TDMA is not bandwidth efficient.
- Uplink is power limited.
- Allocating the entire system bandwidth to one terminal is inefficient in terms of bandwidth utilization.



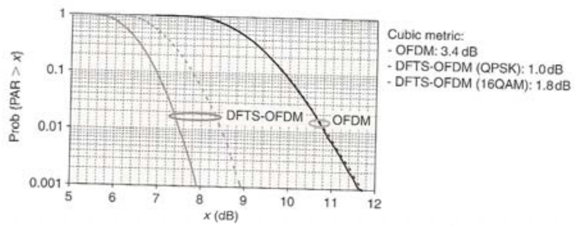
DFT Spread OFDM

- Small variations in the instantaneous power of the transmitted signal.
- Possibility of low complexity and high quality equalization in frequency domain.
- Possibility for FDMA with flexible bandwidth assignment.
- Uplink transmission scheme for LTE.



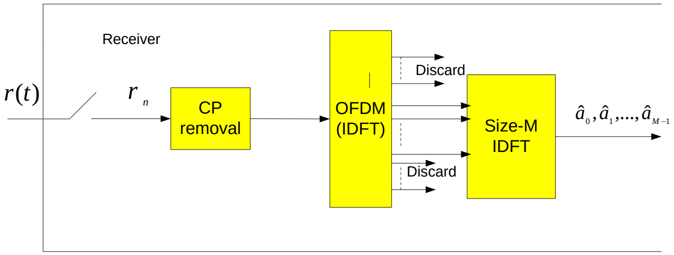
Basic principles

- Small variations in the instantaneous power of the transmitted signal.
- PAR distribution is independent of modulation in OFDM.
- Cubic metric: a measure of the additional back off required for a certain signal wave form relative to the back off needed for some refrence wave form.



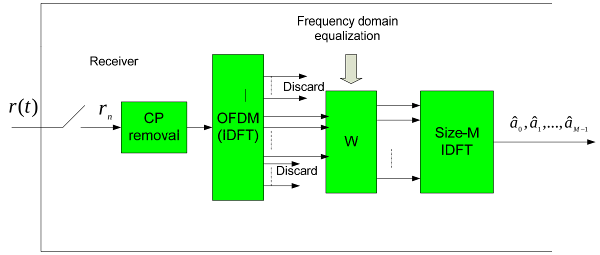
DFTS OFDM Reciever

- DFTS-OFDM spread signal is single carrier wideband signal which will be corrupted in case of time dispersive channel.
- If channel is frequency selective over span of DFt, the inverse DFT at the receiver will not be able to correctly reconstruct the original block of transmitted symbol.
- Need for an equalizer

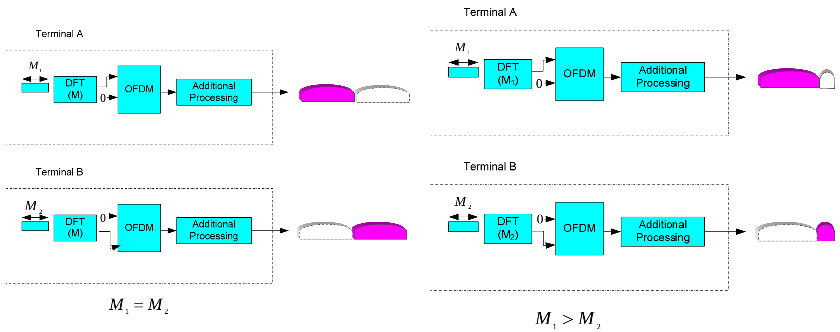


User multiplexing with DFTS-OFDM

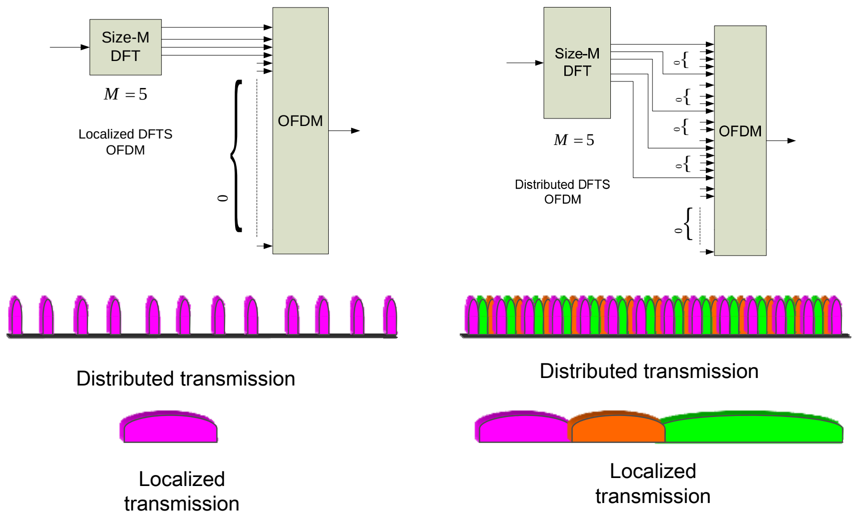
- By dynamically adjusting the transmitter DFT size and the size of block of modulation symbols, the nominal bandwidth of the DFTS-OFDM signal can be dynamically adjusted.
- By shifting the IDFT inputs to which the DFT outputs are mapped , the exact frequency domain position of the signal to be transmitted can be adjusted.
- Allows for uplink FDMA with flexible bandwidth assignments.



User multiplexing with DFTS-OFDM



Localized and distributed DFTS-OFDM



Questions:

Thanks for your attention :

Questions?