3rd COST 289 Workshop
Aveiro, Portugal, July 12-13, 2006

PAPR Reduction Methods for Noncoherent OFDM-MFSK

Matthias Wetz, Werner G. Teich, Jürgen Lindner

matthias.wetz@uni-ulm.de
http://it.e-technik.uni-ulm.de

Motivation

- Fast time variant channels for data transmission to and from high speed trains
- Security relevant data requires robust transmission scheme
- Combination of OFDM and noncoherently detected MFSK offers high data rate and robustnes
- A problem of multicarrier transmission is a high PAPR

Subcarrier phases for noncoherent OFDM-MFSK are arbitrary

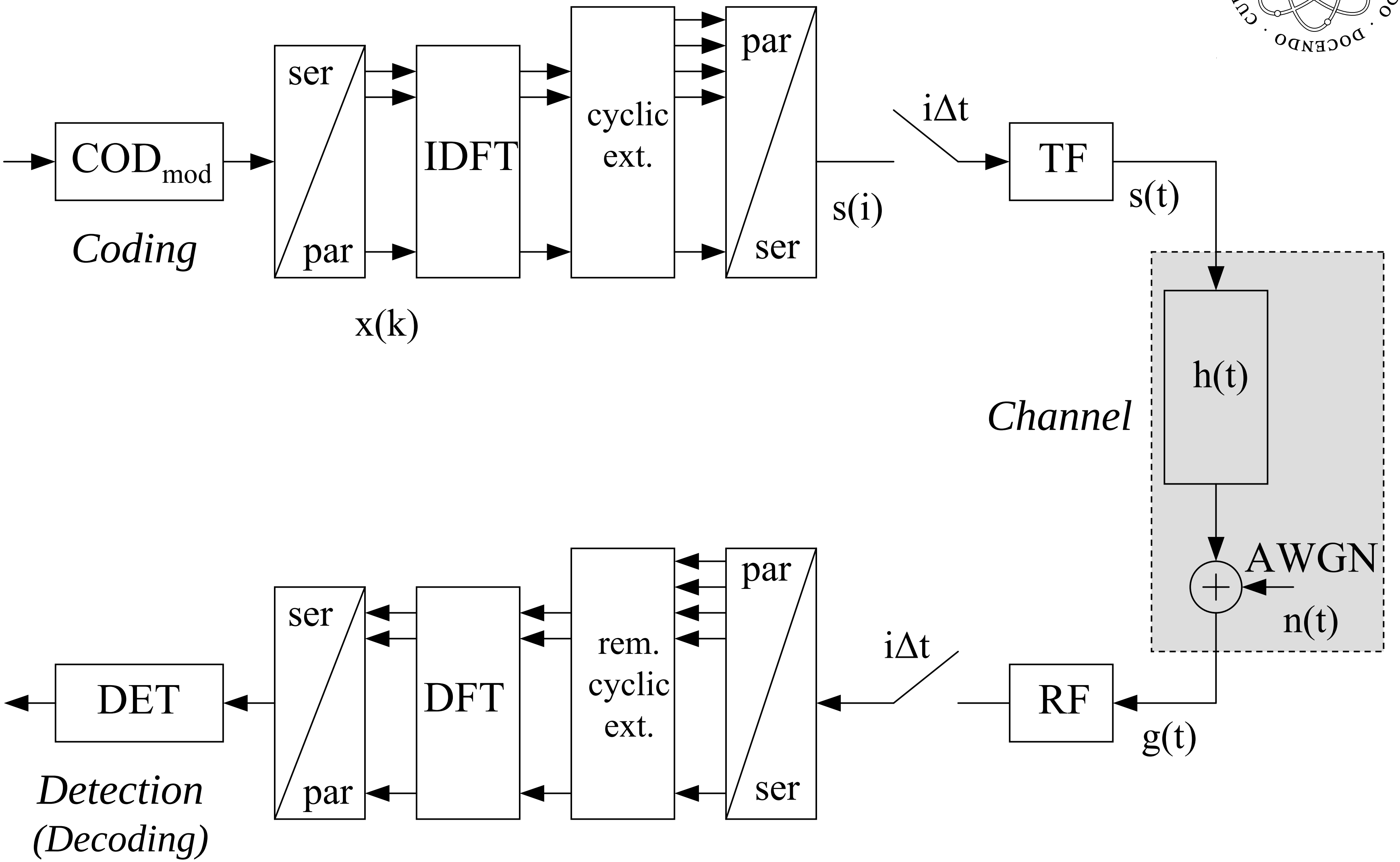
⇩

Use the phases to reduce the PAPR

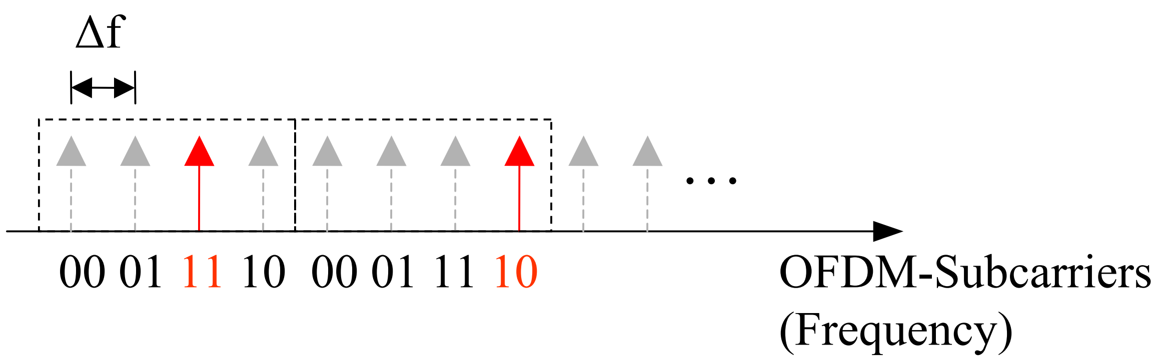
Outline

- Motivation
- Basic OFDM Transmission Model
- A Robust Transmission Scheme - OFDM-MFSK
- PAPR Reduction Algorithms
- Influence on the Spectrum of the Transmit Signal
- Conclusions

OFDM Transmission Model



OFDM-MFSK



- OFDM-4FSK: Subcarriers are grouped into groups of four
- 4FSK modulation over each group
- One out of four carriers is occupied
- Gray coding
- Coherent and noncoherent detection possible

\+ For noncoherent detection no CSI is necessary

\+ Very robust against time variant channels

\+ Subcarrier phases are arbitrary and can be used for PAPR reduction

Peak-to-Average Power Ratio

Definition PAPR:

$$\frac{\left(\max_t \left|s(t)\right|\right)^2}{\frac{1}{T}\int_0^T \left|s(t)\right|^2 dt}$$

Unfavourable superposition of subcarriers in OFDM

⇒ Very high PAPR of time domain signal

Problem: Transmit amplifier has saturation limit

⇒ Nonlinear distortion (Out of Band Radiation)

⇒ High backoff necessary (amplifier inefficient)

Noncoherently detected OFDM-MFSK

⇒ Subcarrier phases can be chosen arbitrarily so that PAPR is reduced

⇒ No side information necessary

PAPR Reduction

Goal: Find optimum subcarrier phases for each possible OFDM symbol, so that PAPR is minimum

Problem: N=256 and OFDM-4FSK

$4^{256/4}$ possible OFDM symbols,

2^{64} possibilities to assign phase, if two phases for each subcarrier are considered

⇒ Exhaustive search impossible

Worst case: All subcarrier phases are the same

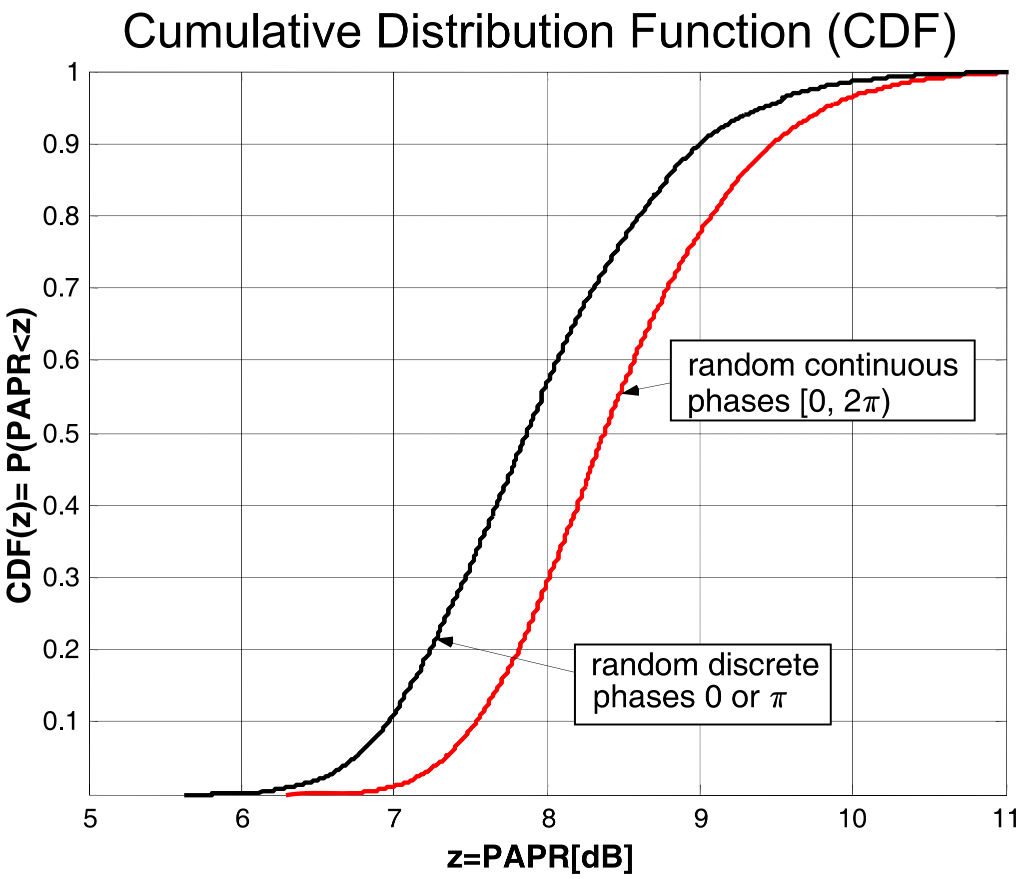
⇒ Subcarriers add coherently

⇒ PAPR = N/M = 256/4 = 18 dB

PAPR Reduction Methods

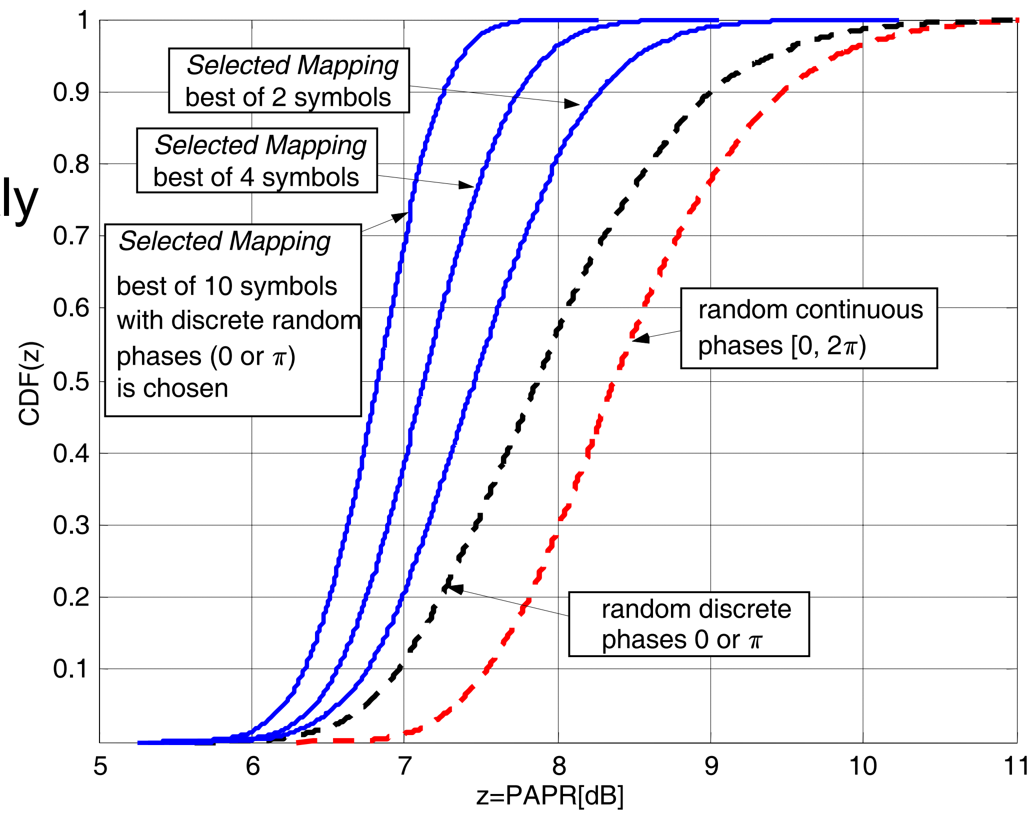
First approach:

- Random phases
- Allow only 0 or π



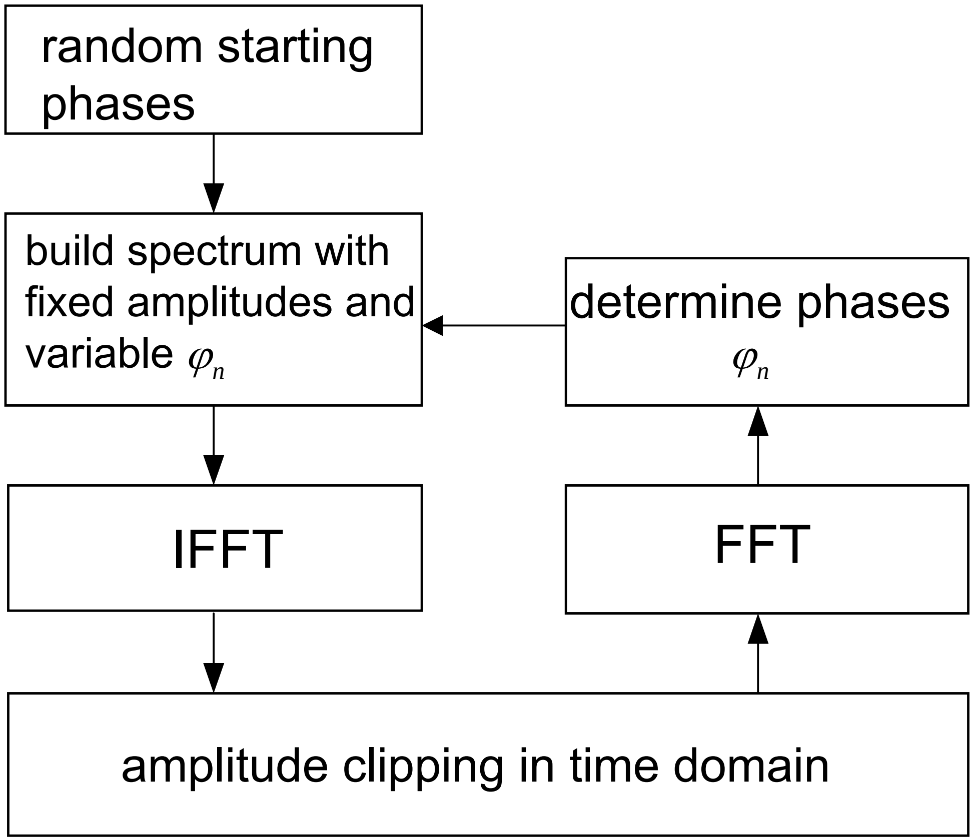
Selected Mapping

- Introduced by Bäuml, Fischer and Huber (´96)
- Assign random subcarrier phases to each symbol several times
- Transmit OFDM symbol with lowest PAPR
- When applied to noncoherently detected OFDM-MFSK, no side information is needed



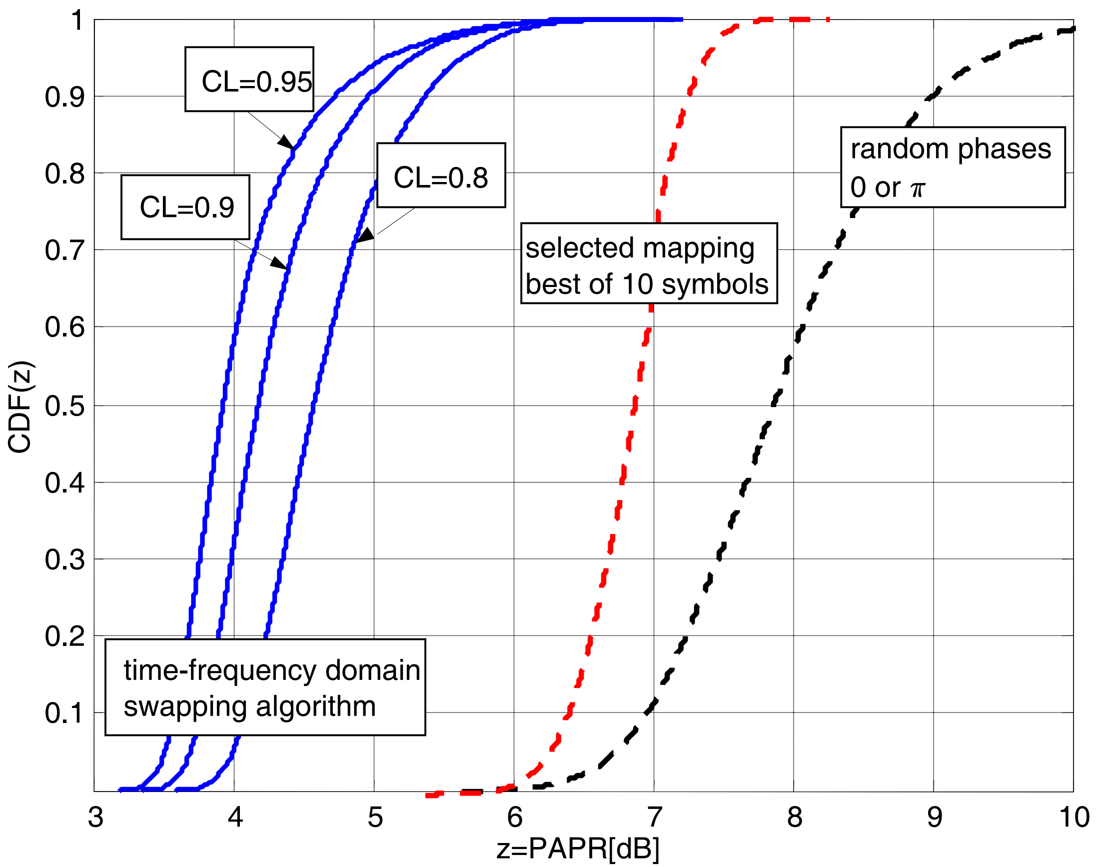
Time-Frequency Domain Swapping

- Introduced by Ouderaa et al. (´88)
- Swapping between time and frequency domain
- Iterative reduction of PAPR
- Stop when PAPR is not decreasing any more
- Parameter: time domain clipping level CL

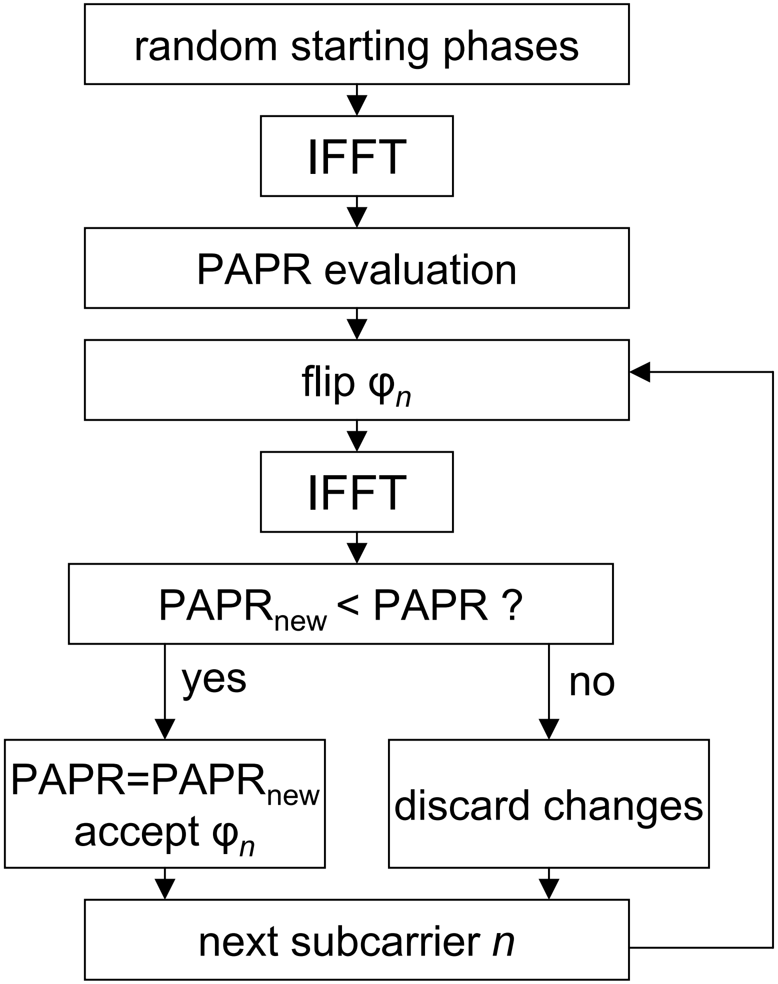


Time-Frequency Domain Swapping (cont´d)

- Good performance
- Very high complexity: up to several hundred iterations per symbol



Sequential Algorithm



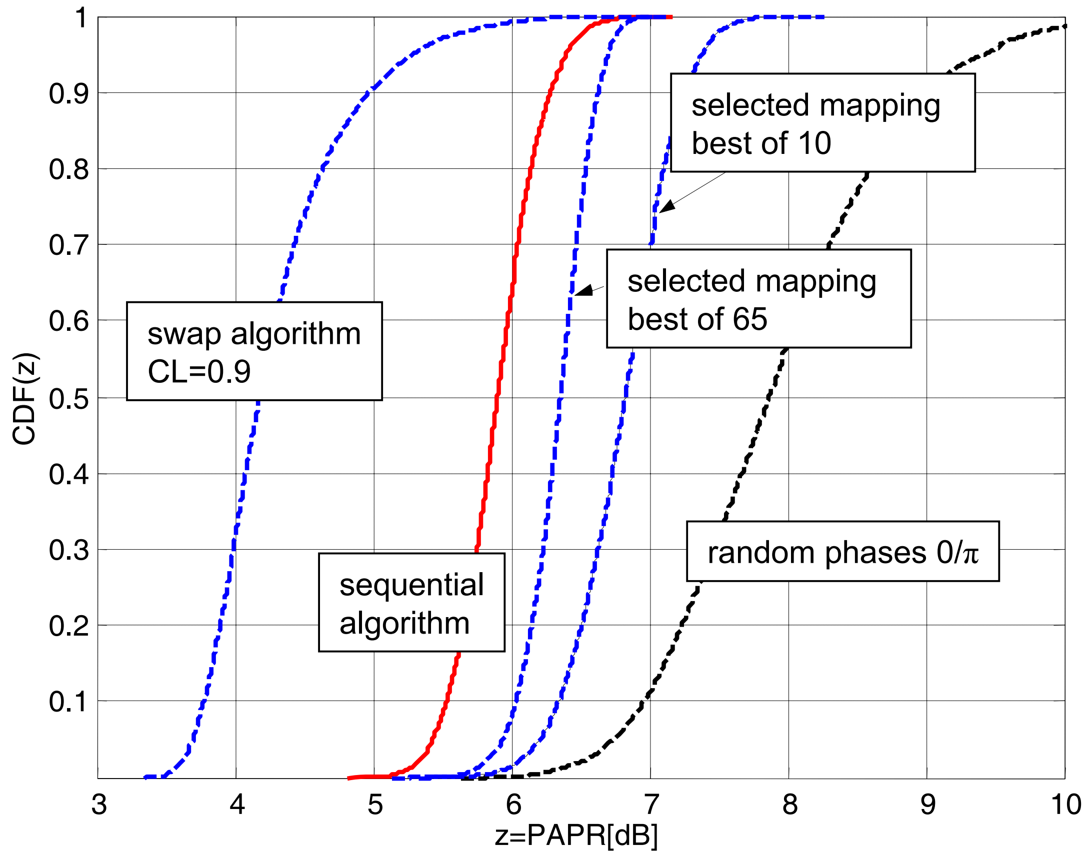
- Subcarrier phases are systematically changed to reduce PAPR
- Subcarrier phases are flipped sequentially
- One extra IFFT per occupied subcarrier

Sequential Algorithm (cont´d)

- Better performance than selected mapping
- Lower complexity than swapping algorithm

⇩

good trade off
complexity / performance



Complexity Comparison

Random Phases:

- PAPR 6-10.5dB

Selected Mapping (best of 10 symbols):

- PAPR 5.8-7.8dB
- 10 FFTs in total

Sequential Algorithm:

- PAPR 5.1-6.9dB
- 1 extra FFT per occupied subcarrier
- 65 FFTs in total

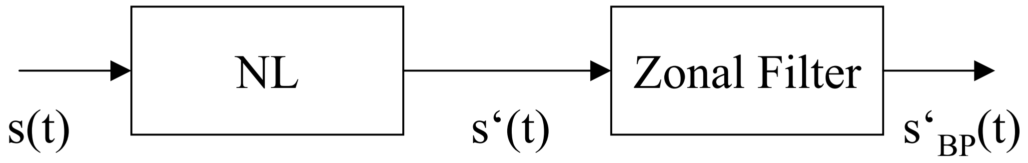
Time-Frequency Domain Swapping (CL=0.8):

- PAPR 3.8-6.5dB
- About 200 FFTs in total

⇨ In general, better performance means higher complexity

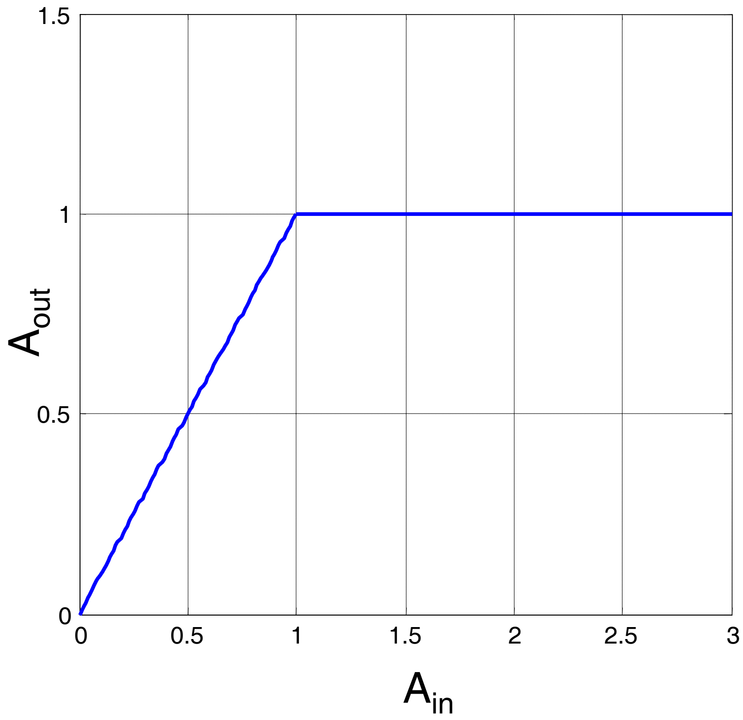
Remaining problem: PAPR reduction has to be done for each symbol

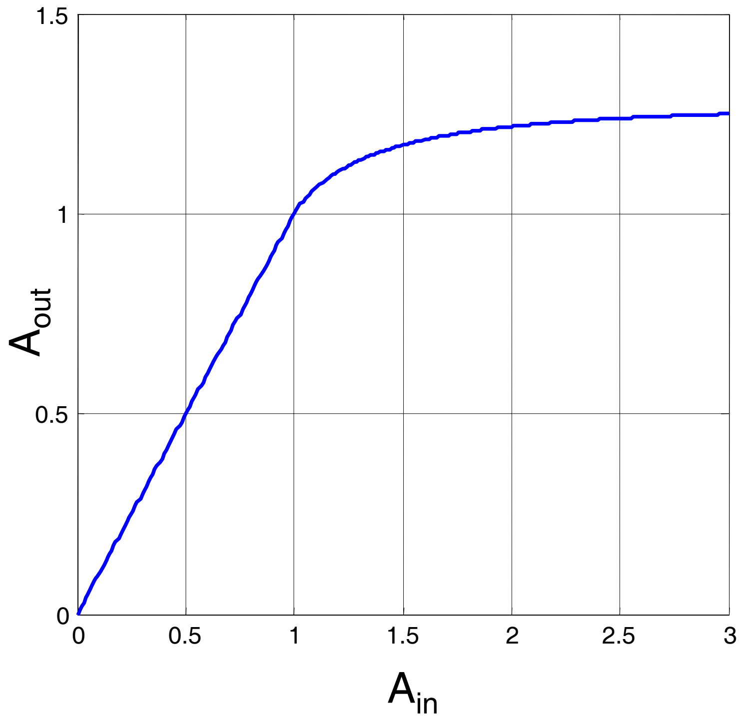
Model of a Nonlinear Transmit Amplifier



- Nonlinearity causes distortion at harmonic bands of carrier frequency
- Zonal filter limits signal to be a bandpass signal
- Nonlinearity can be modeled in the lowpass domain

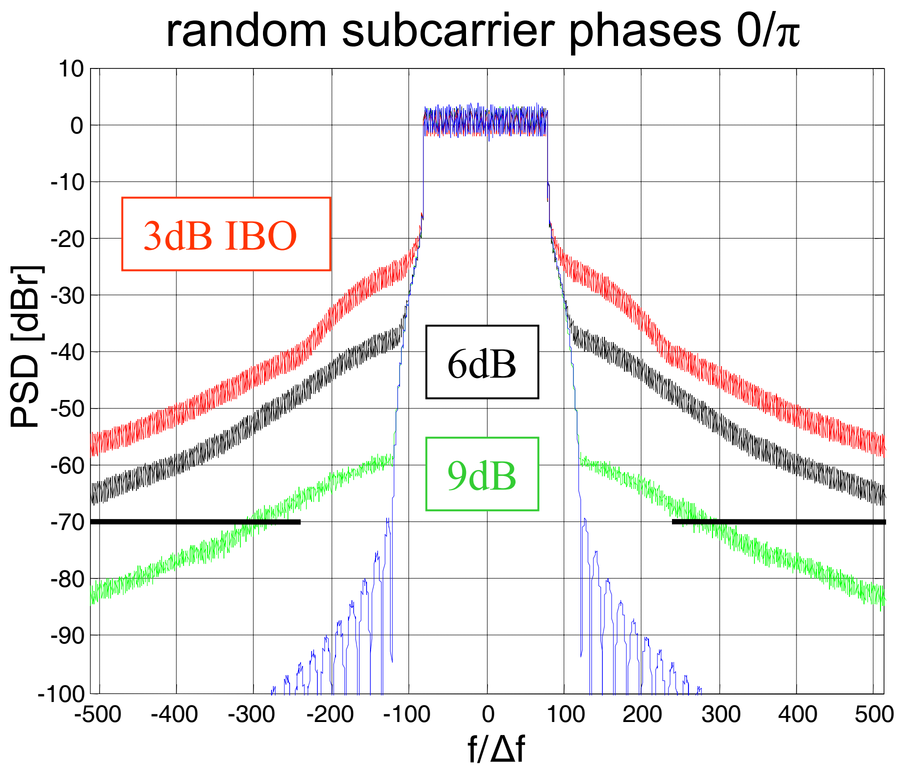
Model of a Nonlinear Transmit Amplifier





Soft limiter in **bandpass domain**: amplitude saturates → Transformation of the characteristics into **lowpass domain**

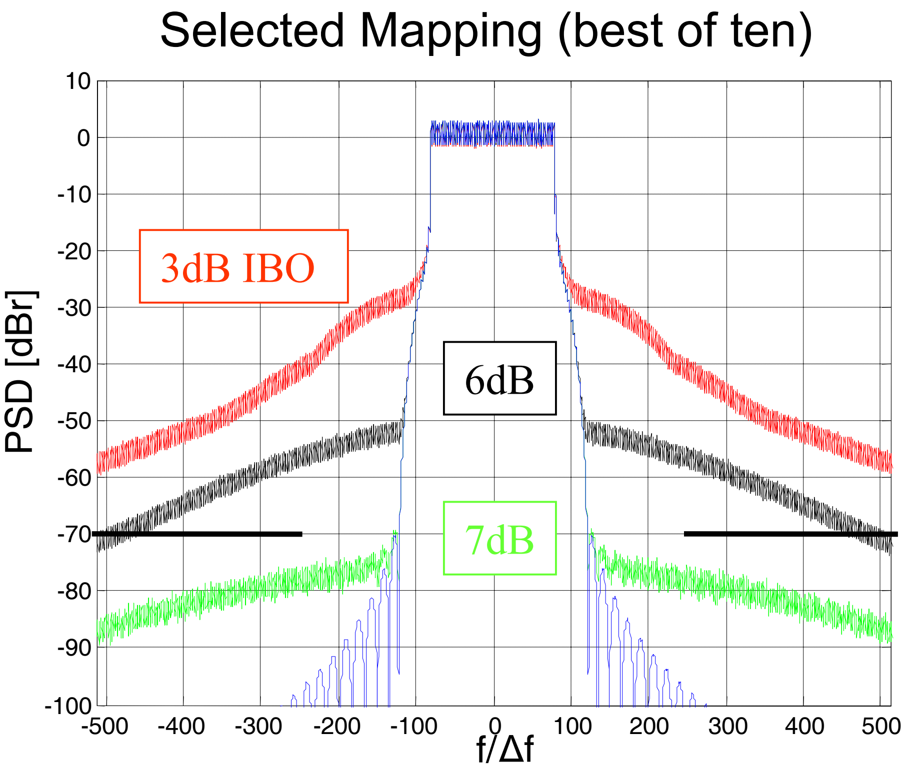
Transmit Spectrum with Nonlinear Distortion

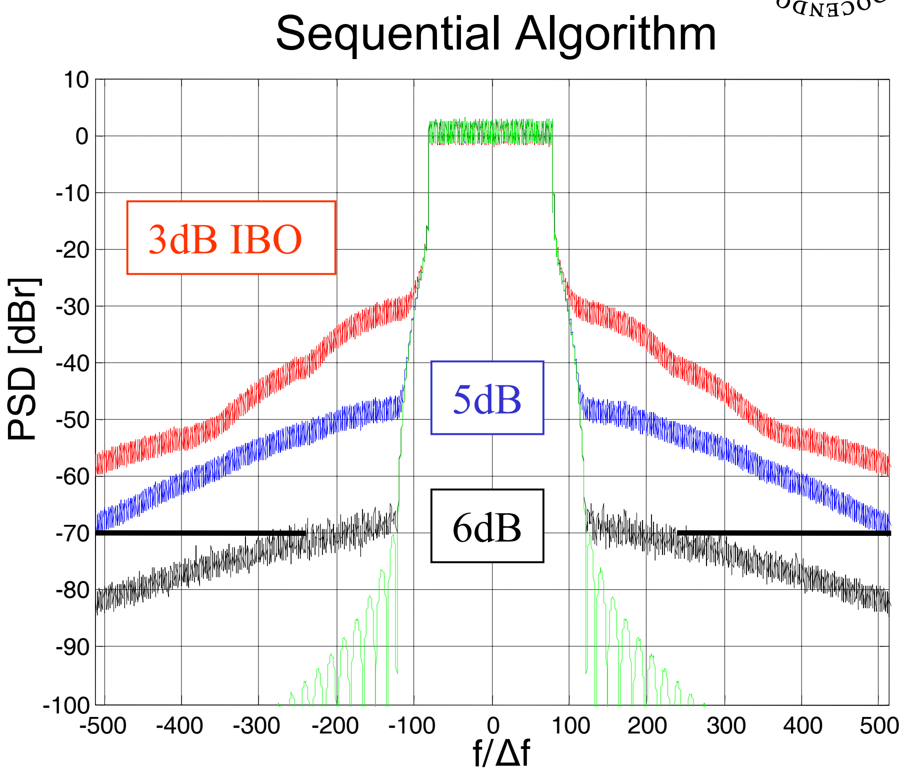


Simulation parameters:

- Raised cosine transmit filter α=0.2
- 160 used subcarriers
- Reference point: Interference in next channel after neighbour channel < -70dBr

Transmit Spectrum with Nonlinear Distortion





- Further reduction possible with swapping algorithm but improvement is small

Summary and Conclusions

OFDM-MFSK was presented

- Noncoherent detection possible
- Robust transmission scheme
- Subcarrier phases can be used for PAPR reduction

PAPR reduction algorithms were analysed

- Selected Mapping
- Time-frequency domain swapping
- Sequential algorithm

Influence on the spectrum of the transmit signal

- Effects of different PAPR reduction methods were compared