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A Hybrid Modulation Scheme for Noncoherently Detected OFDM-MFSK

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Outline

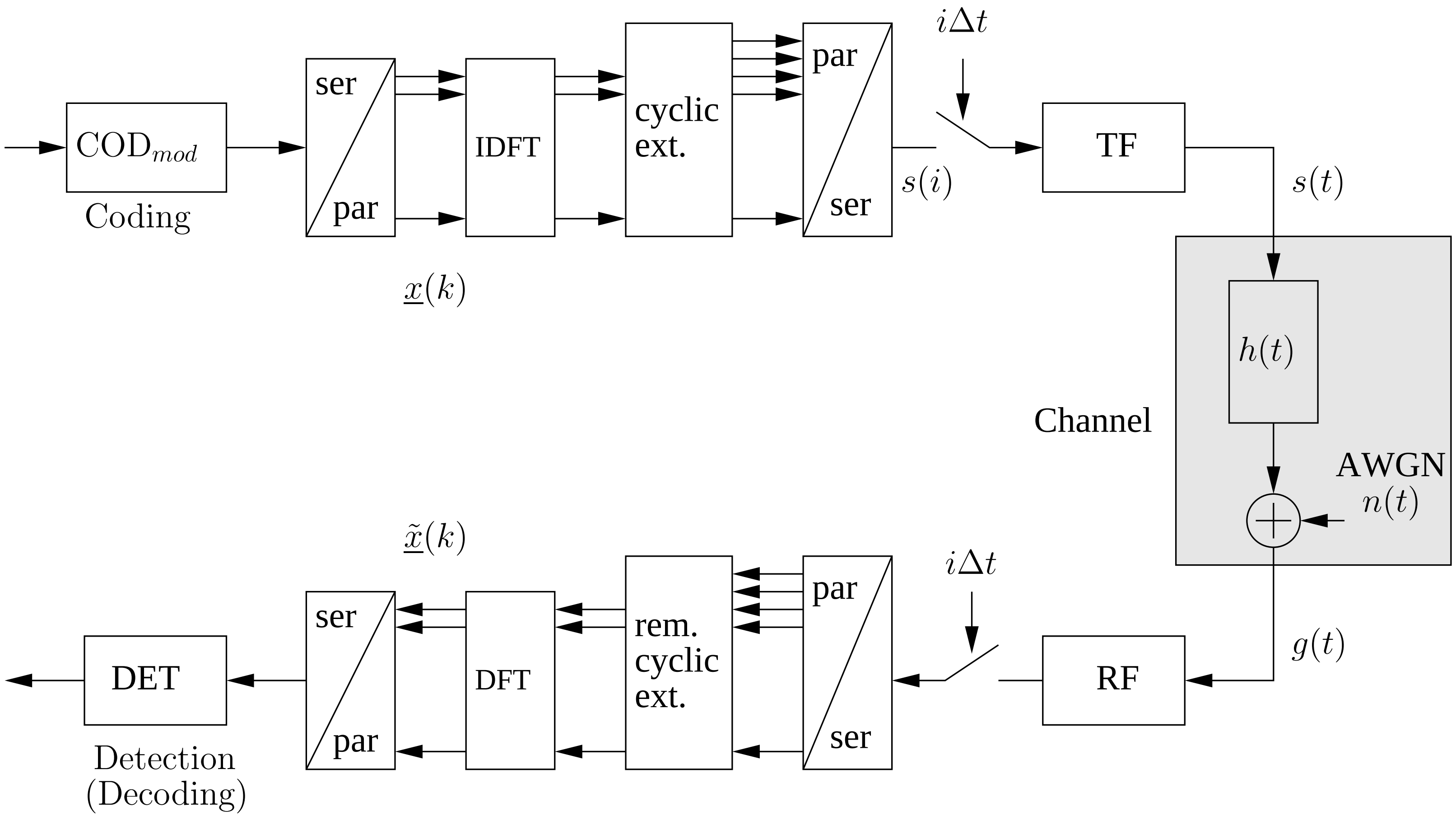
- Motivation
- Basic OFDM Transmission Model
- A Robust Transmission Scheme – OFDM-MFSK
- Increasing the Bandwidth Efficiency using Hybrid Modulation
- Simulation Results
- Conclusions

Motivation

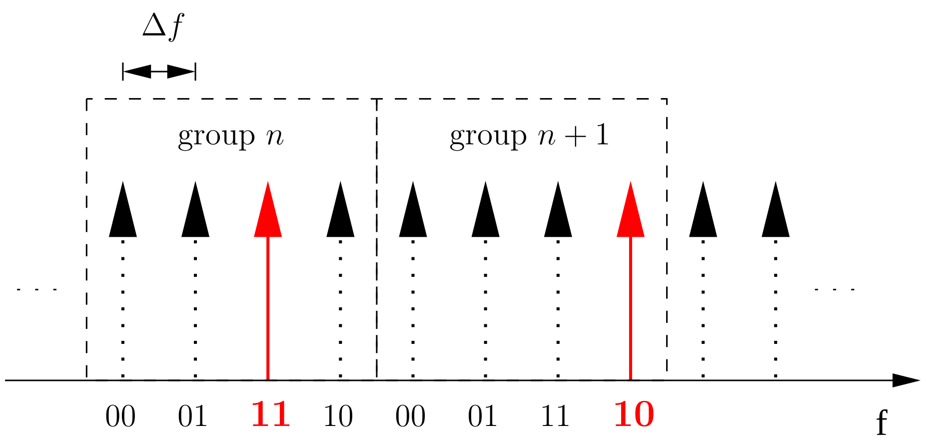
- Scenario: Communication with high speed trains
- Speed up to 600 km/h causes fast changing channels
- Channel estimation is very difficult
- Security relevant control data requires robust transmission
- Additional services for passengers like internet access require high data rates
- FSK schemes are very robust and are currently in use

Goal: Robust transmission scheme based on OFDM with high data rate

Basic OFDM Transmission Model



A Robust Transmission Scheme – OFDM-MFSK



- Subcarriers are grouped into groups of M and MFSK modulation is applied to each group
- $\log_2 M$ bits can be assigned to each group
- No CSI is needed for noncoherent detection
- Very robust against time variant channels
- Low bandwidth efficiency (uncoded OFDM-4FSK: 0.5 bit/subcarrier)

A Robust Transmission Scheme – OFDM-MFSK

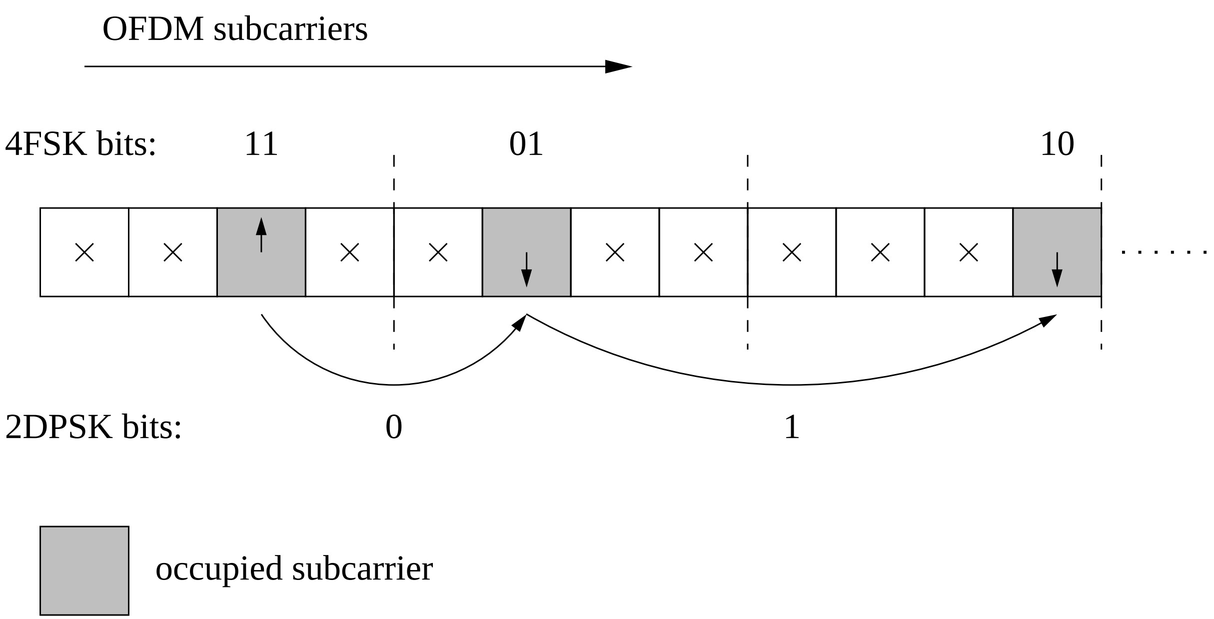
Noncoherent detection

- Subcarrier phase of transmit symbols is arbitrary

This degree of freedom can be exploited

- Phases can be used for PAPR reduction
- Use phases to increase bandwidth efficiency by transmitting additional data
- Noncoherent detection of OFDM-MFSK is not influenced

Hybrid Modulation Scheme



- Additional differential encoding of phases of occupied subcarriers
- Encoding in frequency or time direction
- Noncoherent detection, no CSI needed

Channel Coding

- Separate encoding of MFSK and DPSK component
- Detection and decoding of MFSK component first to determine occupied subcarriers
- Afterwards detection and decoding of DPSK component

Advantages:

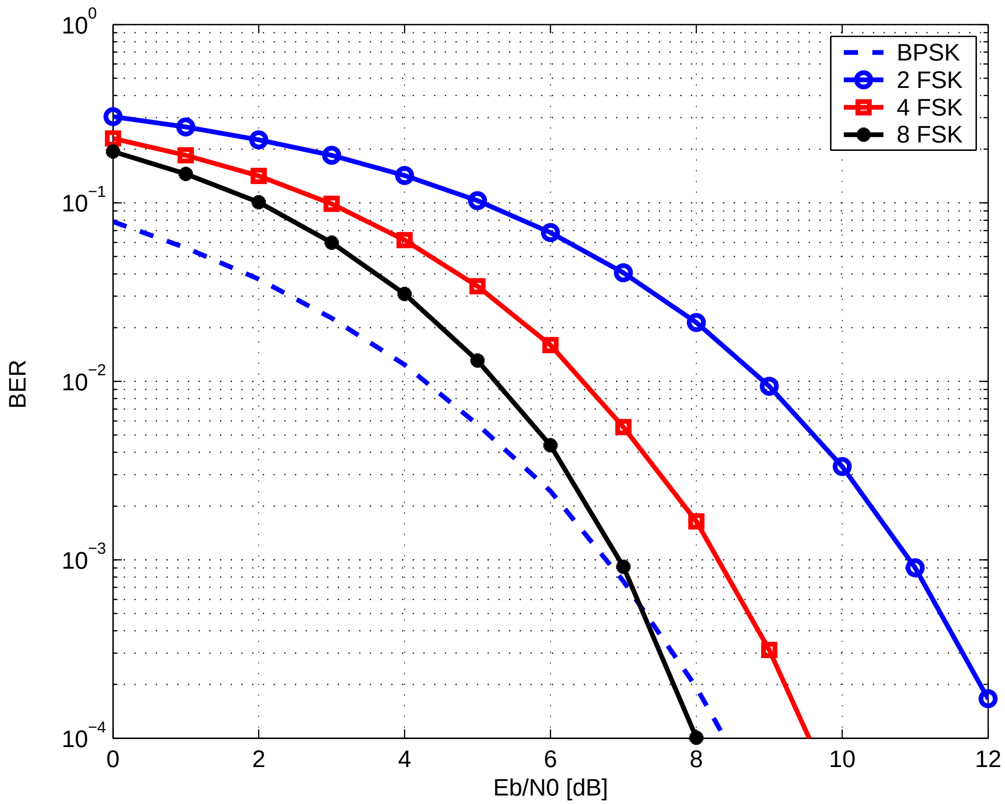
- Different level of protection for both components using different codes
- Coded OFDM-MFSK transmission is not affected by DPSK component

Convolutional code: rate $1/2$, memory 6, generator polynomial [133,171], soft decision detection

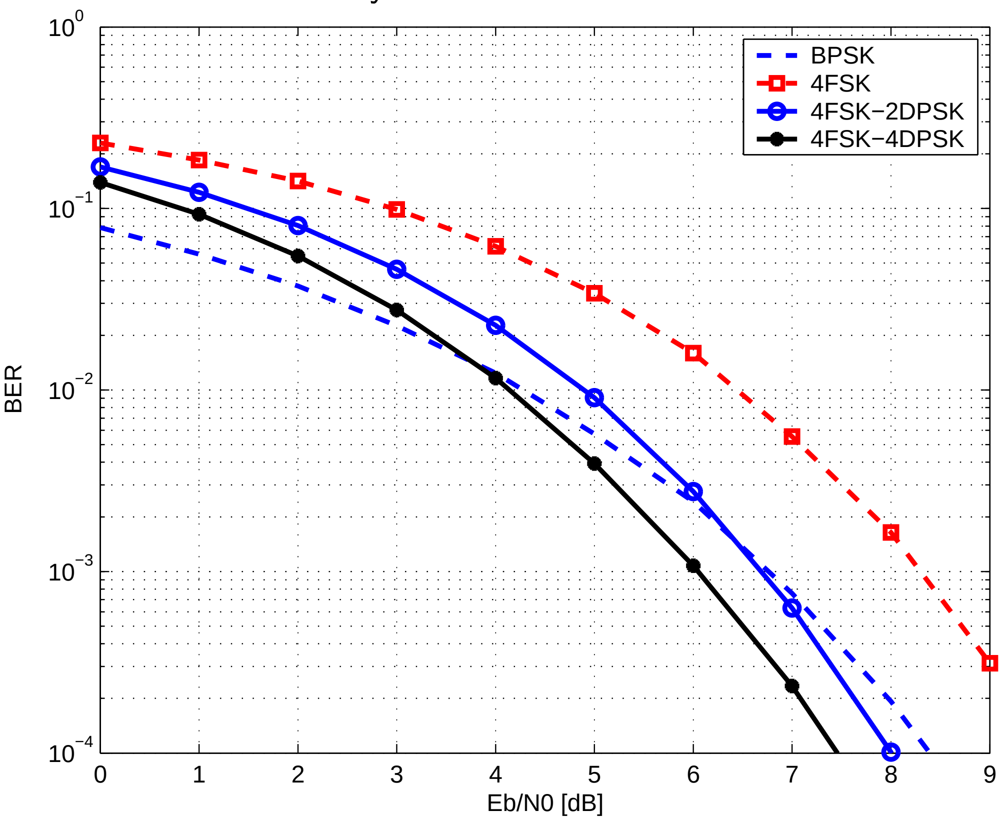
Simulation Results – AWGN

Overall BER for uncoded transmission:

Basic OFDM-MFSK



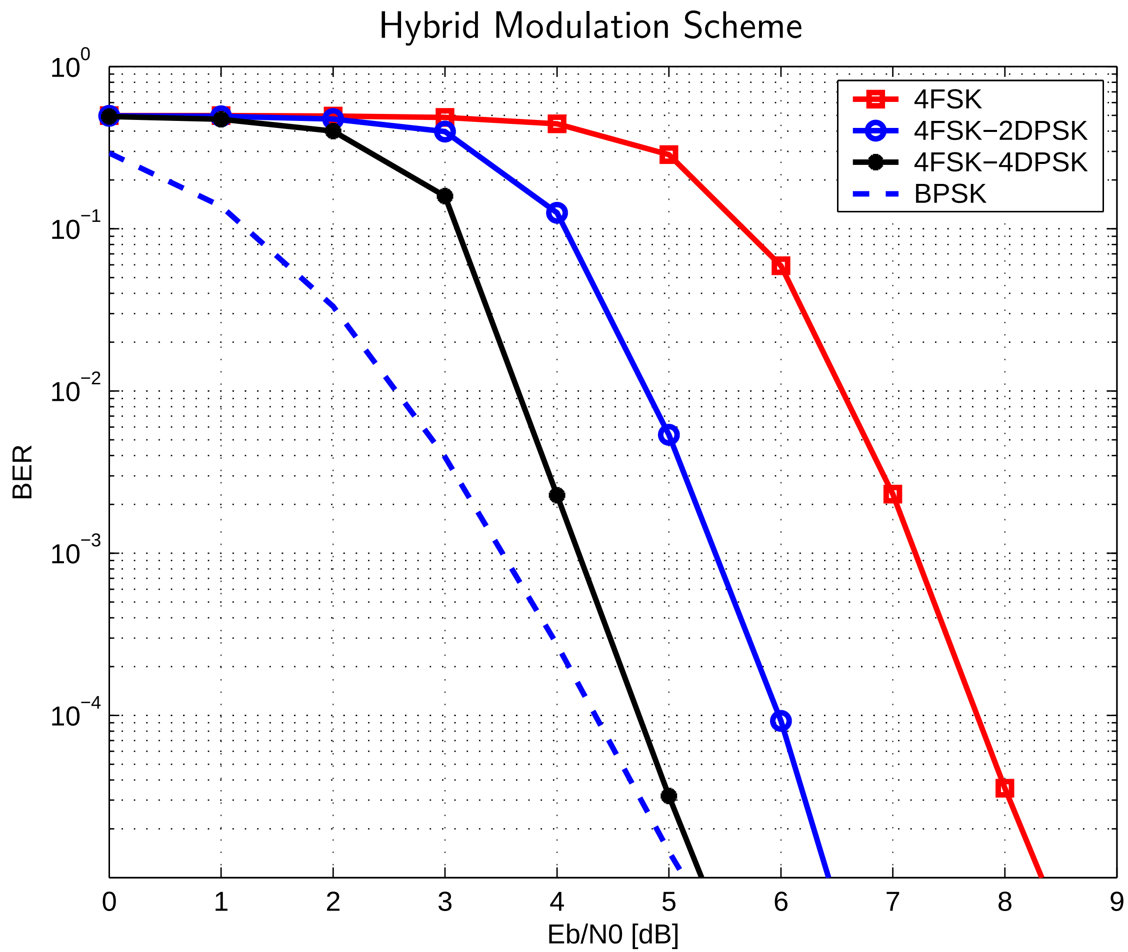
Hybrid Modulation Scheme



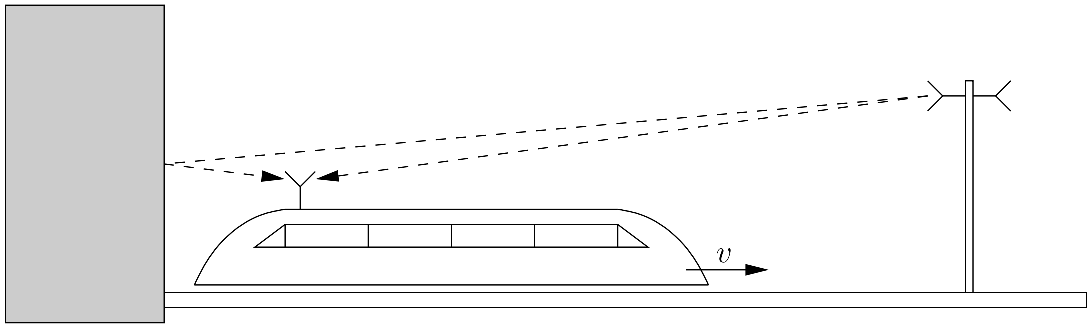
Simulation Results – AWGN

Overall BER for coded transmission:

- Separate coding for 4FSK and DPSK component using the same convolutional code
- BER is dominated by 4FSK errors for AWGN
- Codes can be adapted



Worst Case Channel Model



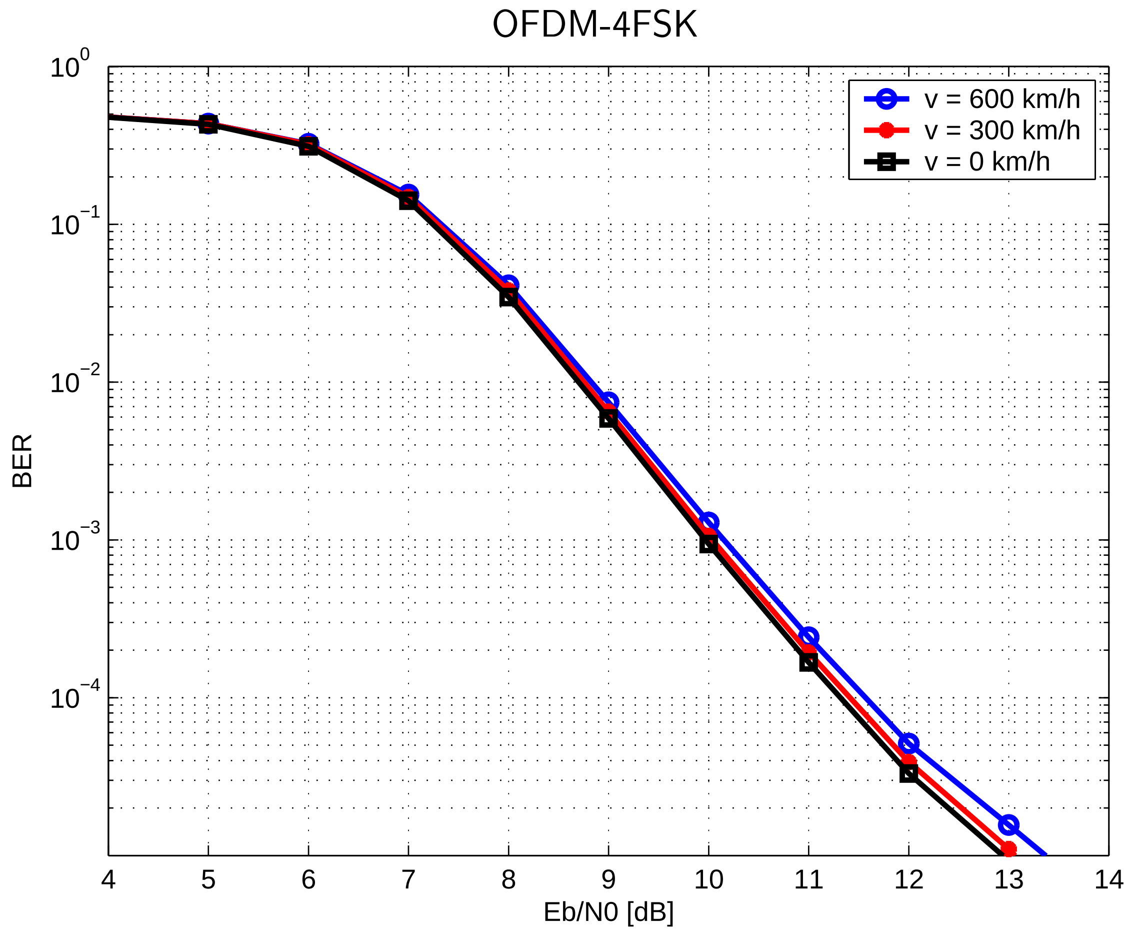
- Reflection at tunnel entrance or bridge
- Two paths with equal attenuation
- Maximum Doppler spread $2f_d = 2f_c\frac{v}{c}$ due to opposite direction of arrival

carrier frequency	$f_c = 38\,\text{GHz}$	subcarrier separation	$\Delta f = 312.5\,\text{kHz}$
FFT length	$N_f = 256$	cyclic extension	$T_g = N_g \Delta t = 0.8\,\mu\text{s}$
no. of used subcarriers	$N_{fused} = 160$	symbol duration	$T_s = (N_g + N_f)\,\Delta t = 4\,\mu\text{s}$

Simulation Results

BER for coded OFDM-4FSK:

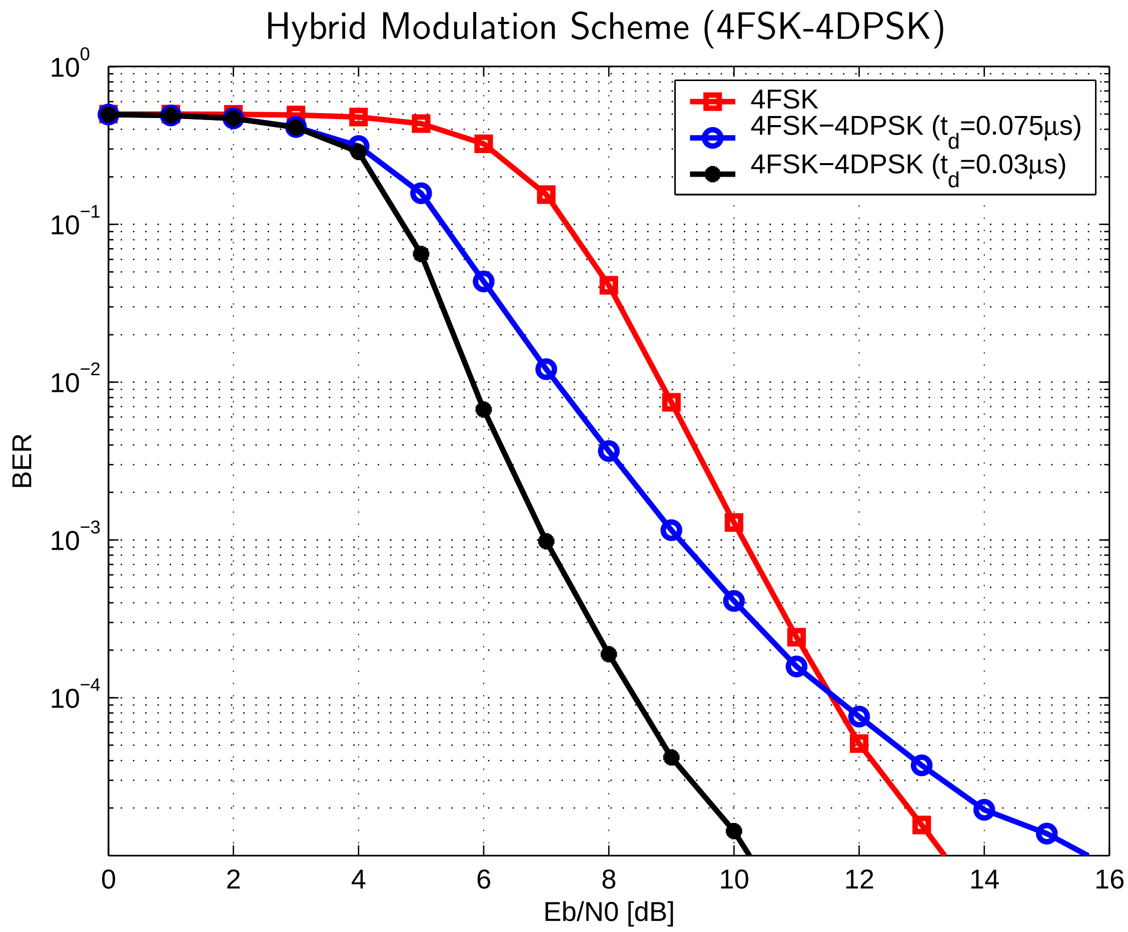
- Path delay $t_d = 0.75\,\mu s$
- Strong frequency selectivity
- Very robust against frequency selectivity
- Very robust against high velocity



Simulation Results

Overall BER for coded transmission:

- DPSK component encoded in frequency direction
- Speed $v = 600\,km/h$
- Very robust against high velocity
- DPSK component very sensitive against frequency selectivity (large distance between used subcarriers)



Conclusions

Conclusions

- Noncoherently detected OFDM-MFSK is a robust transmission scheme in fast fading environments
- Subcarrier phases can be used for PAPR reduction or transmission of additional data
- Hybrid modulation does not affect the underlying MFSK transmission but offers additional data rate for moderate channels
- no CSI necessary

Future Work

- Adaption of codes for both components
- Improvement of robustness against frequency selectivity of DPSK component