Equalization and Coding for Ultra Low Delay Wireless Digital Communication

A Comparison

Christoph Rachinger, Johannes B. Huber, Wolfgang Gerstacker

Friedrich-Alexander-Universität Erlangen-Nürnberg
Institute for Information Transmission

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Outline

1. Motivation
2. Approaches to Equalization and Decoding
3. Simulation Results
4. Conclusion

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Motivation

Requirements for upcoming wireless standards (e.g. 5G) include, among others,

- High data rate
- Low delay
- High reliability

Low delay and high reliability are especially important for Internet of Things (IoT) applications with strict delay constraints, e.g., due to control loops

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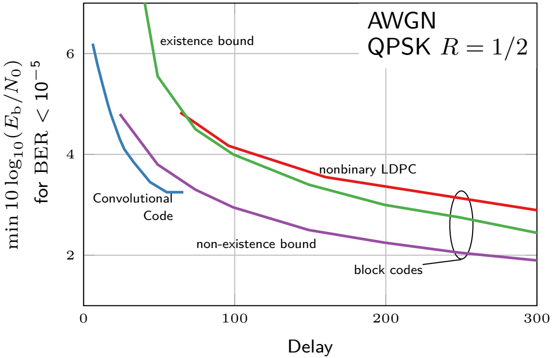
Low delay and high reliability are especially important for Internet of Things (IoT) applications with strict delay constraints, e.g., due to control loops

But: (Ultra) Low delay and high reliability do not work well together

Convolutional Codes for Low Delay

Exchange of coding gain and structural delay over the AWGN channel



From Rachinger, Huber, Müller: Comparison of Convolutional and Block Codes for Low Structural Delay, IEEE Tr. Comm. 63, pp. 4629-4638, 2015

For delays $< 200\,\mathrm{bit}$ convolutional codes are superior to any block codes.

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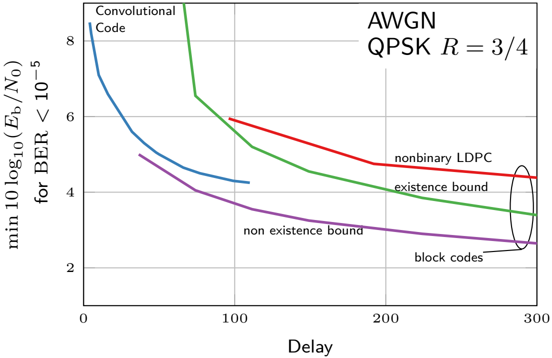

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Approaches to Equalization and Decoding

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Approaches to Equalization and Decoding

Overview

OFDM	- Gray mapped OFDM - Anti-Gray mapped OFDM with iterative detection and decoding (Turbo approach)

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Single-Carrier

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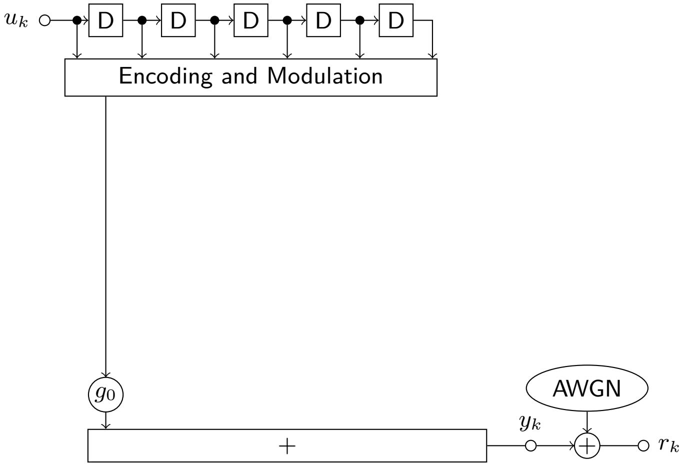
- Iterative Detection and Decoding (Turbo approach): Separate BCJR algorithms to equalize the channel and decode the CCs
  Problem: High complexity for long CIRs
- Matched Decoder for CCs + ISI
  Problem: Also quite complex, but complexity reduction is possible
  - Prefiltering for minimum phase CIRs
  - Delayed Decision Feedback Sequence Estimation: Combine MLSE and DFE to reduce complexity
  - Reduced State Sequence Estimation

Approaches to Equalization and Decoding

Matched Decoding



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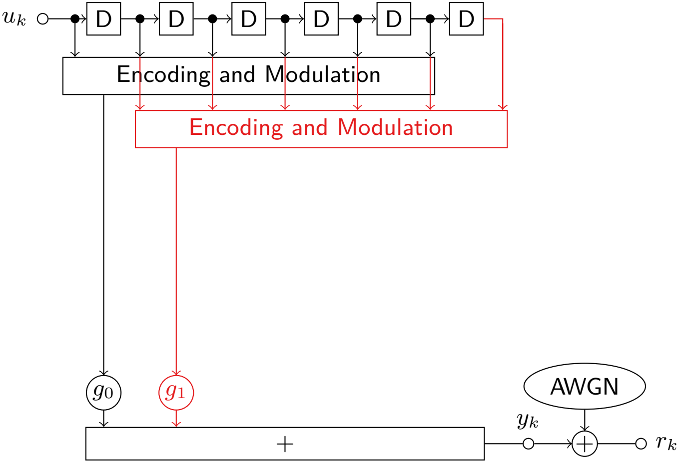

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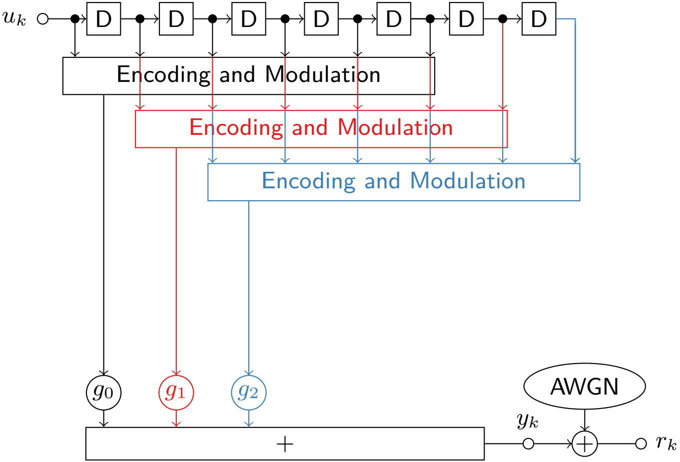

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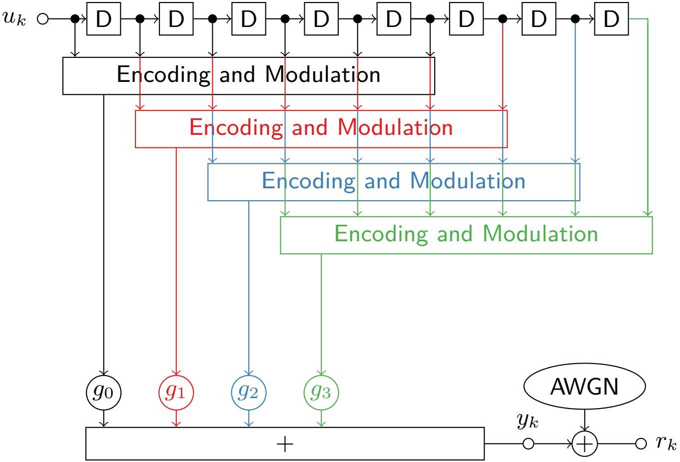

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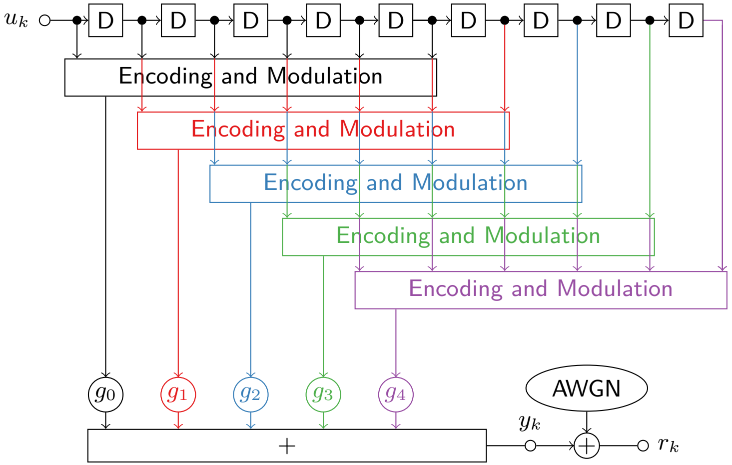

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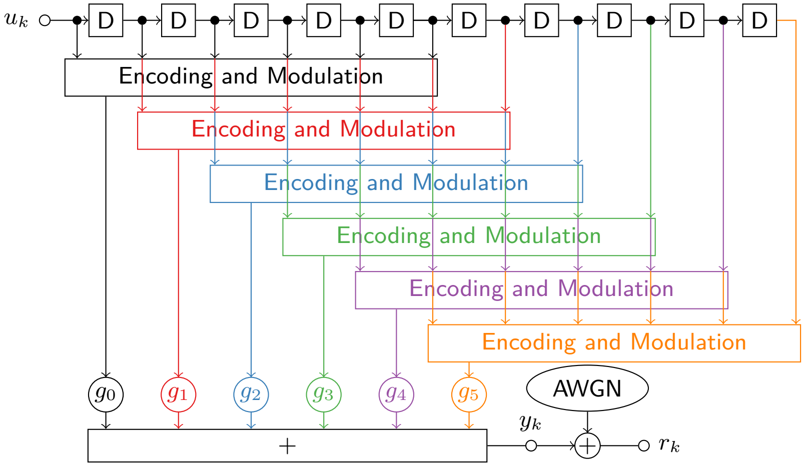

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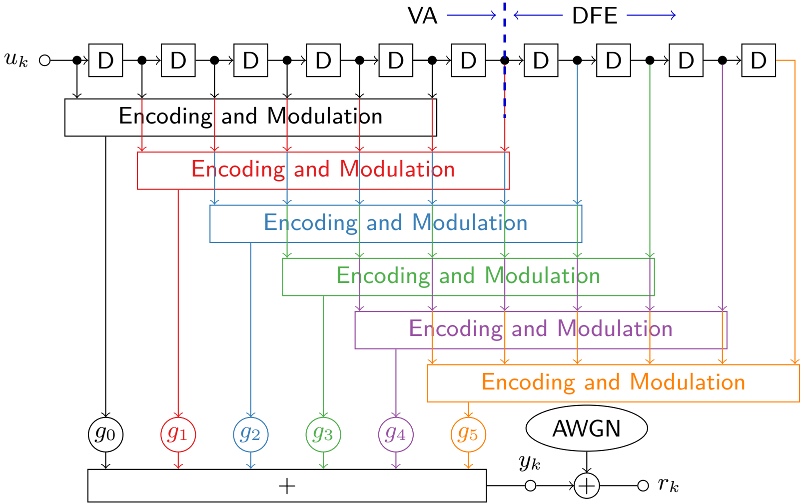

Simulation Results

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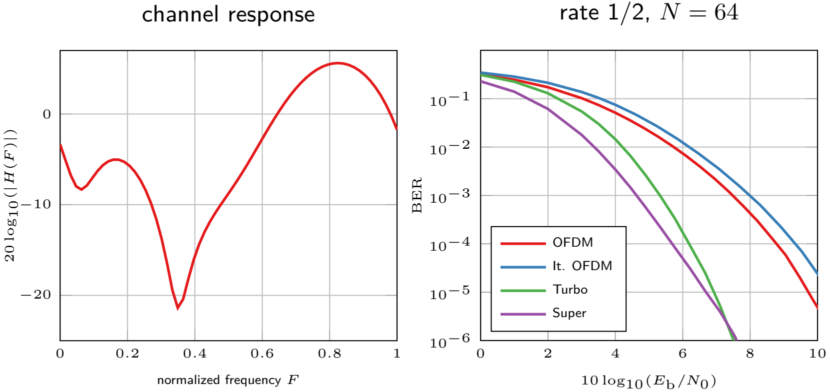
Simulation Setup

- Equal gain CIR, complex Gaussian distributed $\mathcal{CN}(0,1)$, with normalized power, i.e., $\sum |h_i|^2 = 1$
- No CSI at the transmitter
- Blocks of length $N = 64$ and $N = 128$ channel symbols
- 4-QAM, 64 state $(133, 171)_8$ CC of rates $1/2$ and $3/4$ (punctured)
- Independent terminated code frames for each block
- Interleaver: block-interleaver (16×8 and 16×16) for OFDM and iterative single-carrier, no interleaver for MD

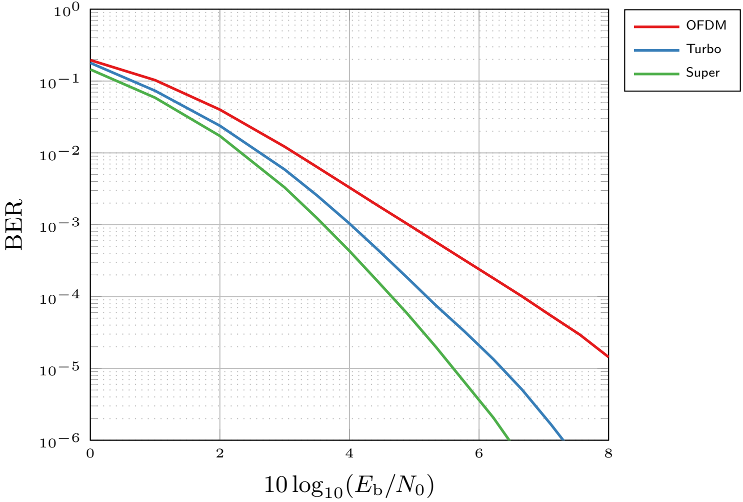
Specific Example: Channel with $L = 5$ taps

Channel coefficients: $-0{,}1394 + 0{,}0021\mathrm{i}$, $-0{,}3795 + 0{,}2700\mathrm{i}$, $0{,}4533 + 0{,}4022\mathrm{i}$, $0{,}5393 - 0{,}2498\mathrm{i}$ and $0{,}1470 - 0{,}1466\mathrm{i}$



Simulation Results

Rate 1/2, $N = 64$, $L = 5$



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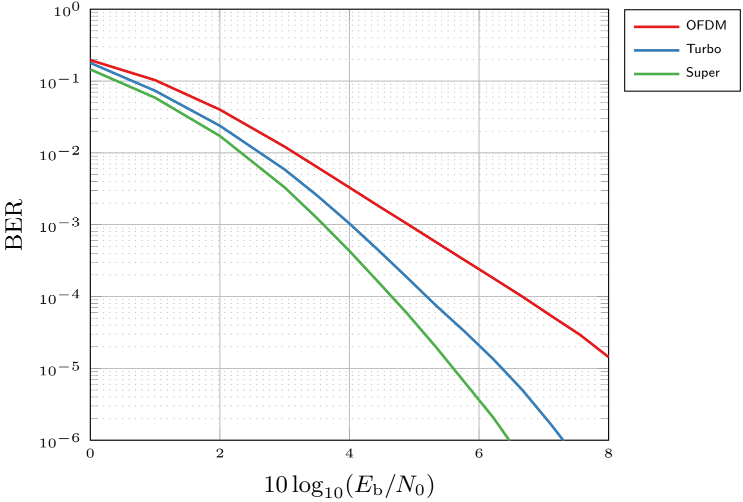
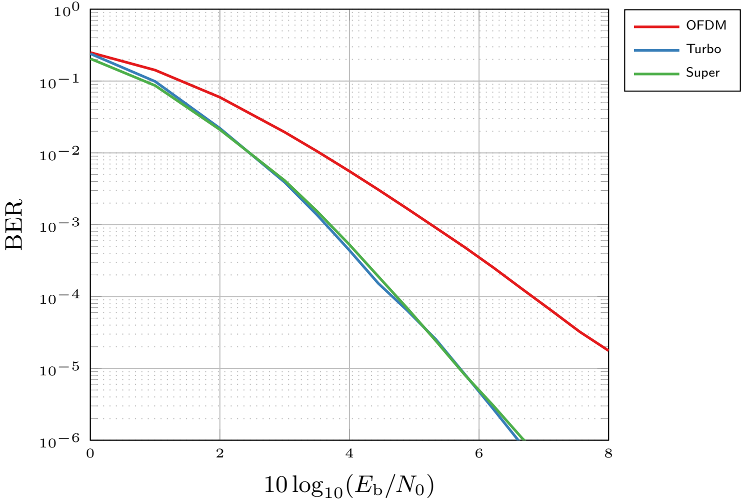


2.5 dB gain at 10^{-5}

Simulation Results

Rate 1/2, $N = 128$, $L = 5$



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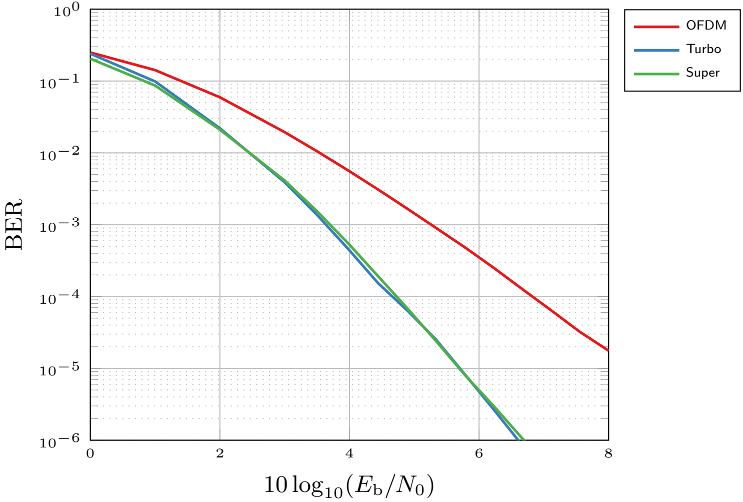

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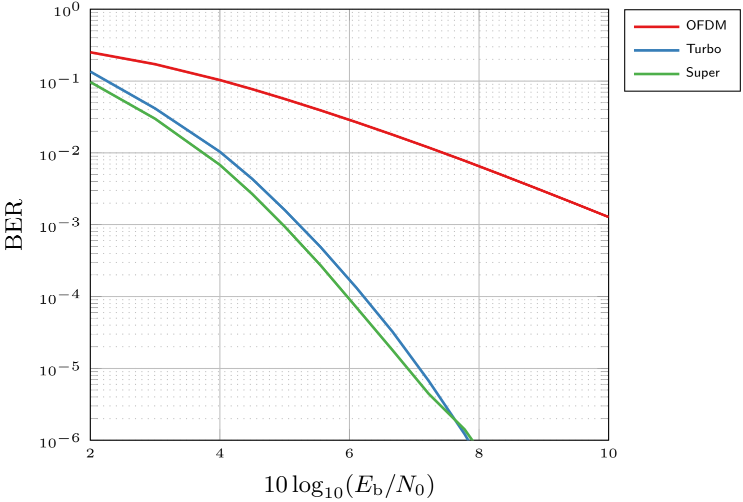
Rate 3/4, $N = 64$, $L = 5$



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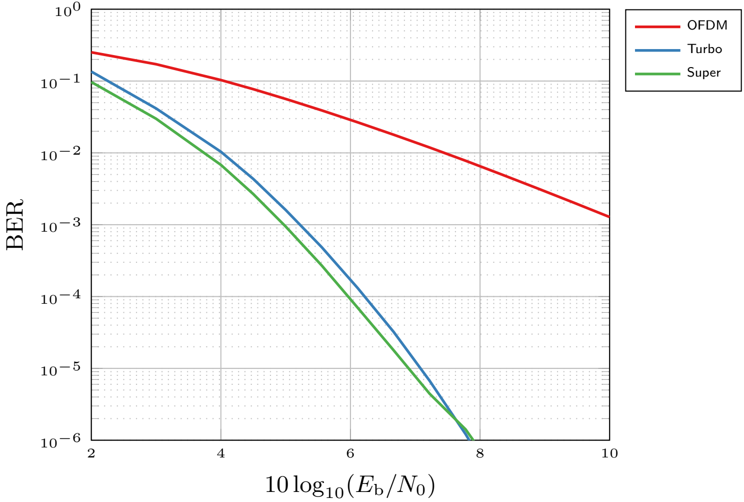
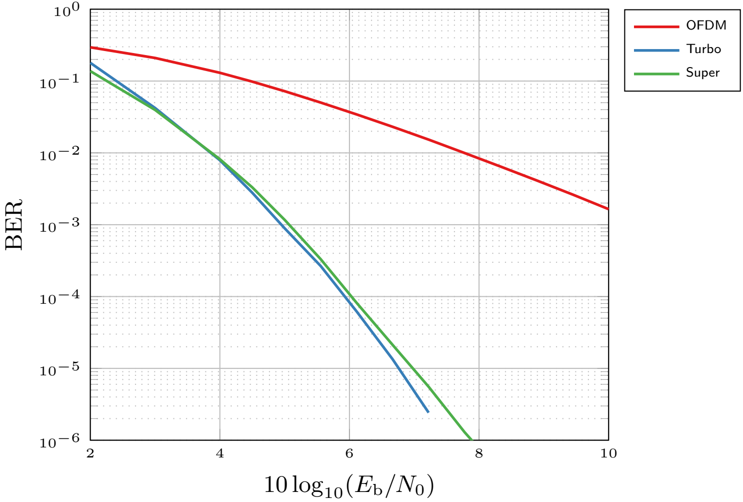


7 dB gain at 10^{-5}

Simulation Results

Rate 3/4, $N = 128$, $L = 5$



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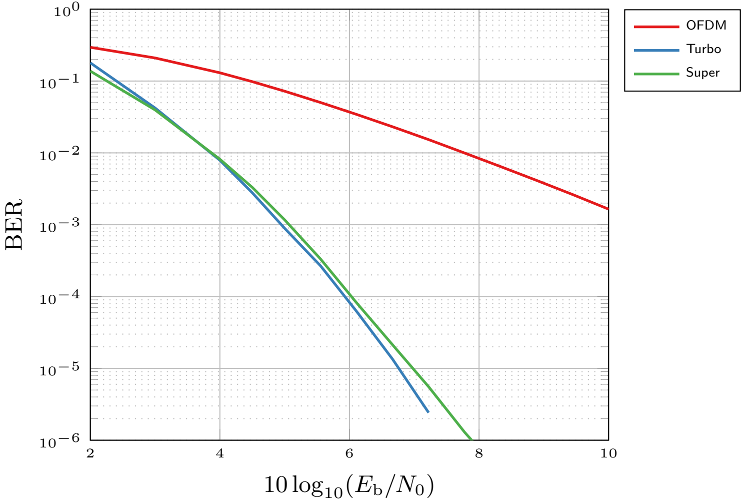

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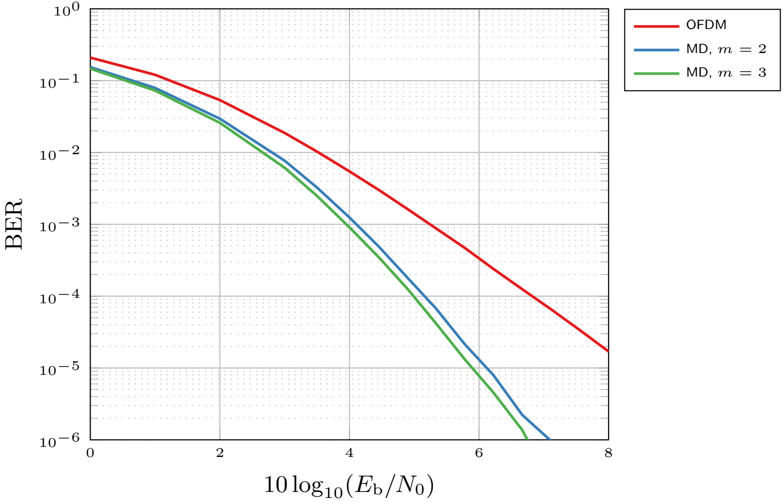
Rate 1/2, $N = 64$*,* $L = 15$



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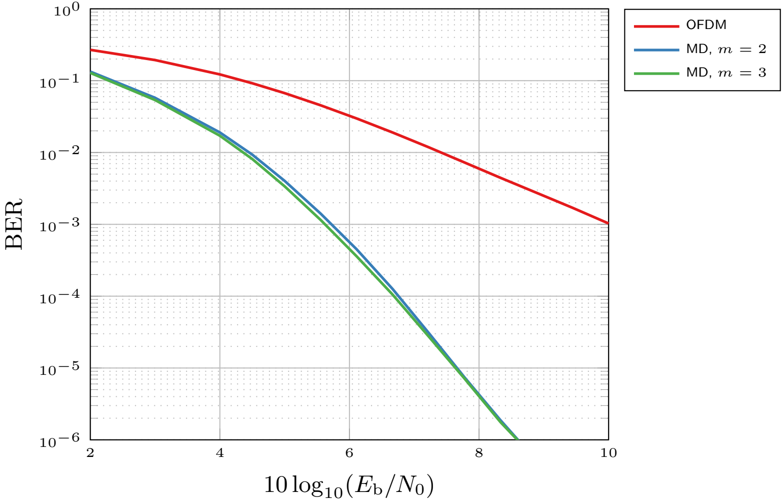
Rate 3/4, $N = 64$, $L = 15$



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- OFDM does not use any time-dependencies of adjacent symbols
- Short codes are not able to fully recover symbols in a frequency notch of the CIR for OFDM
- Time-domain based methods exploit an overall code made from both channel code and ISI
- Even algorithms with greatly reduced complexity are sufficient to achieve high gains compared to OFDM

⇒ OFDM not well suited for ultra low delay applications

Questions?

Thank you for your interest!

Any questions?