Filter Bank Multi-Carrier (FBMC) for Future Wireless Systems

CD Laboratory Workshop

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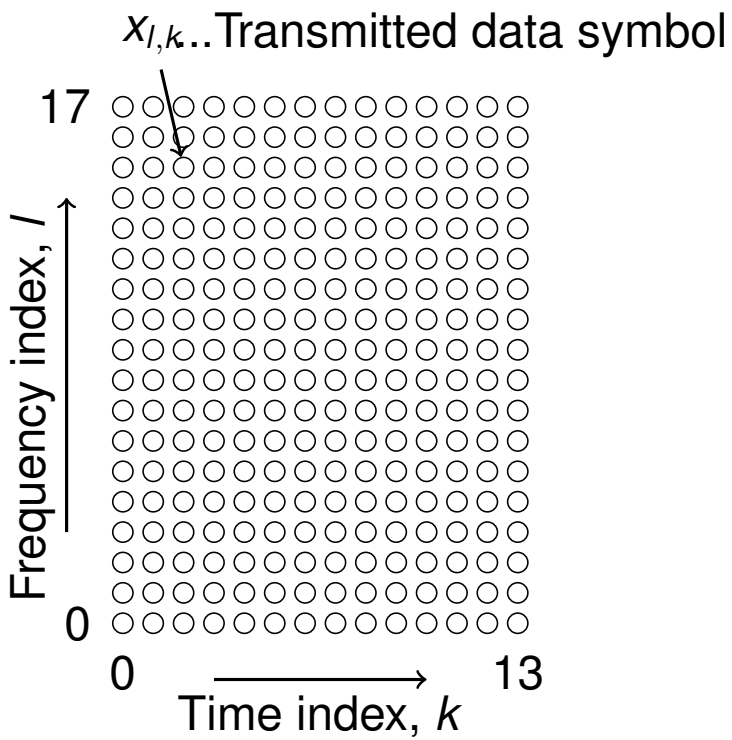
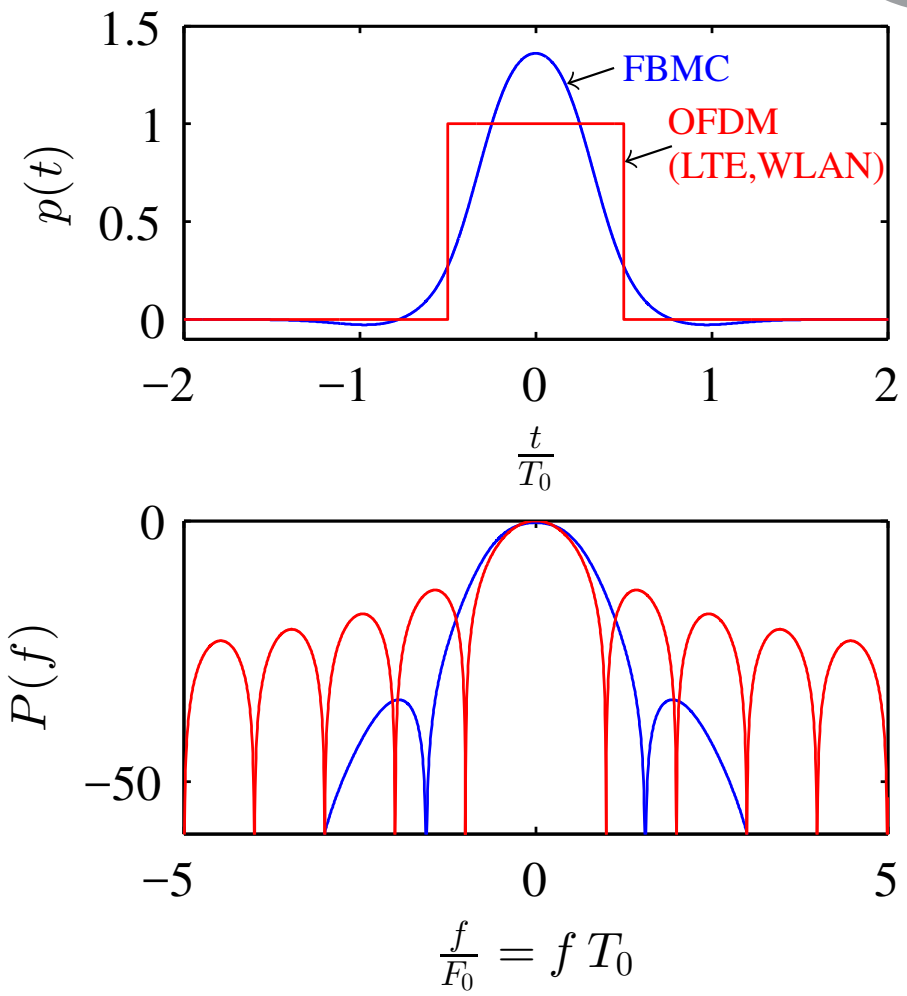
Motivation

Multicarrier Modulation

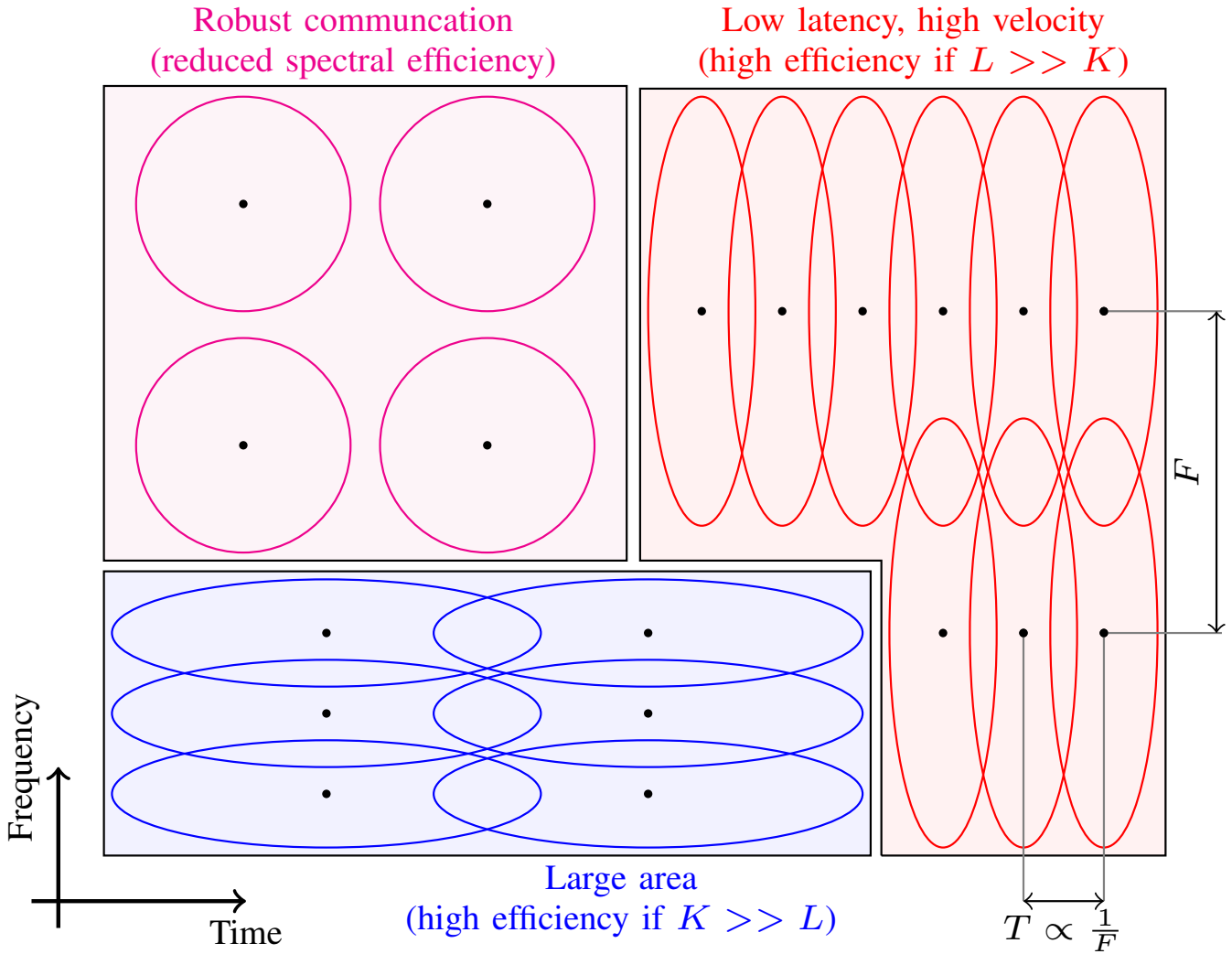




Current generation of wireless systems use OFDM.

Can we do better?

5G Design Paradigm: Flexible Time-Frequency Allocation



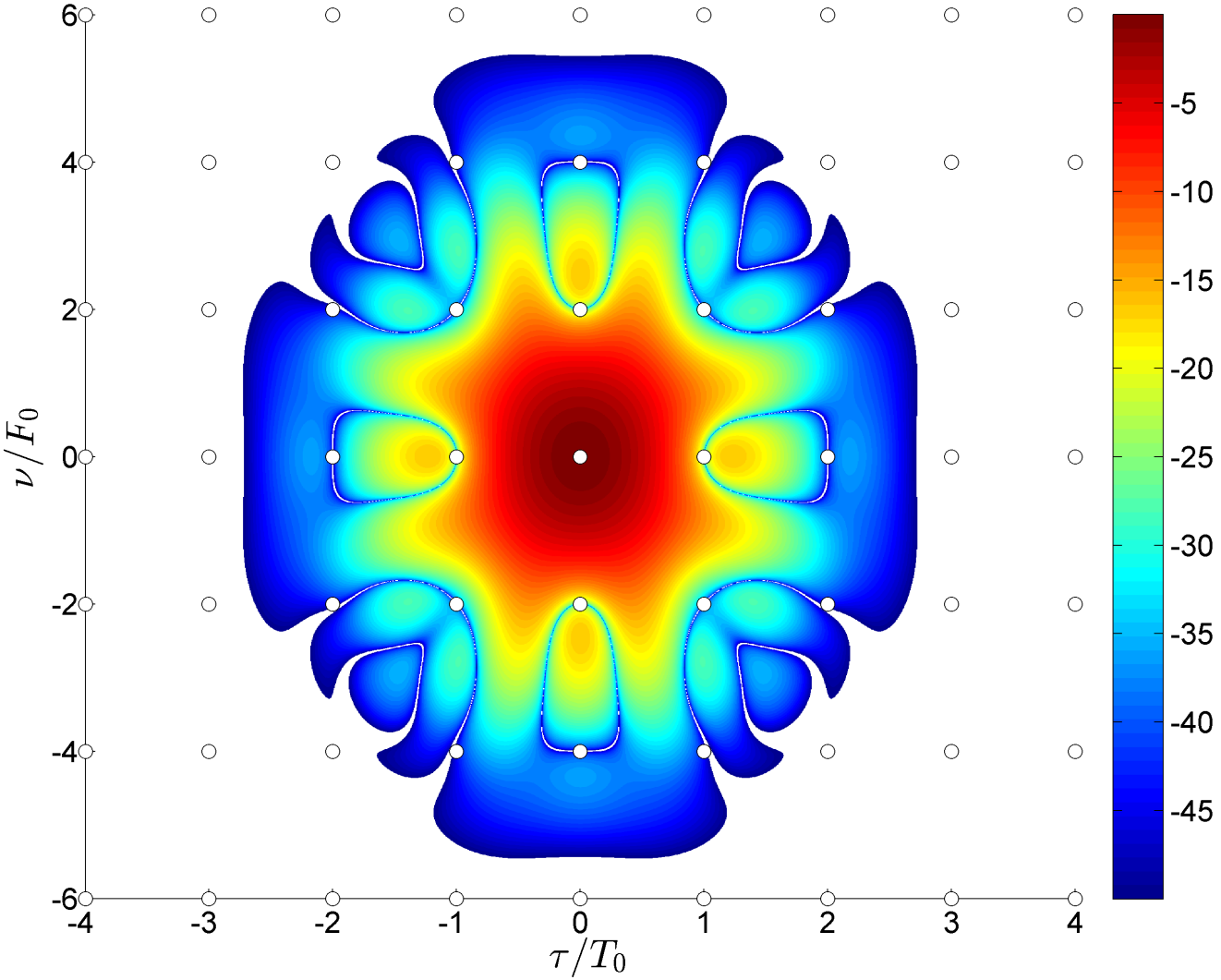
Required time-frequency resources for one symbol

L ... Number of subcarriers per block
K ... Number of time-symbols per block
F ... Frequency-spacing
T ... Time-spacing

How does FBMC work?

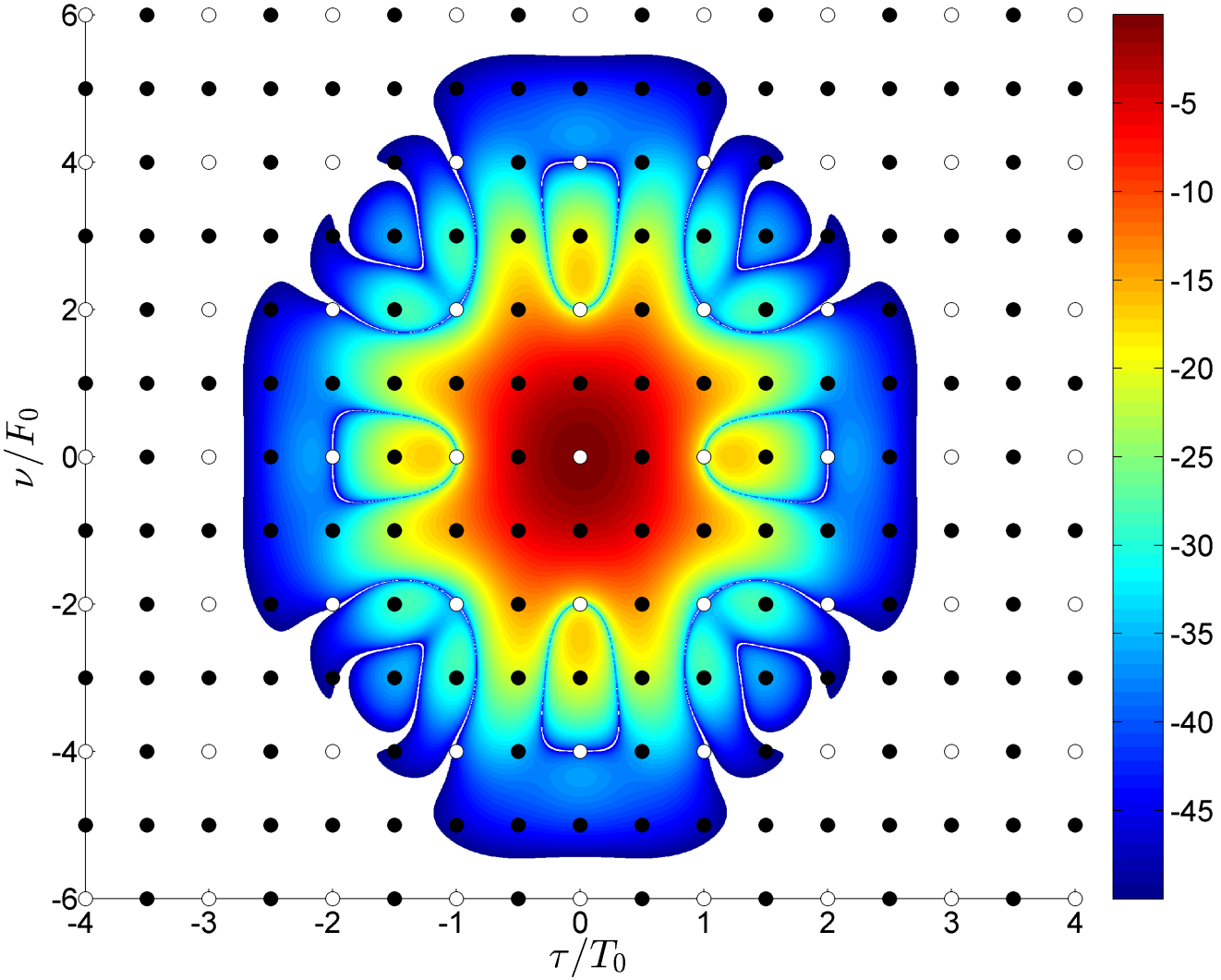
FBMC: Time-Frequency Localized Prototype Filter

(Complex) orthogonal for $TF = 2$



FBMC Offset-QAM: Transmit Real-Valued Symbols

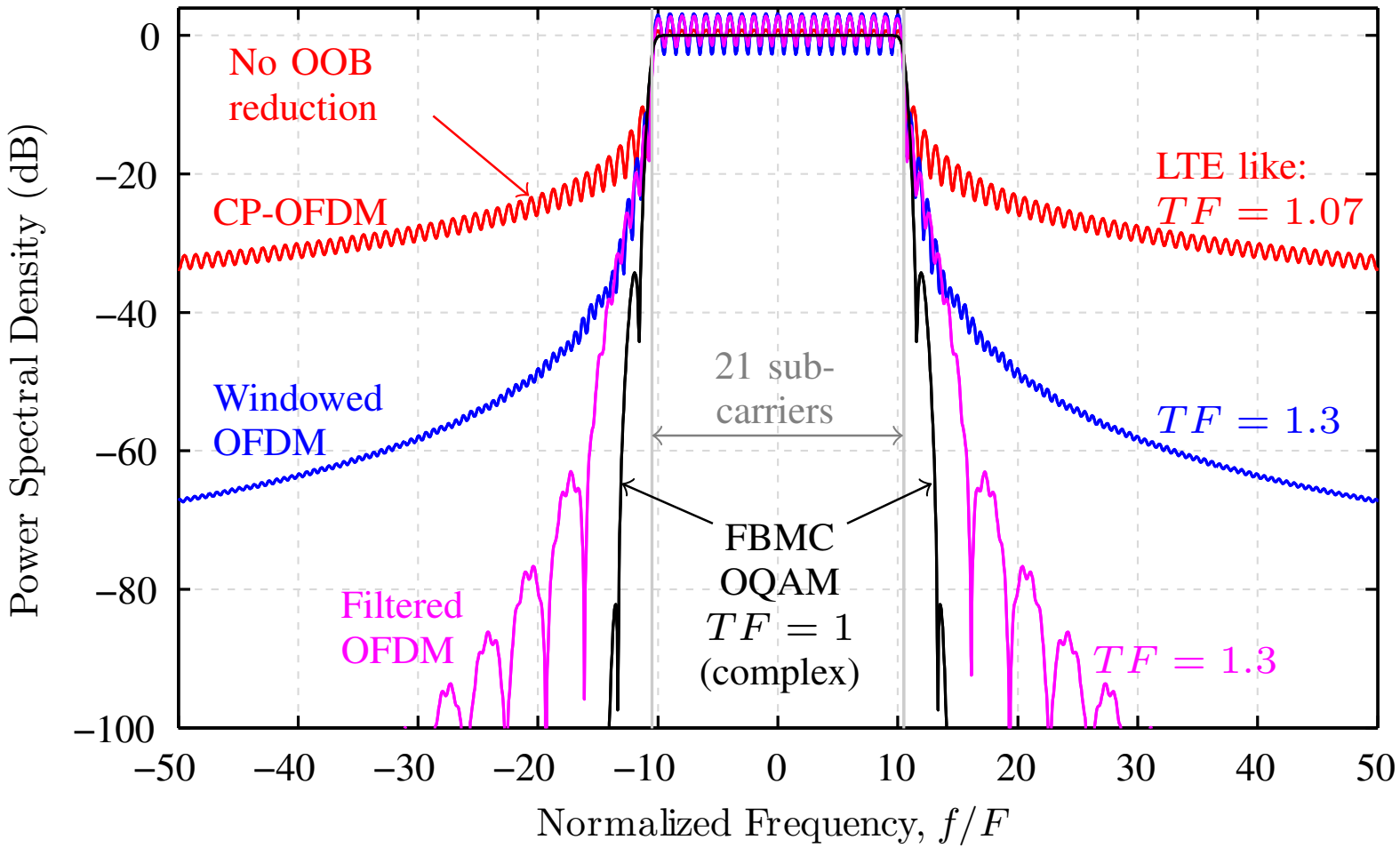
Orthogonal only in the **real domain**: $TF = 0.5$



Comparison of Multicarrier Schemes

	Maximum Spectral Efficiency $TF = 1$	Time-Localization	Frequency-Localization	(Bi)-Orthogonal	Independent Transmit Symbols
Pure OFDM	yes	yes	no	yes	yes
Windowed /Filtered OFDM	no	yes	yes	yes	yes
FBMC-OQAM	yes	yes	yes	real only	yes
Coded FBMC-OQAM	yes	yes	yes	yes, after de-spreading	no

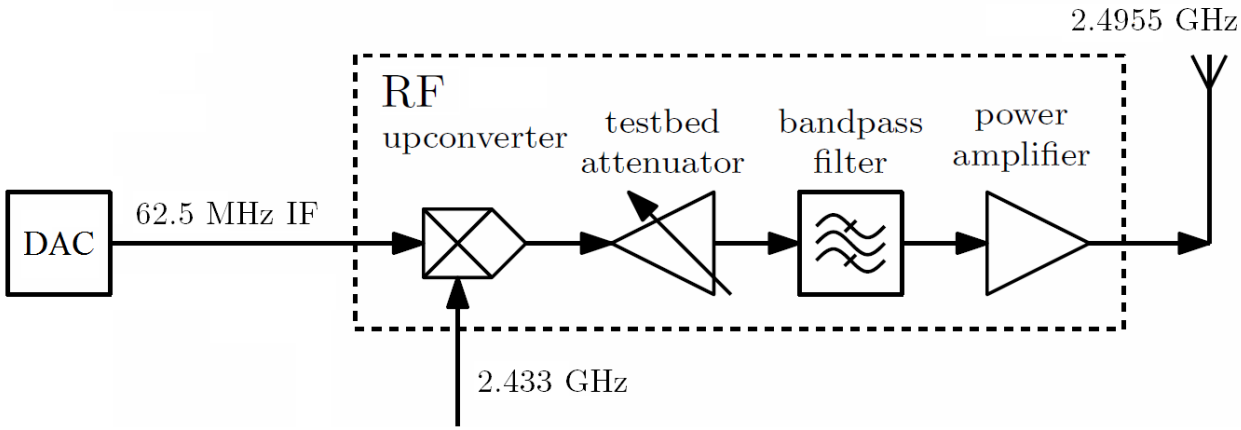
Comparison of Multicarrier Schemes



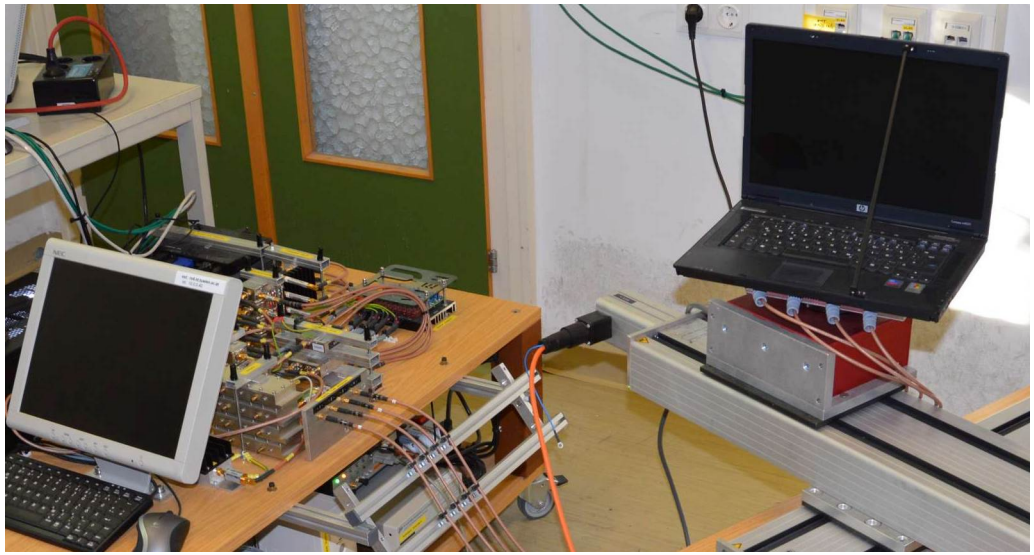
Real World Testbed Measurements

Vienna Wireless Testbed

Transmitter:



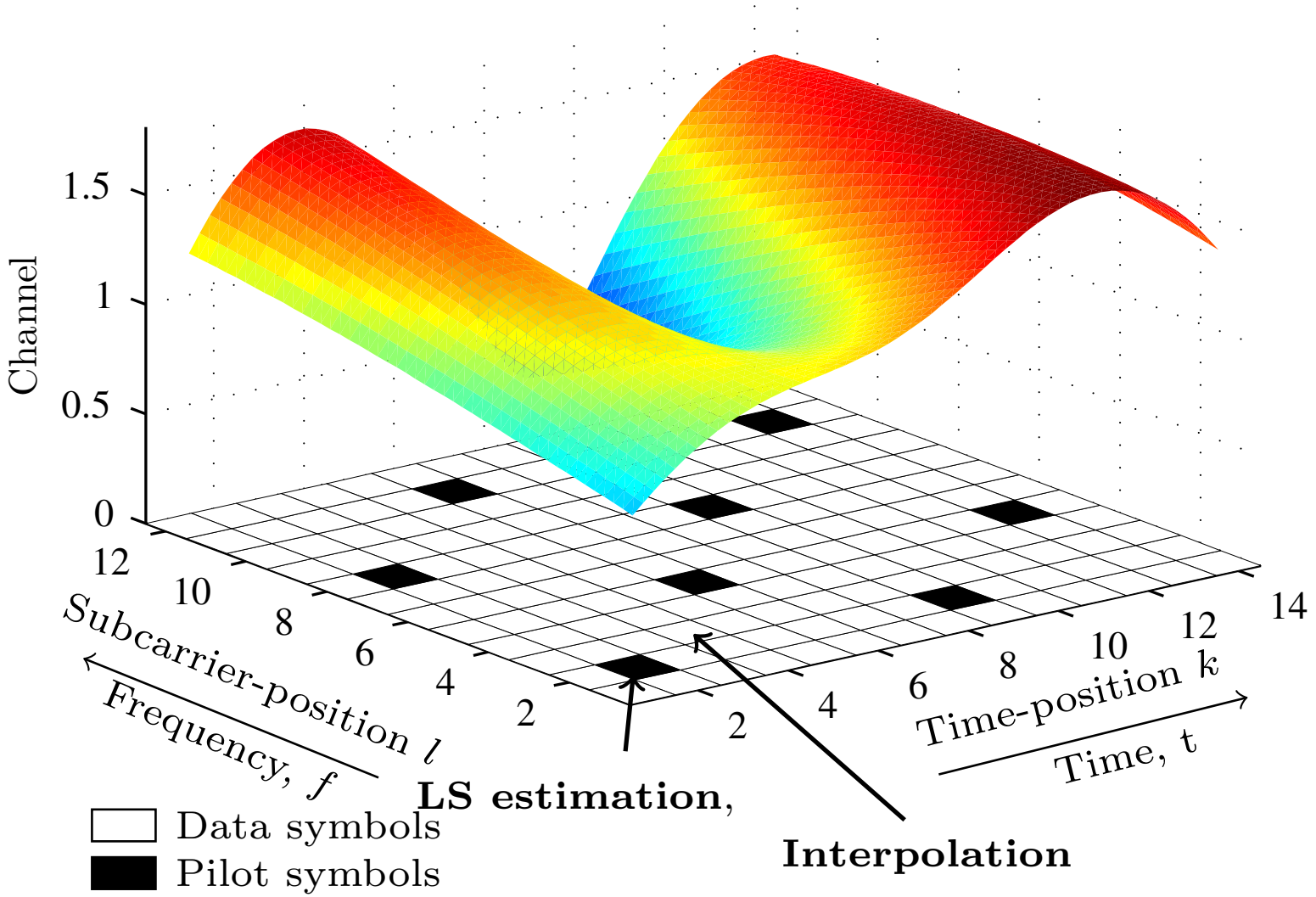
Receiver:



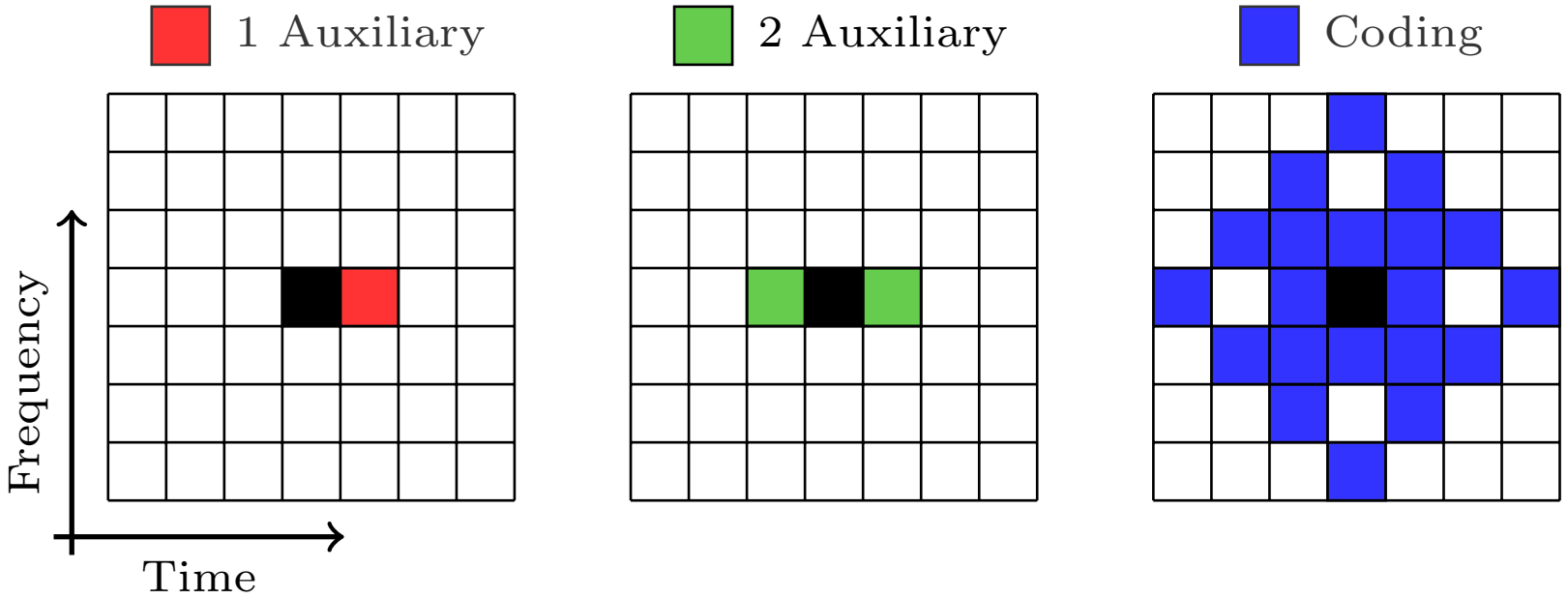
Channel Estimation in FBMC[1]

[1] "On Pilot-Symbol Aided Channel Estimation in FBMC-OQAM",R. Nissel,et.al.,2016

Channel Estimation in FBMC



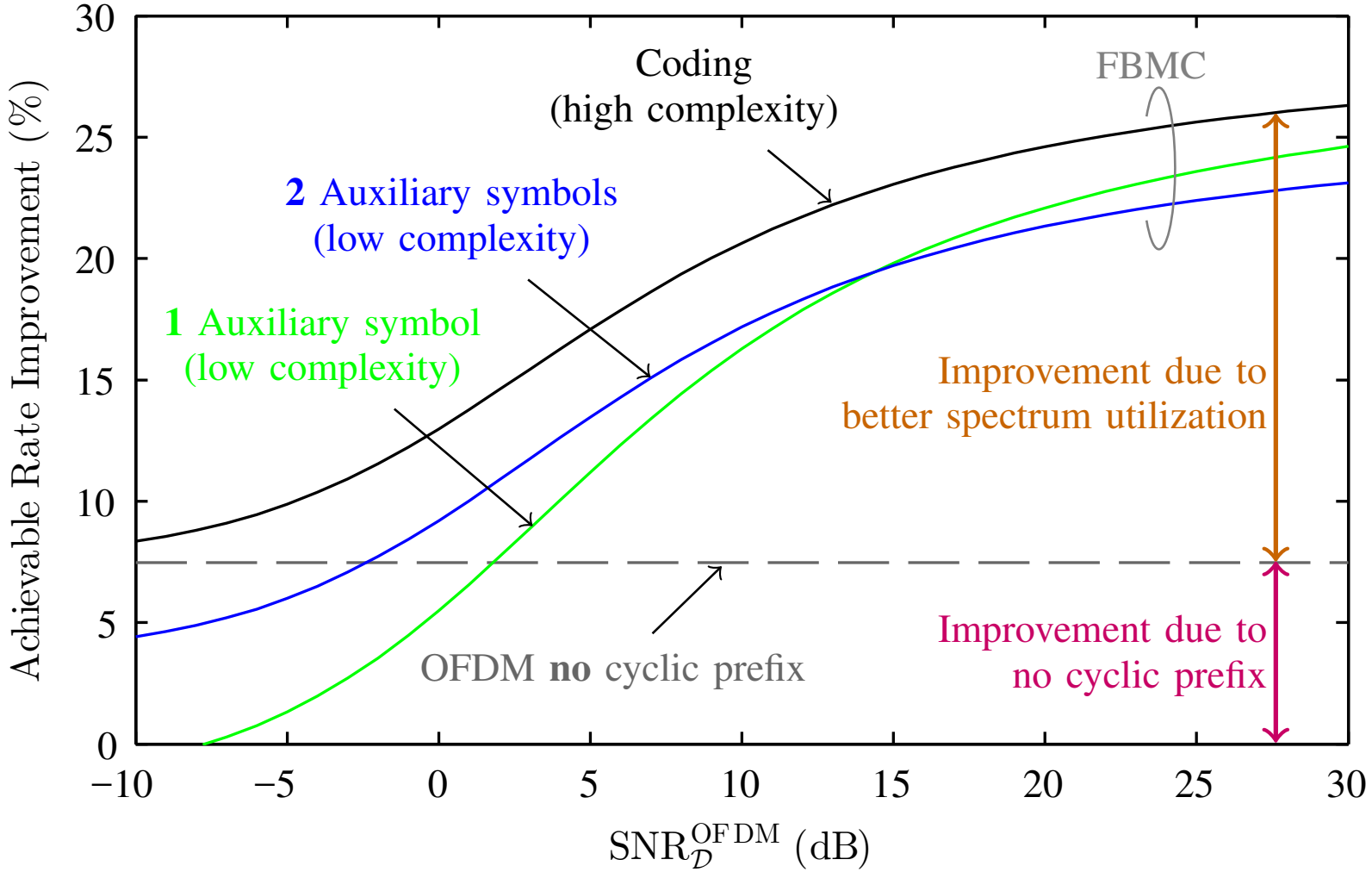
Cancel the imaginary interference at the pilot positions:



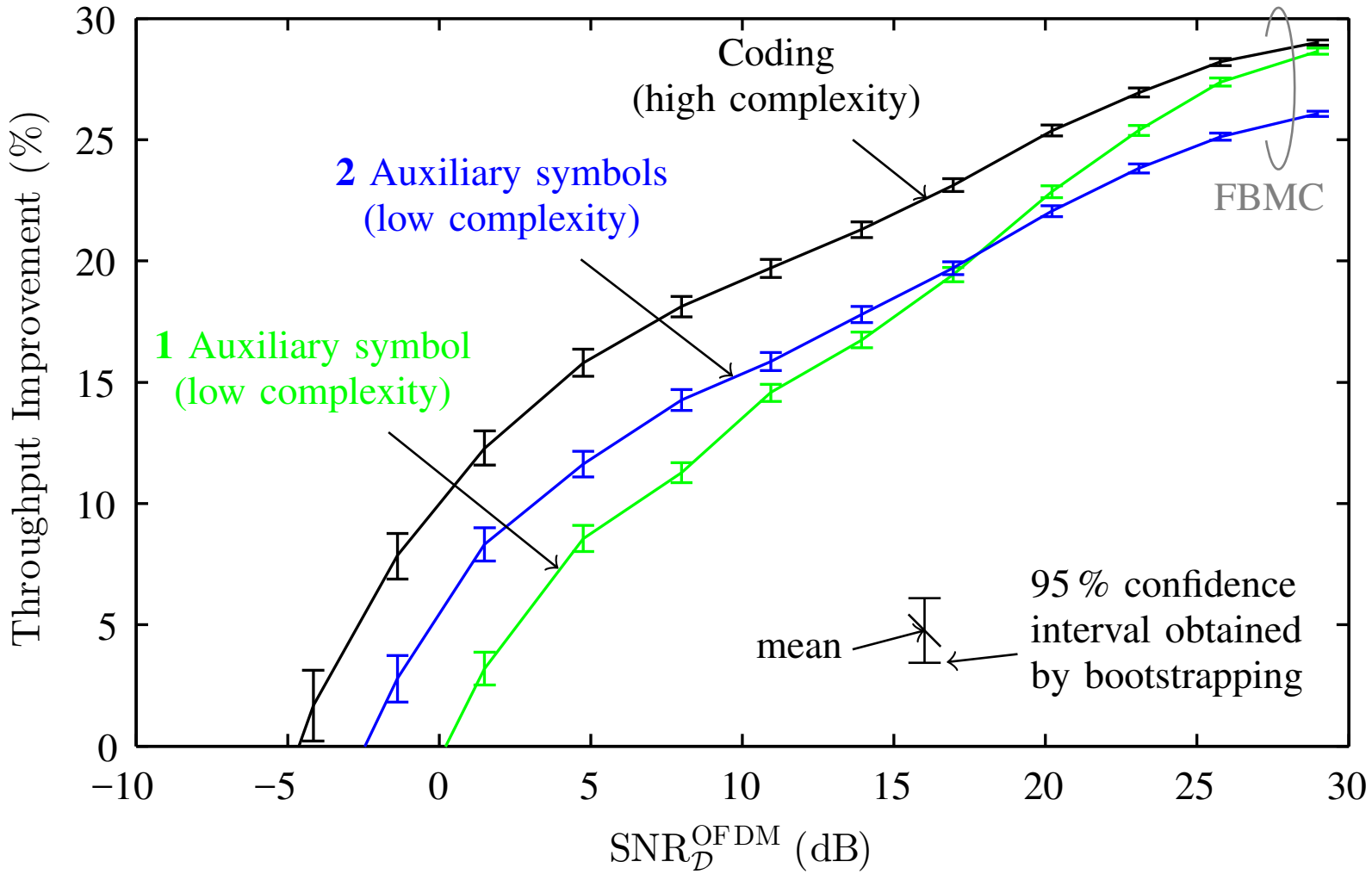
Novel Contribution:

- We suggest the usage of two auxiliary symbols.
- We extended the coding approach to more than 8 symbols
- Downloadable MATLAB code: `www.nt.tuwien.ac.at/downloads/`
- Validated by real world measurements

Achievable Rate Improvement: FBMC vs. OFDM (LTE)



Real World Throughput Measurements

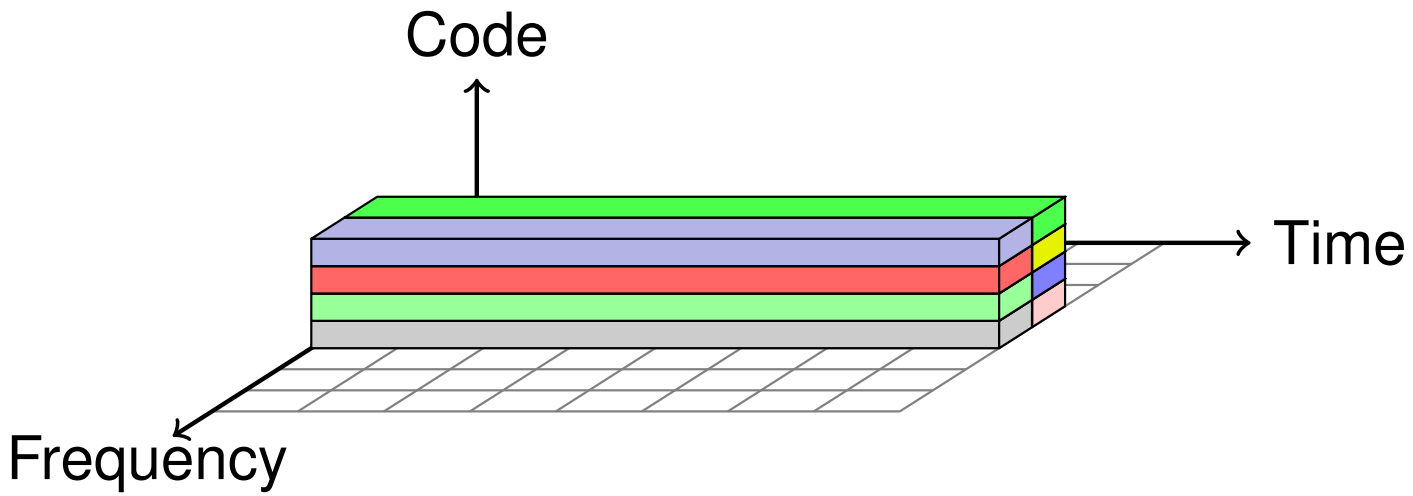


MIMO in FBMC[2]

[2] "Enabling Low-Complexity MIMO in FBMC-OQAM", R. Nissel and M. Rupp, 2016

Enabling MIMO in FBMC By Hadamard Spreading (+1,-1)

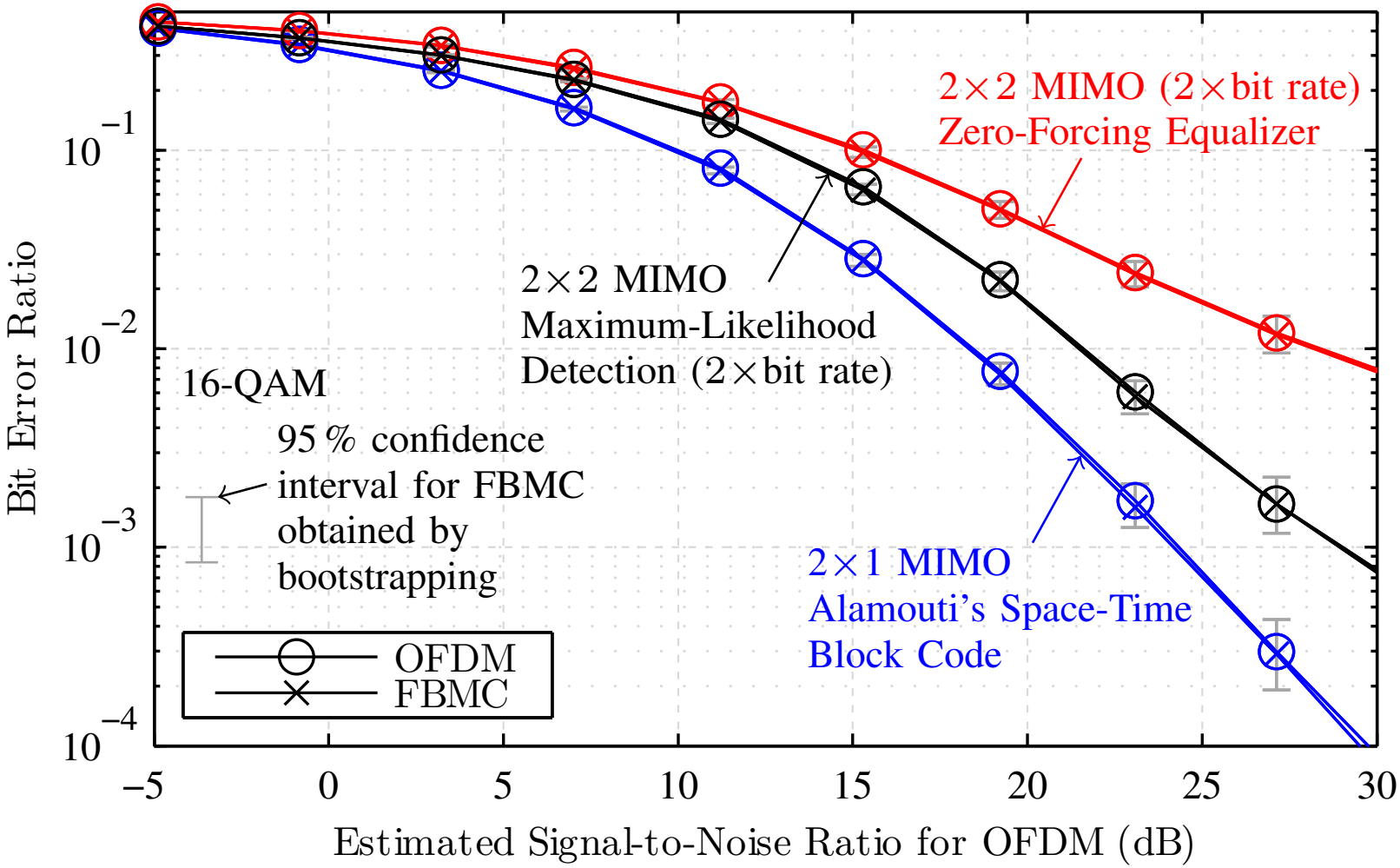
Coded FBMC-OQAM:



Novel Contribution:

- Matrix formulation: new analytical insights
- We investigate the block interference and the influence of time-varying channels
- Downloadable MATLAB code: `www.nt.tuwien.ac.at/downloads/`
- Validated by real world measurements

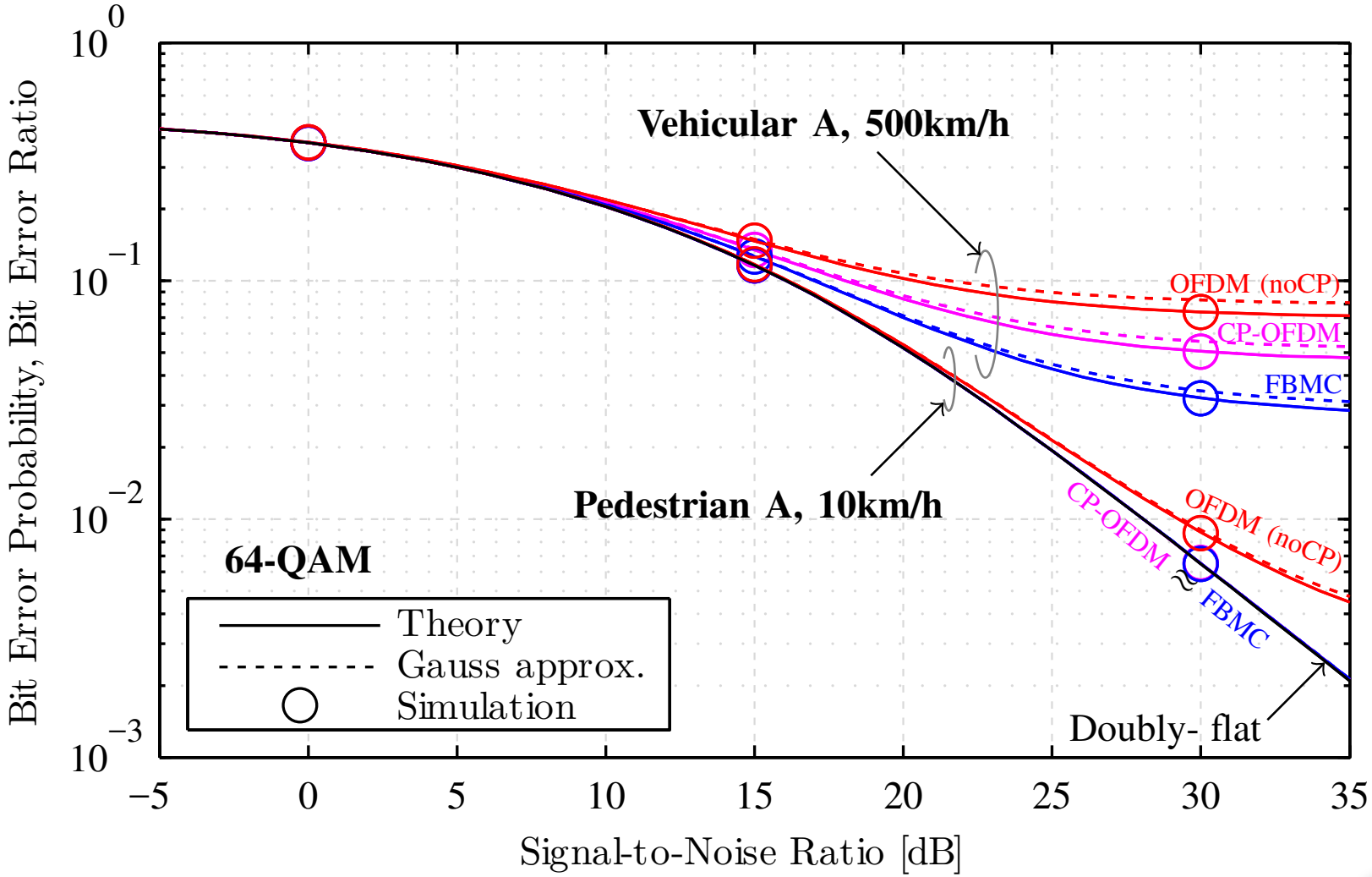
Real World MIMO Measurements



Bit Error Probability for FBMC in Doubly Selective Channels[3]

[3] "OFDM and FBMC-OQAM in Doubly-Selective Channels: Calculating the Bit Error Probability", R. Nissel and M. Rupp, 2016, submitted

Closed-Form BEP Expression

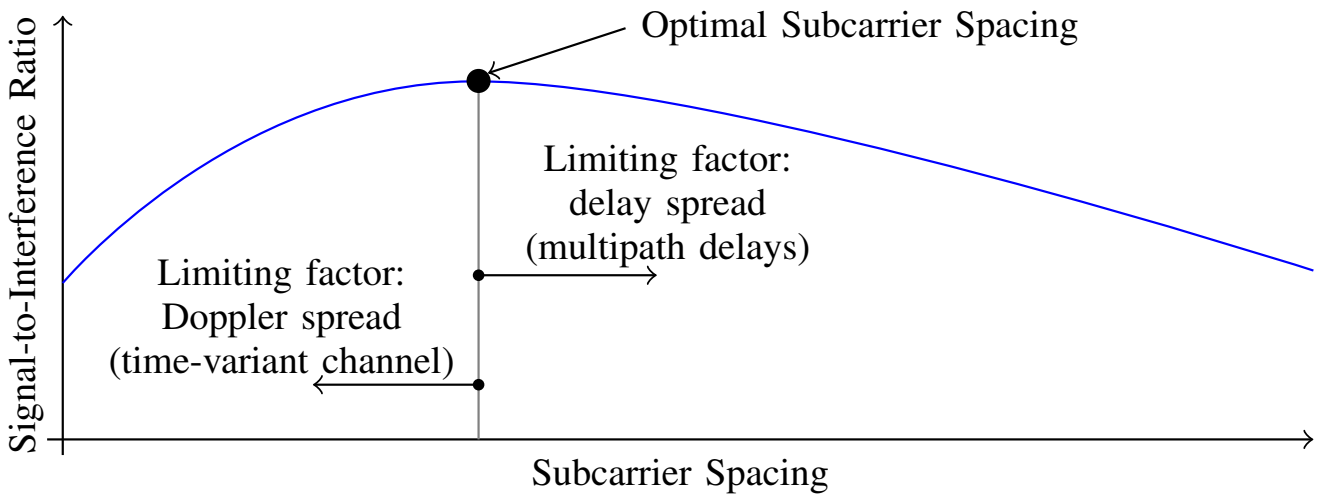


Outlook

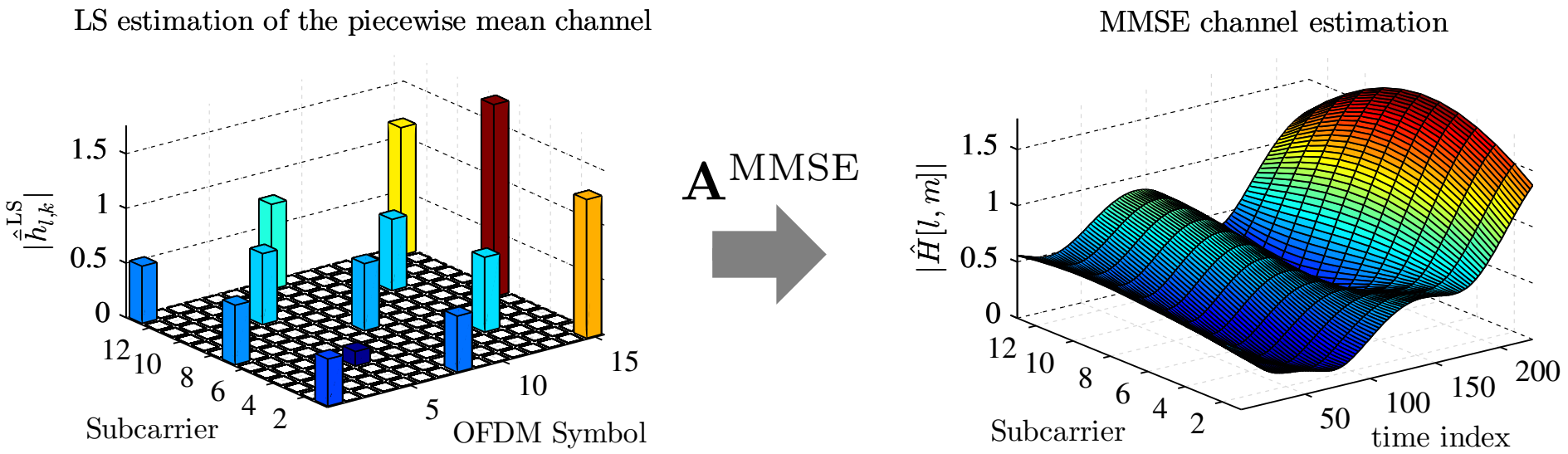
Questions:

- Are one-tap equalizers good enough?
- How good is FBMC compared to OFDM?
- Which prototype filter
  - Hermite
  - PHYDYAS

Fair comparison:



Doubly-Selective Channels in FBMC



- Channel estimation using time-frequency correlation
- Channel equalization

Further Questions in FBMC

Bit error probability, including channel estimation

- Similar to our submitted paper (which assumes perfect channel knowledge),
- But now also include channel estimation.

mmWave transmissions

- Testbed
- Jointly with Erich and Martin

Further investigate real world hardware effects

- Quantization
- Non-linear power amplifier

Conclusions

Conclusions

In contrast to most other research groups:

- Downloadable MATLAB code: `www.nt.tuwien.ac.at/downloads/`
- Theory is validated by real world testbed measurements

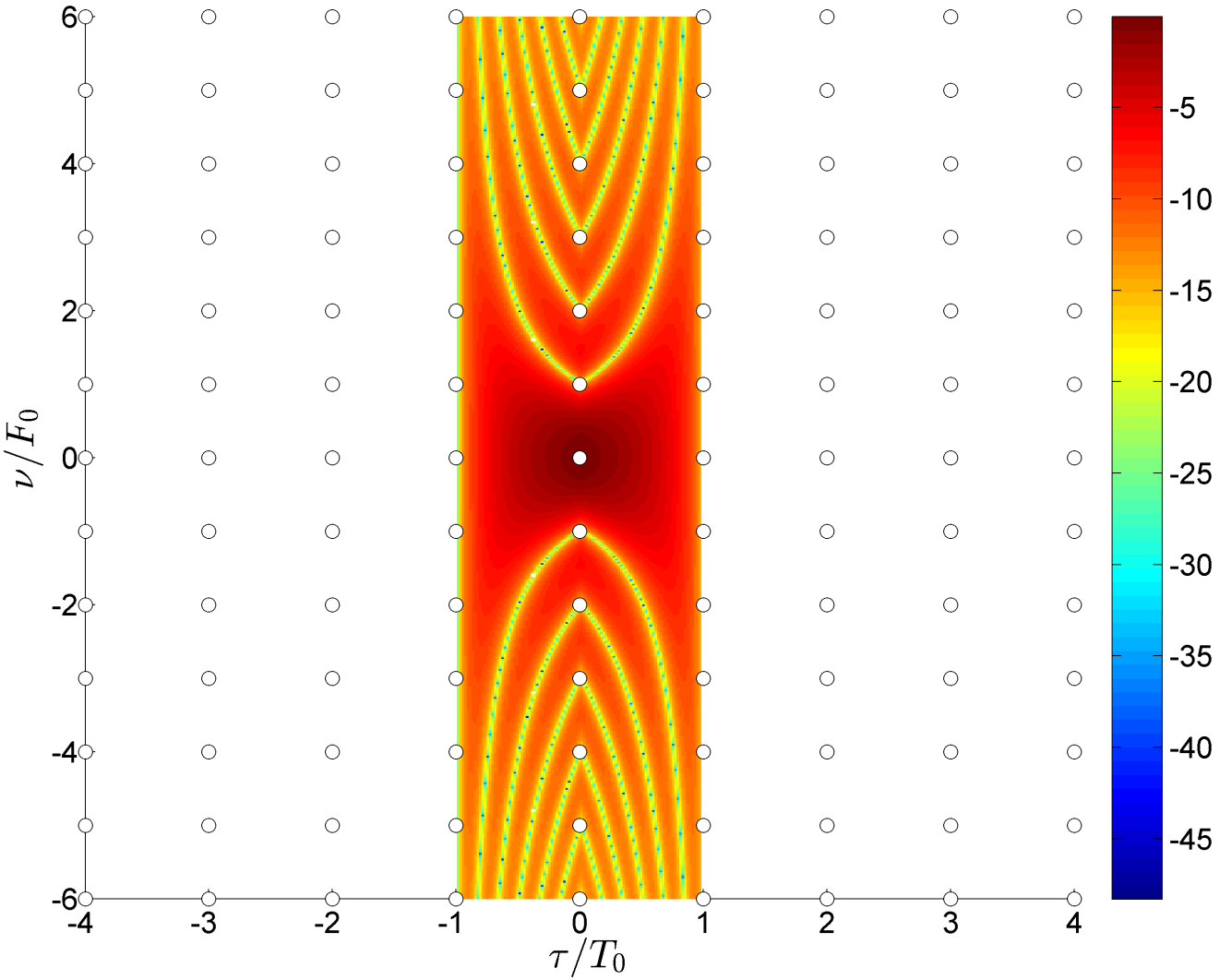
Main contribution in 2016:

- Channel estimation in FBMC
- MIMO in FBMC
- Bit error probability for FBMC in doubly-selective channels

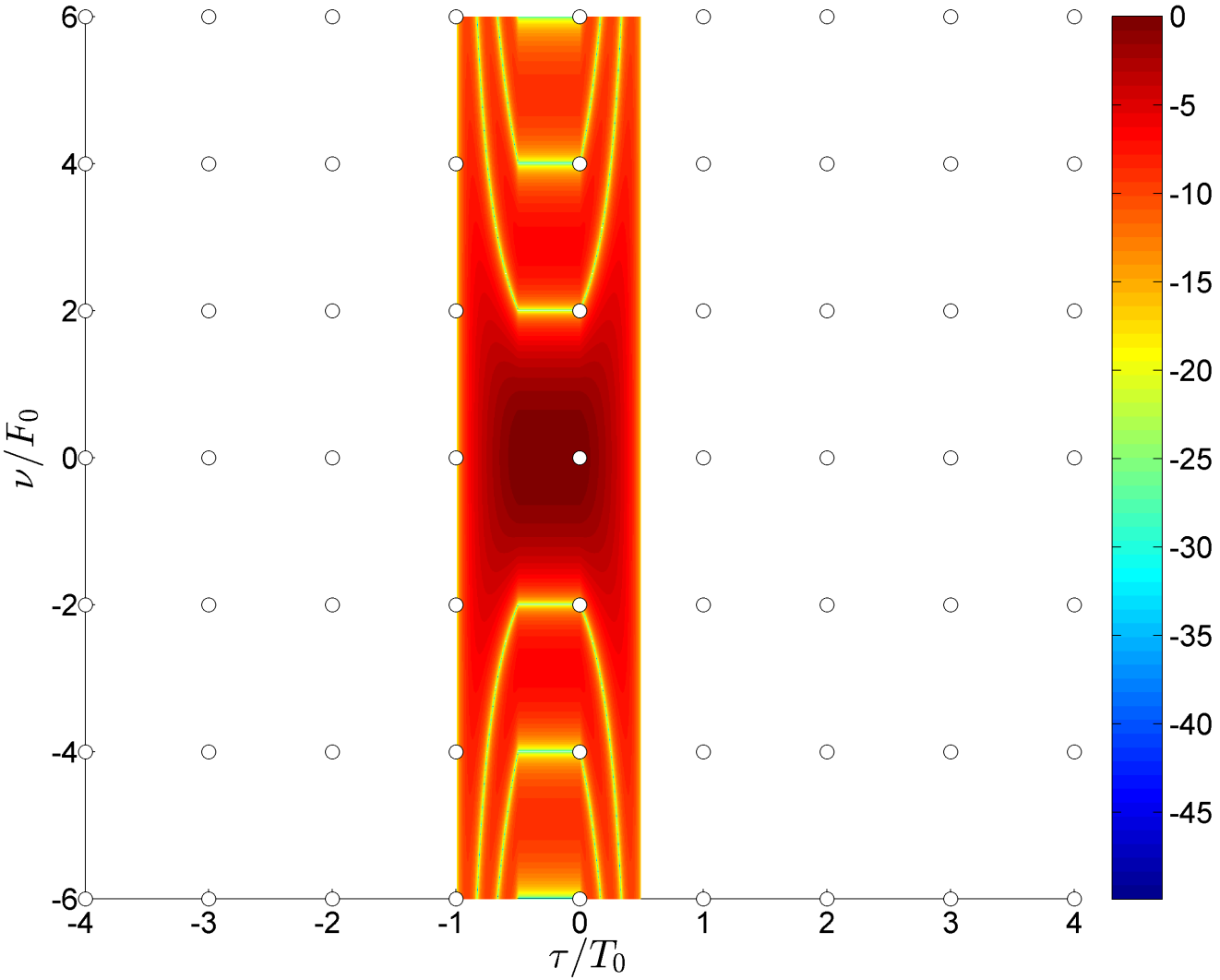
Outlook: A lot of open questions for the next years!

Backup Slides

Ambiguity Function OFDM

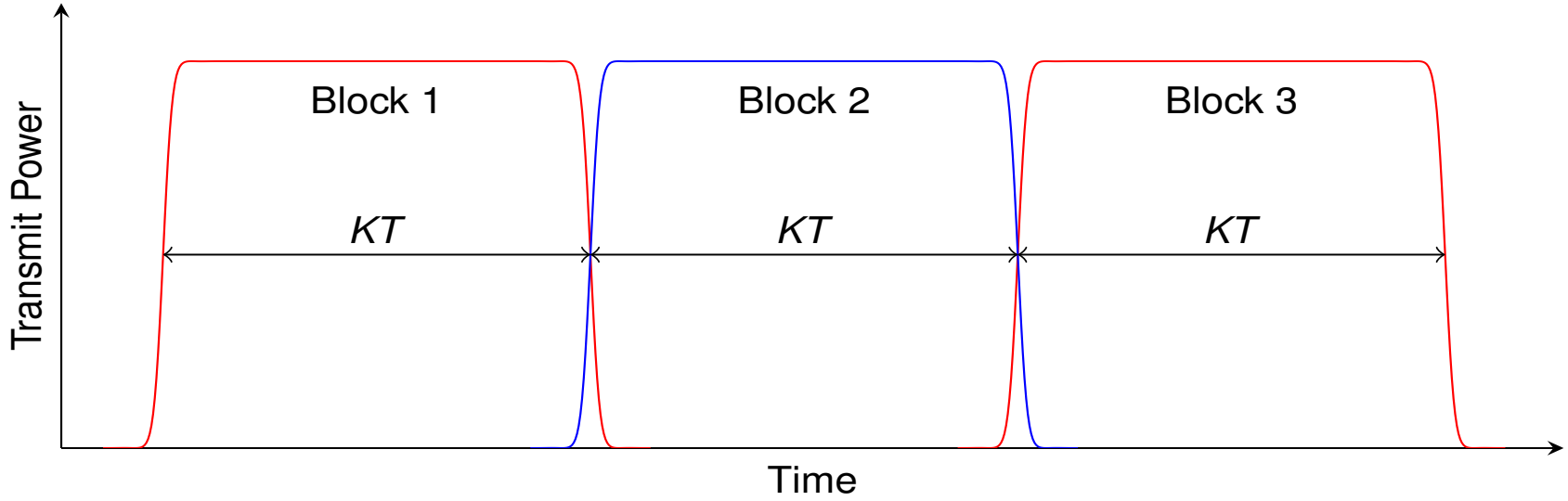


Ambiguity Function CP-OFDM

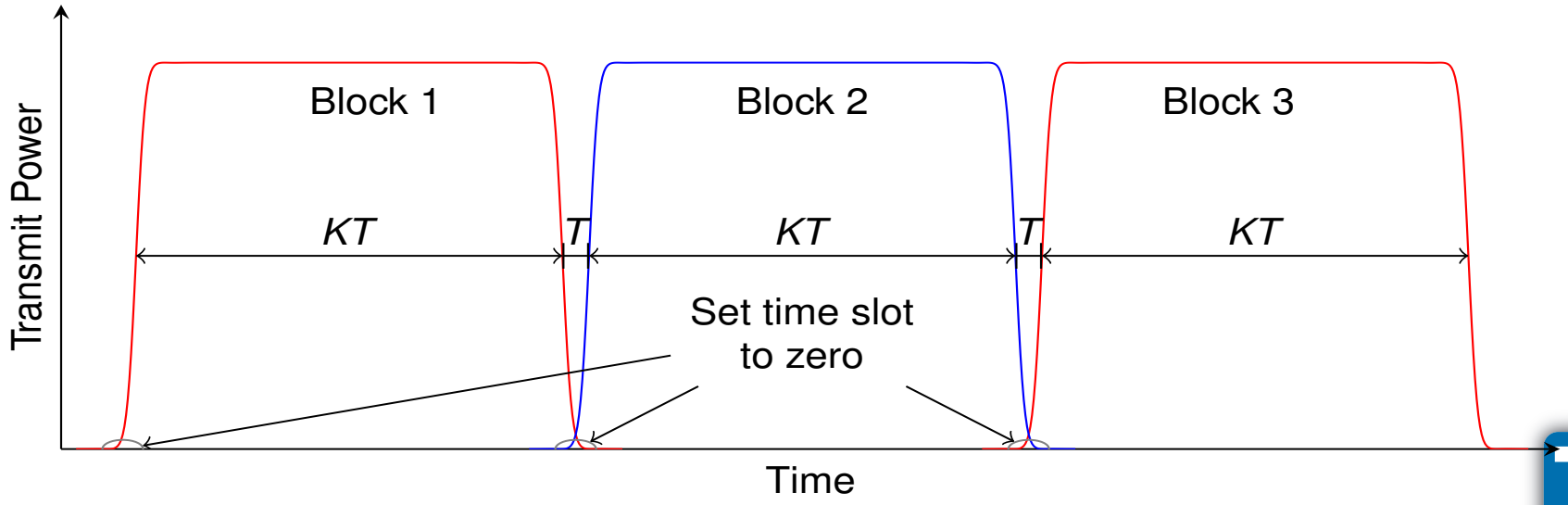


Block Interference

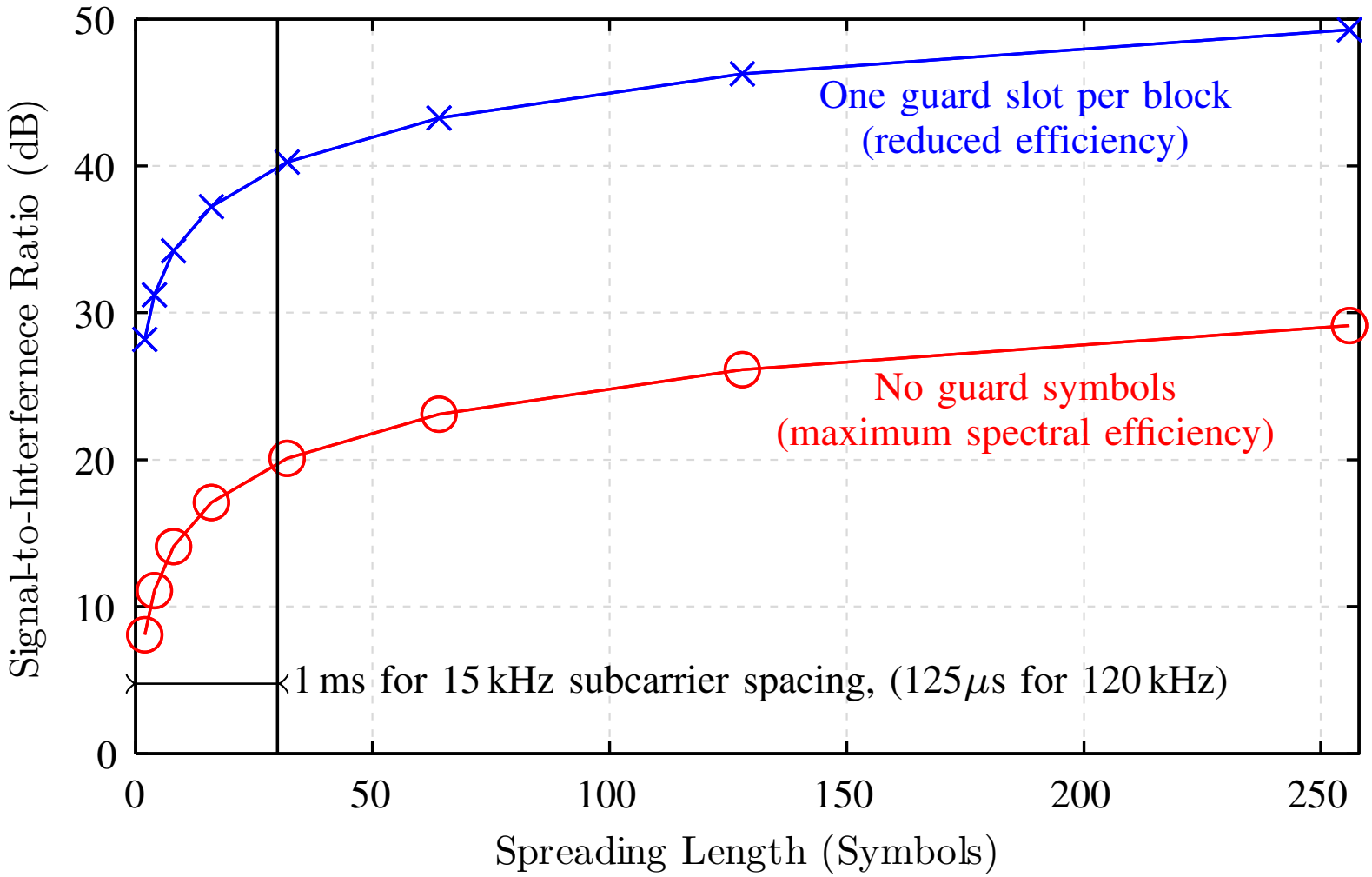
No guard-symbols:



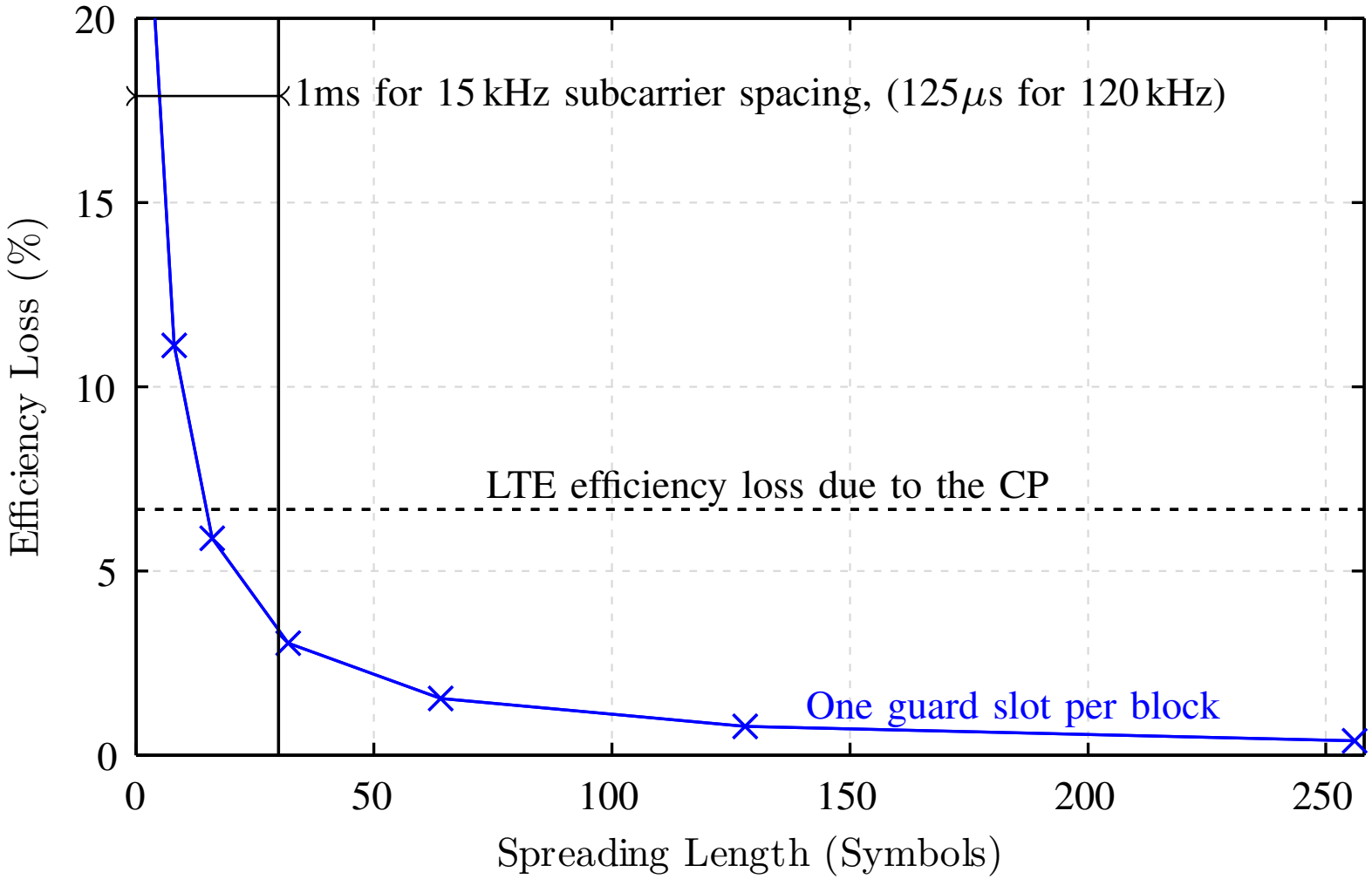
Guard time-slot:



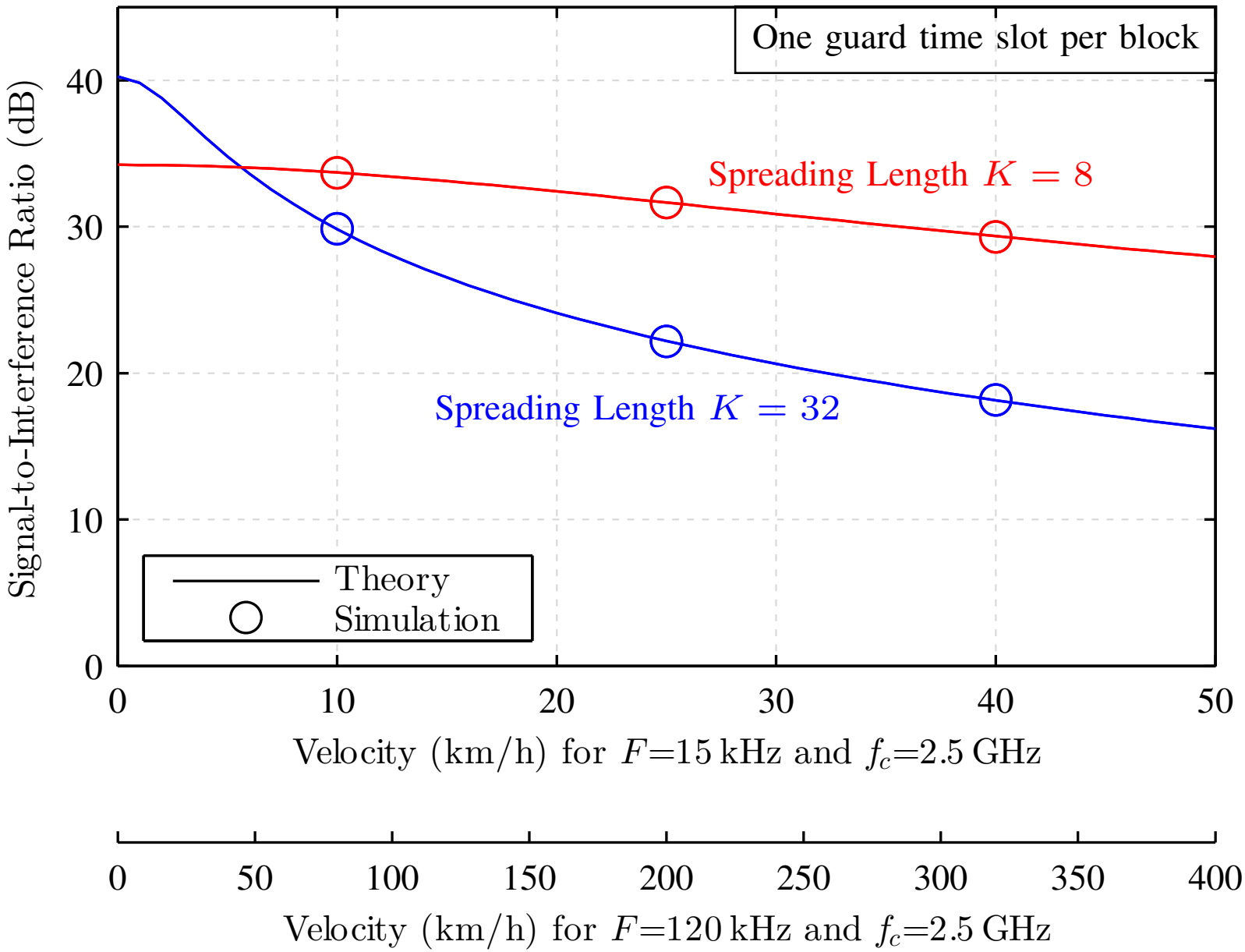
Block Interference



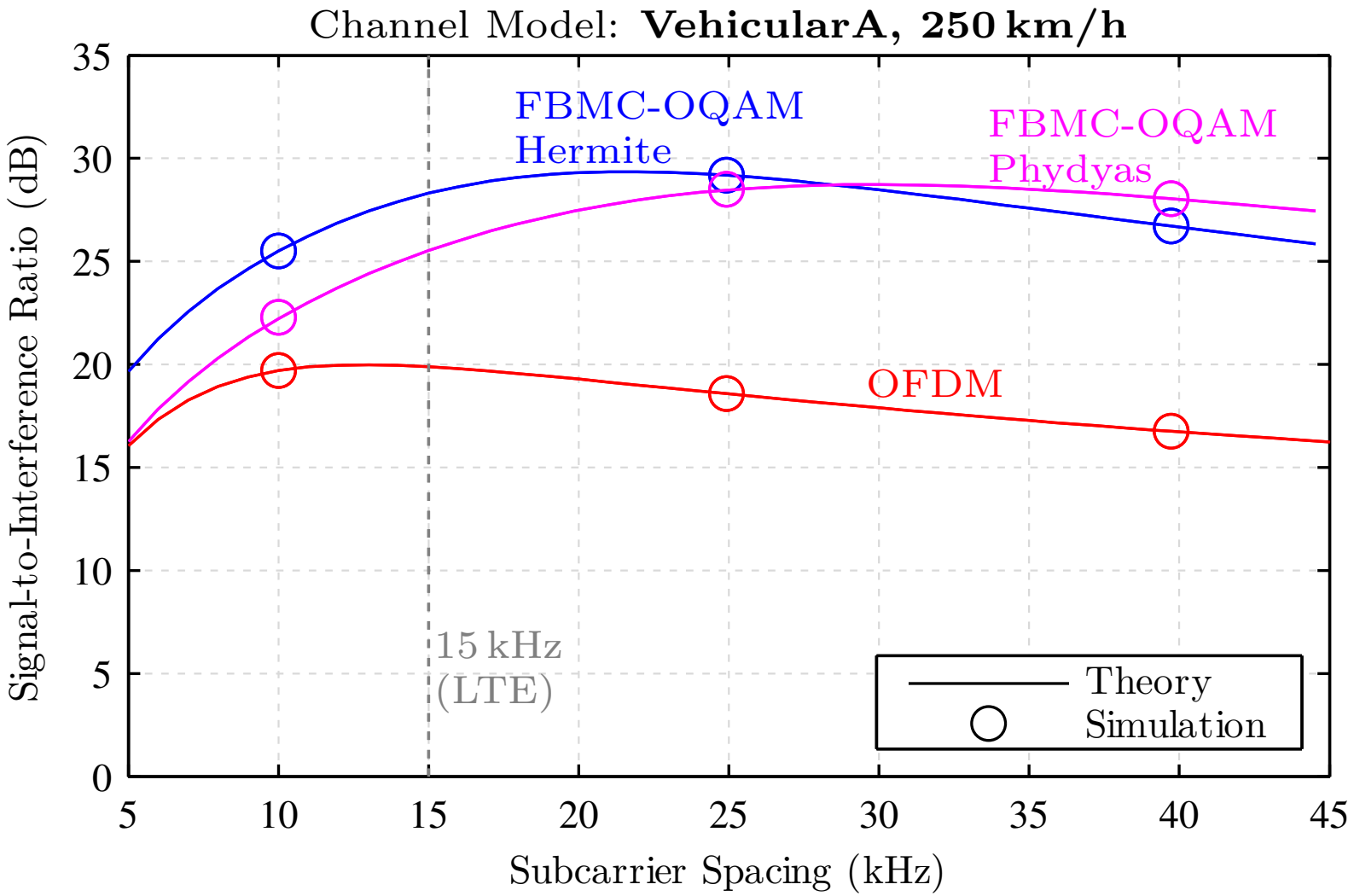
Block Interference



Time-Variant Channels



Flexible Subcarrier Spacing, $TF = 1$ (no CP)



Peak-To-Power Average Ratio and Signal Power Over Time