OTFS Performance Over Different Measured Vehicular 60 GHz Millimeter-Wave Channels

Doctoral School 5G Internet of Things Workshop

Danilo Radovic, September, 2021

Technische Universität Wien

Institute of Telecommunications

Contents

Introduction

Simulation Setup

Simulation Results

Conclusion

Motivation

- Vehicular communications
  - Openness of space
  - High mobility
- Challenges
  - Large delayspread
  - Large Dopplerspread
  - Channel prone to fast changes
- Proposed solution: OFDM
  - Simple equalization of static channels
  - Challenging for channel prone to fast changes - outdated estimate

Figure: Vehicle to vehicle communication.

[Online] Available: https://d3e3a9wpte0df0.cloudfront.net/wp-content/uploads/2018/06/vehicle-to-vehicle-communication.png

OTFS - Orthogonal Time Frequency Space

- Data symbols placed in delay-Doppler domain
  - Exploits the diversity
  - Non-fading channel
  - Improves throughput
- Complex iterative decoders are necessary
  - Computational complexity
  - Time consuming
- Simulation over the real V2V channels missing!

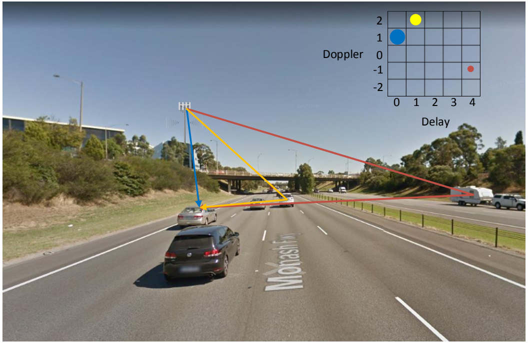

Figure: Example of a V2X channel.

[Online] Available: https://ecse.monash.edu/staff/eviterbo/OTFS-VTC18/Tutorial_ICC2019___OTFS_modulation.pdf

OTFS - Orthogonal Time Frequency Space

$$\Gamma = \left\{ \left(\frac{m'}{M\Delta f}, \frac{n'}{NT} \right) : m' \in [0, M-1], n' \in [0, N-1] \right\}$$

- m' and n' indices in delay and Doppler domain
- M number of symbols in delay domain
- N number of symbols in Doppler domain
- $T_{OTFS} = NT$ transmission time
- $B = M\Delta f$ occupied bandwidth

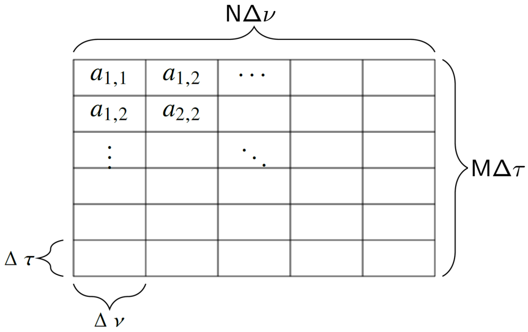

Figure: Example of an OTFS symbol grid.

Contents

Introduction

Simulation Setup

Simulation Results

Conclusion

Scope of work

- OTFS applicability over the real channels
- Different V2V channel measurements at 60 GHz are considered
- Performance of OTFS vs. OFDM
- The effect of increasing the dimensionality in the Doppler domain

Simulation model

- Data block
  $\boldsymbol{X}[\mathrm{m},\mathrm{n}]\,,\;\; \mathrm{m} \in [0, \mathrm{M}-1], \mathrm{n} \in [0, \mathrm{N}-1]$
- Inverse symplectic fast Fourier transform (ISFFT) converts to t-f domain
  $\boldsymbol{U}[\mathrm{f},\mathrm{t}] = \boldsymbol{F}_{\mathrm{M}}\boldsymbol{X}[\mathrm{m},\mathrm{n}]$
- Received symbol matrix
  $\boldsymbol{R} = \boldsymbol{H} \odot \boldsymbol{U}$
- Symplectic Fourier transform (DSFT) converts to d-D domain
  $\boldsymbol{Y}[\mathrm{m},\mathrm{n}]$
- Message Passing algorithm* for detection and interference cancellation
  $\hat{\boldsymbol{X}} = \arg\max_{\boldsymbol{X} \in \mathbb{A}^{\mathrm{N}\times\mathrm{M}}} \Pr(\boldsymbol{X}|\boldsymbol{Y},\boldsymbol{H})$

*P. Raviteja, K. T. Phan, Y. Hong, and E. Viterbo, "Interference cancellation and iterative detection for orthogonal time frequency space modulation," IEEE Transactions on Wireless Communications, vol. 17, no. 10, pp. 6501-6515, Oct 2018.

Measured channel

- Vienna down-town urban measurement campaign
- Approximation of an vehicle overtaking scenario
- Center freqeuncy 60 GHz
- Subcarrier spacing 4.96 MHz, 102 subcarriers
- Delay resolution 1.96 ns

Figure: Measurement in urban scenario.

E. Zöchmann et al., "Measured delay and Doppler profiles of overtaking vehicles at 60 GHz," in Proc. of the 12th European Conference on Antennas and Propagation (EuCAP), London, Great Britain, 2018, pp.1-5.

Measurment scenarios

Measurment scenario I - car scenario

- A small passenger car is passing through the street
- Motion speed $v_1 = 9.6\,\mathrm{m/s}$
- At the transmitter side a 18° horn antenna
- At the receiver an $\lambda/4$ omnidirectional antenna

Measurment scenario II - bus scenario

- A bus is passing through the street
- Motion speed $v_2 = 4.6\,\mathrm{m/s}$
- At the transmitter side a 18° horn antenna
- At the receiver an open-ended waveguide (OEW), pointing towards the departing vehicles

Measured channel

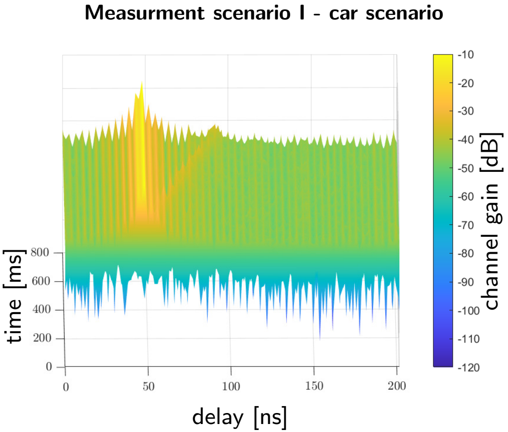

Figure: Time-variant channel power delay profile, channel sounder measurement data for the car scenario.

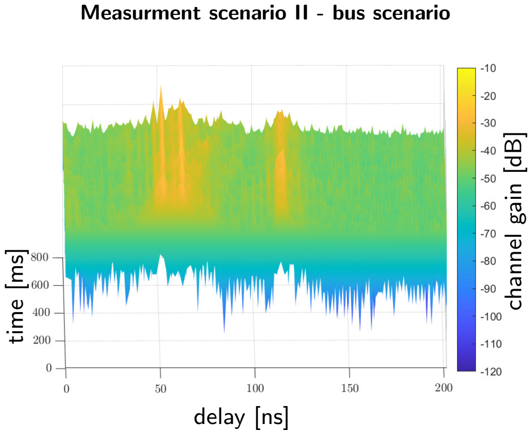

Figure: Time-variant channel power delay profile, channel sounder measurement data for the bus scenario.

Contents

Introduction

Simulation Setup

Simulation Results

Conclusion

Simulation Parameters

- 4-QAM symbols spread over the d-D grid
- Forward Error Correction with feedback convolutional encoder
- Random interleaver
- Viterbi decoder used for decoding
- BER over SNR is calculated

Table: Simulation Parameters

Parameter	Value
Center frequency (f_c)	60 GHz
Subcarrier spacing (Δf)	1.875 MHz
Number of subcarriers (M)	64
Time aggregation (N)	2, 64

Simulation Results

Measurment scenario I - car scenario

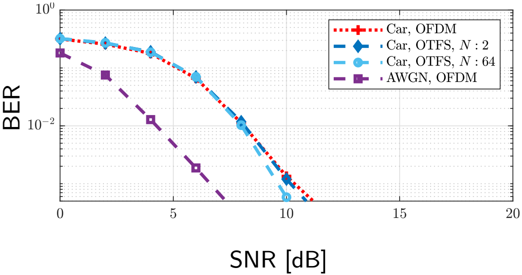

Figure: Bit error ratio simulation results for M = 64 subcarriers and channel bandwidth 120 MHz over measured channel, car scenario.

Measurment scenario II - bus scenario

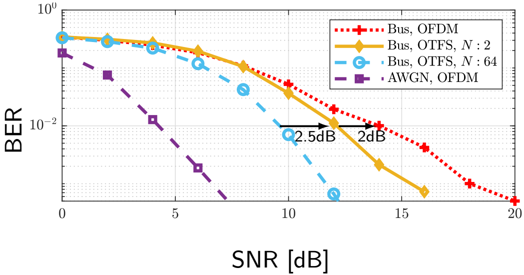

Figure: Bit error ratio simulation results for M = 64 subcarriers and channel bandwidth 120 MHz over measured channel, bus scenario.

Contents

Introduction

Simulation Setup

Simulation Results

Conclusion

Conclusion

- We study performance of OTFS vs. OFDM over the real V2V channels
- The effect of increasing the dimensionality in the Doppler domain has been studied
- BER decline can be achieved by applying OTFS
- By applying OTFS over the channels with many delay-Doppler components, a performance gain can be achieved
- OTFS application over the channels with a dominant LOS component does not provide any benefit compared to OFDM

Thank You

Danilo Radovic
danilo.radovic@tuwien.ac.at

Technische Universität Wien

Institute of Telecommunications