Radar Communications: A solution for mitigating automotive radar interference

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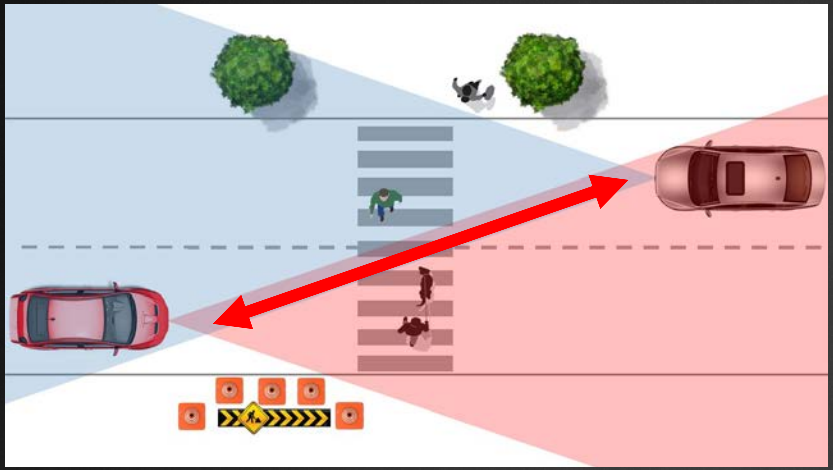
Financial support:
Marie Curie Individual Fellowships (H2020-MSCA-IF-2016)
Chalmers E2 Interdisciplinary Seed Grant

Outline

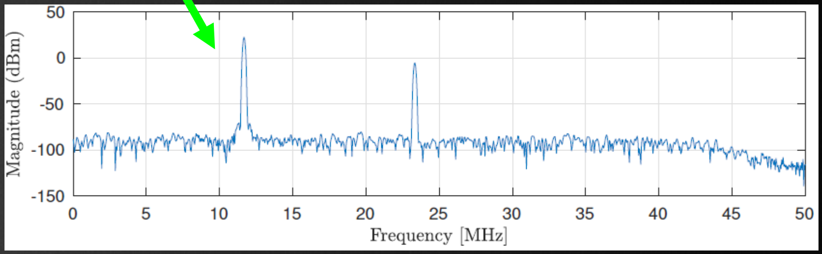
- Problem: Mutual radar interference
- Background: Automotive radars
- Proposed solution: Radar Communications
- Results
- Conclusions

Problem

- **Mutual radar interference**



Interference=ghost target

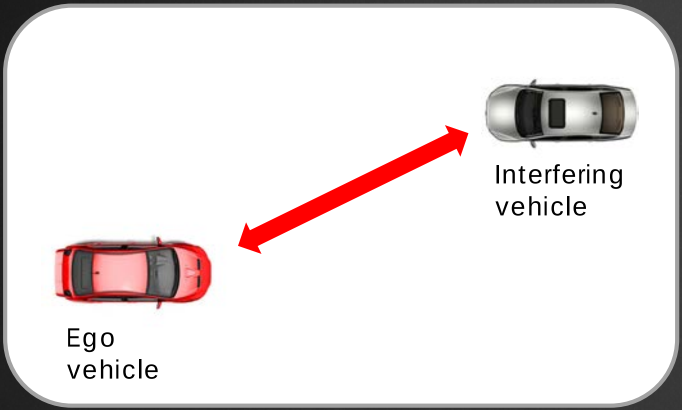


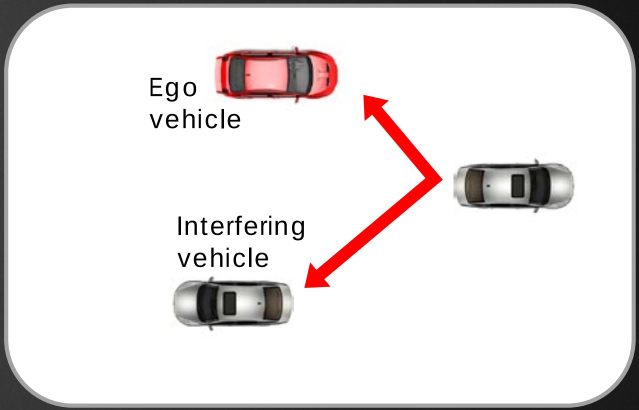
Increased noise floor

- Interference has higher power than target itself
- Interference range is twice radar range $(2d_{max})$
- Safety ↓
  - Radars per vehicle ↑
  - Vehicles with radars/ Autonomous vehicles ↑

Problem

- **When do we have mutual radar interference?**
  - Facing radars (radars receiving each other's direct or reflected radar signals)

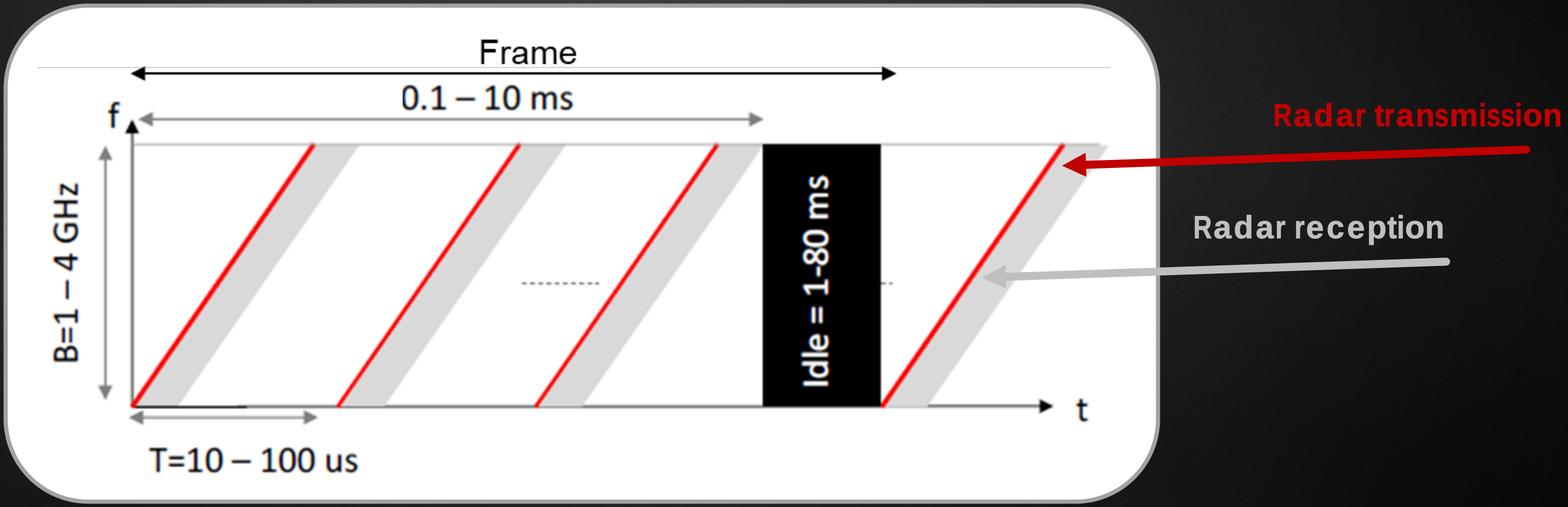




  - Facing radars transmit during a 'vulnerable period'

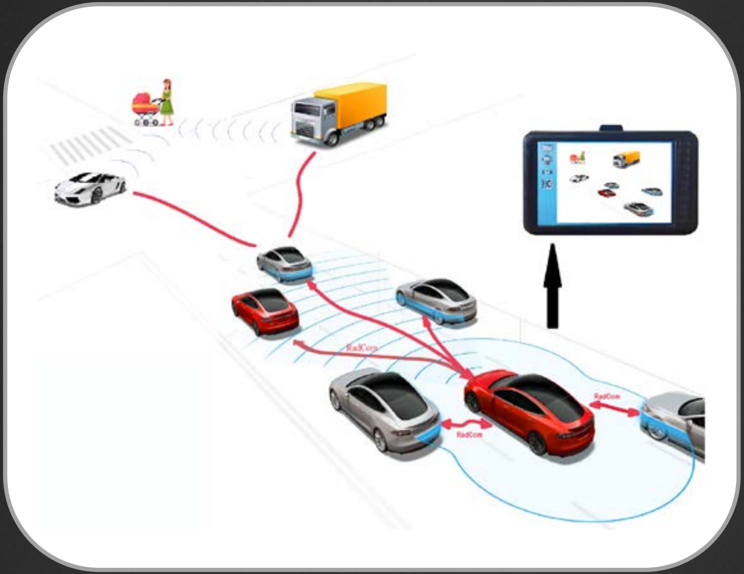
Background

- **Automotive radars**
  - 77 GHz (76-77) – used today most frequently
  - 79 GHz (77-81)
- The most common modulation format used for automotive radar is **frequency modulated continuous-wave (FMCW)**
  - Inefficient spectrum use
  - Idle time for processing, i.e. inefficient use of time



Proposed Solution

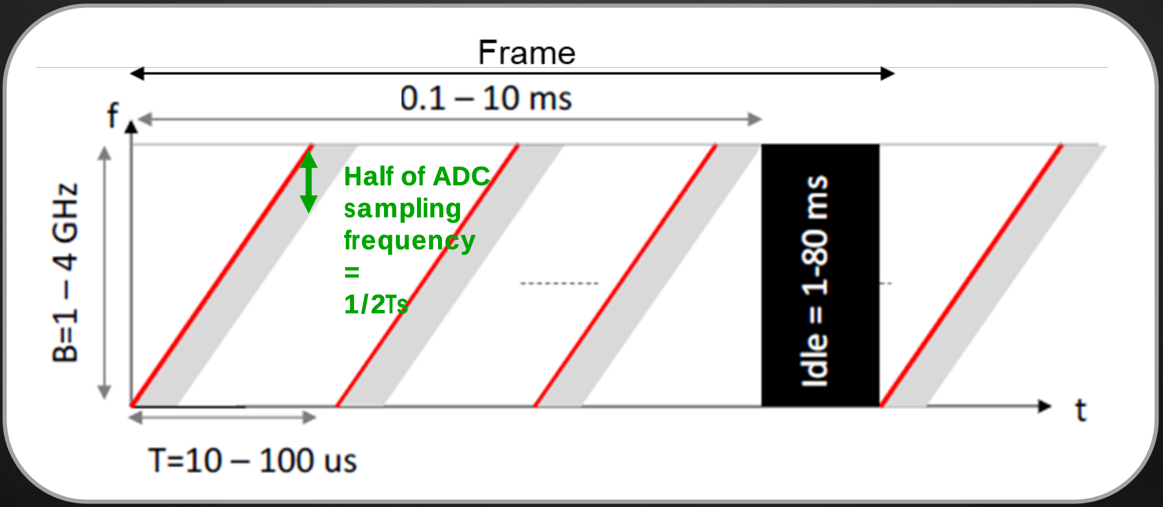
- **Radar Communications (RadCom)**
  - Single hardware for two functions



- Data communication (See-through driving, radar map dissemination, etc.)
- Removal of mutual interference

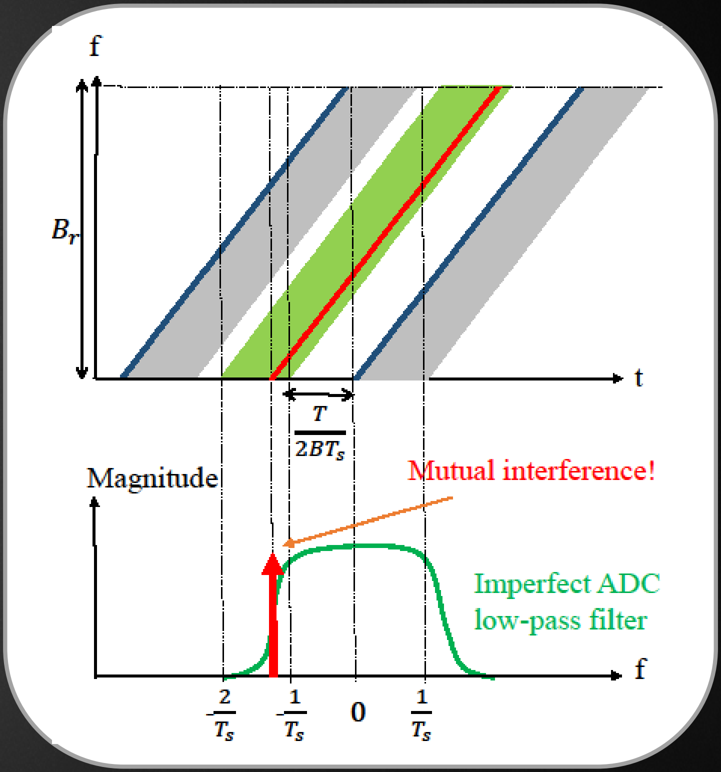
Radar Communications

- **How can RadCom remove mutual interference?**
  - Make use of idle times
  - Squeeze other radars into one chirp sequence
    - But be cautious!
    - Is it enough for **'gray regions'** not to overlap?



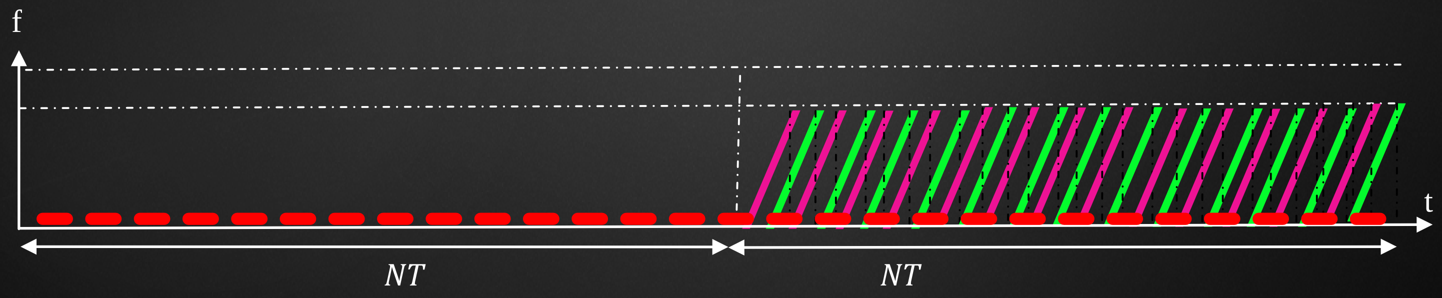
Vulnerable Period

- **Vulnerable period V:** Set of τ, given FMCW transmissions start at
  - $t = 0$ for the ego vehicle and
  - $t = \tau$ for the facing vehicle
- Imperfect ADC low-pass filters lead to mutual interference for negative frequencies also
- Counting for propagation delay, Doppler, imperfect filtering:
  - $V = \frac{2T}{BT_s}$
  - T: Chirp duration, B total bandwidth, T_s ADC sampling period



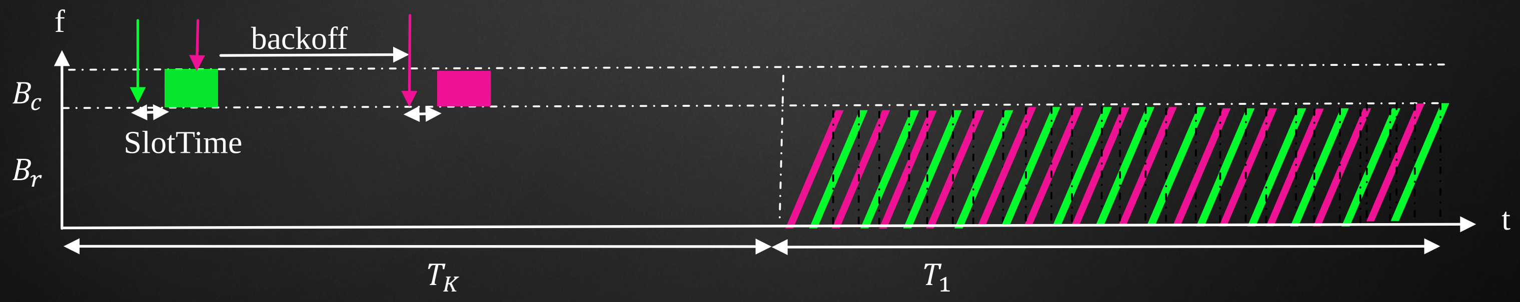
Radar Communications

- Vulnerable period:
  - $V = \frac{2T}{BT_s}$
- Extended vulnerable period:
  - $\boldsymbol{V_{ext} = 2NTV}$, N number of chirps per frame
- Probability of interference *without* Radar Communication:
  - $P_{int}^{f} = \frac{V_{ext}}{T_f}$ per frame
  - $P_{int} = 1 - (1 - P_{int}^{f})^{M}$, M facing vehicles



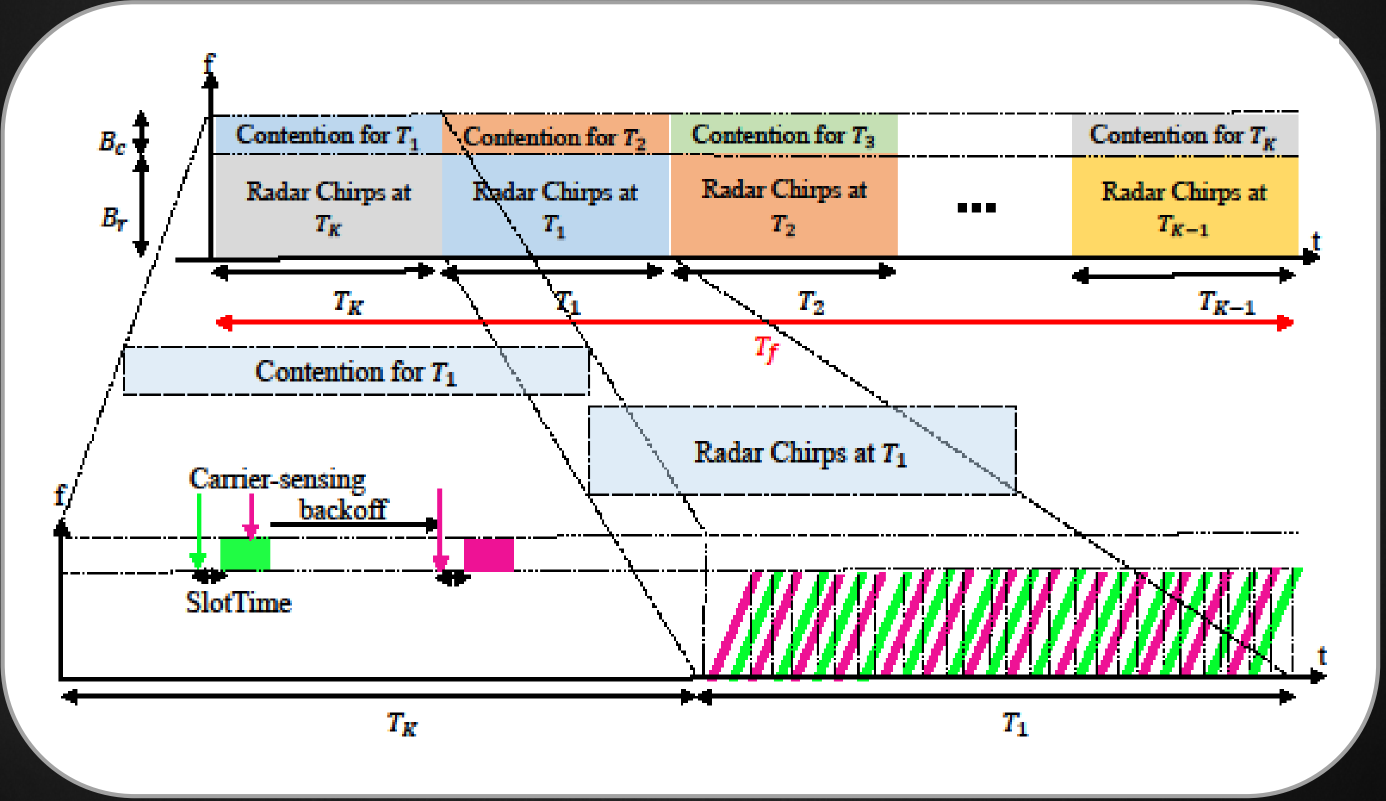
Radar Communications

- One proposal:
  - Use different frequency bands for radar (B_r) and communication (B_c)
  - Switch in time between radar and communication
- Radar Medium Access: rTDMA
  - Different radars allocated rTDMA slots
- Communication Medium Access for scheduling radars:
  - Non-persistent CSMA with backoff (no ACK)



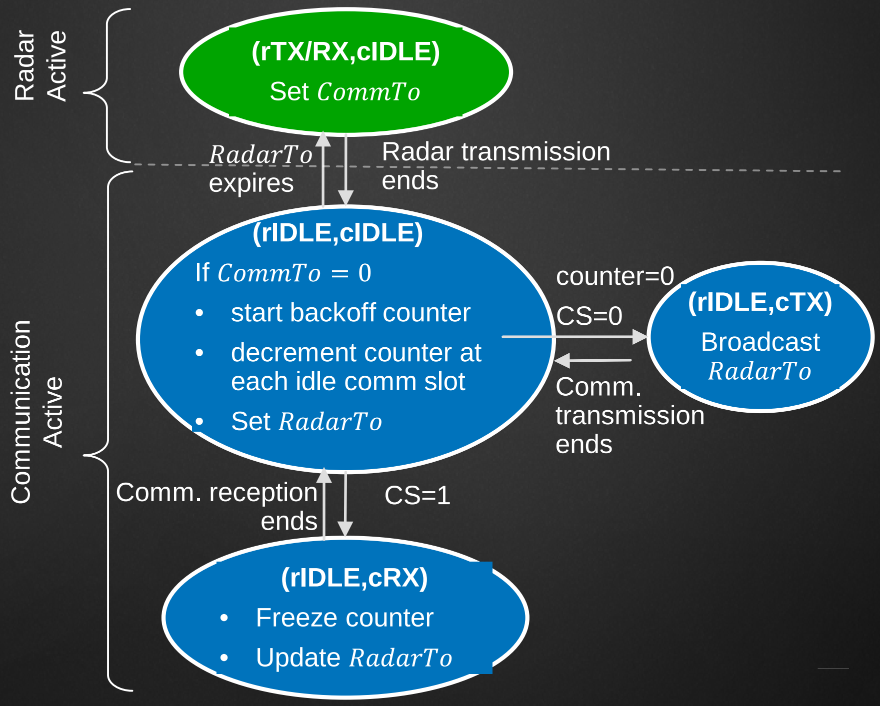
Radar Communications

- Overall time-frequency domain for the proposed RadCom



Radar Communications

- Non-persistent cCSMA:
  - Used to broadcast rTDMA slots
  - No ACKs (due to high mobility)
  - CommTO: timeout for communication
  - RadarTO: timeout for radar transmission
- State Diagram for proposed Radar Communications:



Assumptions/Parameters

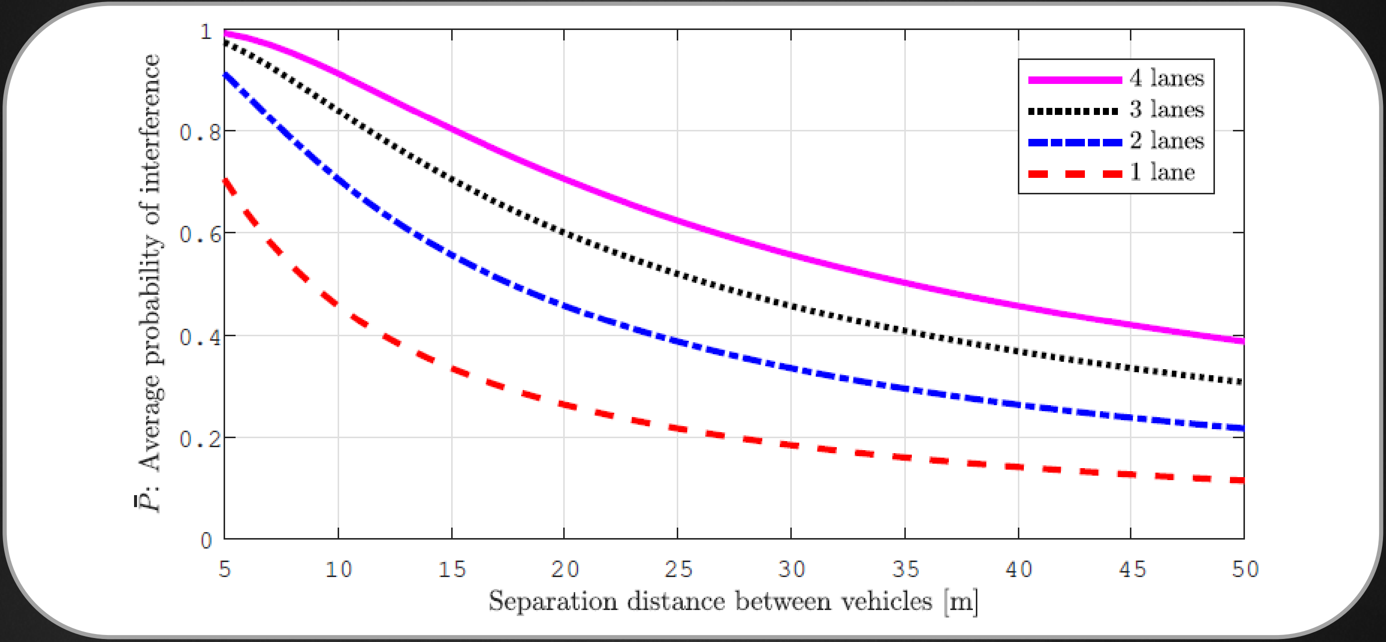
- Automotive radars
  - Homogeneous
  - FMCW
- Single-hop network

TABLE I
SIMULATION PARAMETERS.

	Parameter	Value
Radar	Chirp duration (T)	20 µs
	Frame duration (T_f)	20 ms
	Time slots per frame (K)	10
	Radar bandwidth	0.96 GHz–1 GHz
	$d_{\max}$ for $B_c = 0$	150 m
	$v_{\max}$	140 km/h
	P_{tx}	11 dB
	SNR	10 dB
	N	99
	f_c	77
	T_s	0.01 µs
	Chebyshev low-pass filter order	13
	Thermal noise temperature	290 K
	Receiver's noise figure	4.5 dB
Comm.	Communication bandwidth B_c	20 MHz,40 MHz
	Packet size (N_{pkt})	4800 Bits
	Modulation	16-QAM
	MAC	non-persistent CSMA
	SlotTime	10 µs
	Backoff window size	6

Results

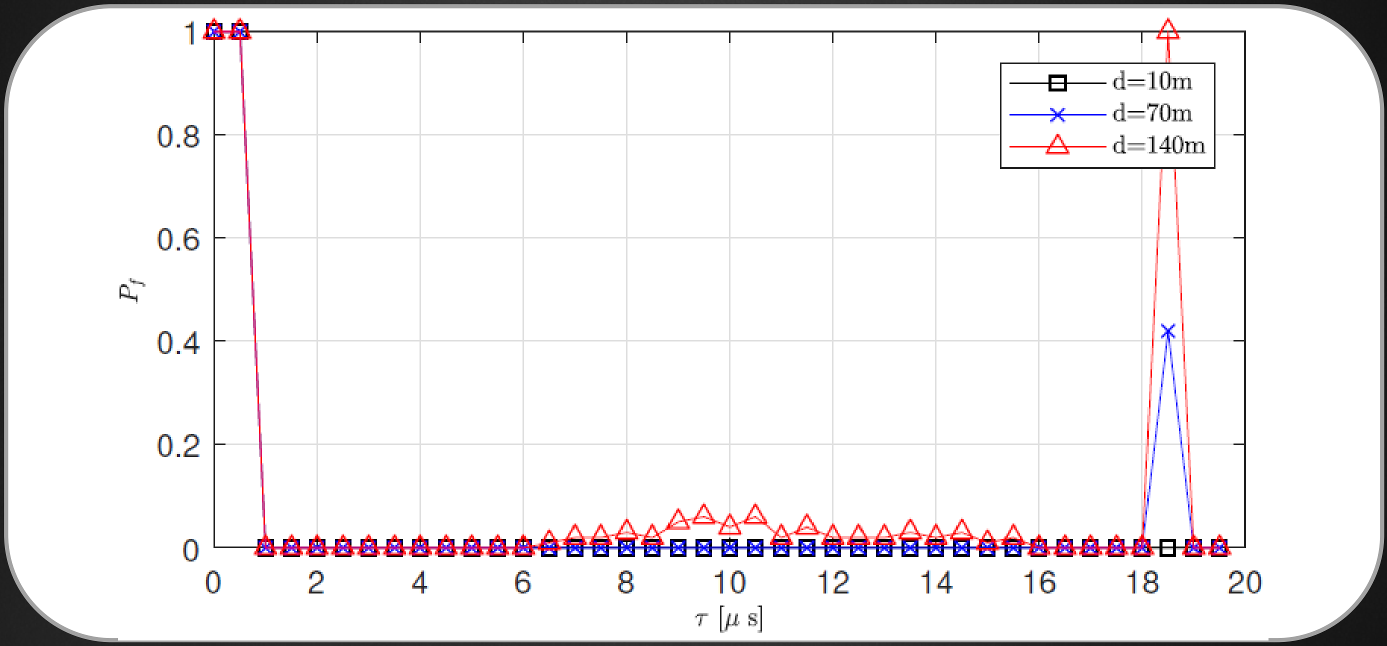
- Probability of interference without Radar Communications



- Mutual interference is not negligable for automotive radars

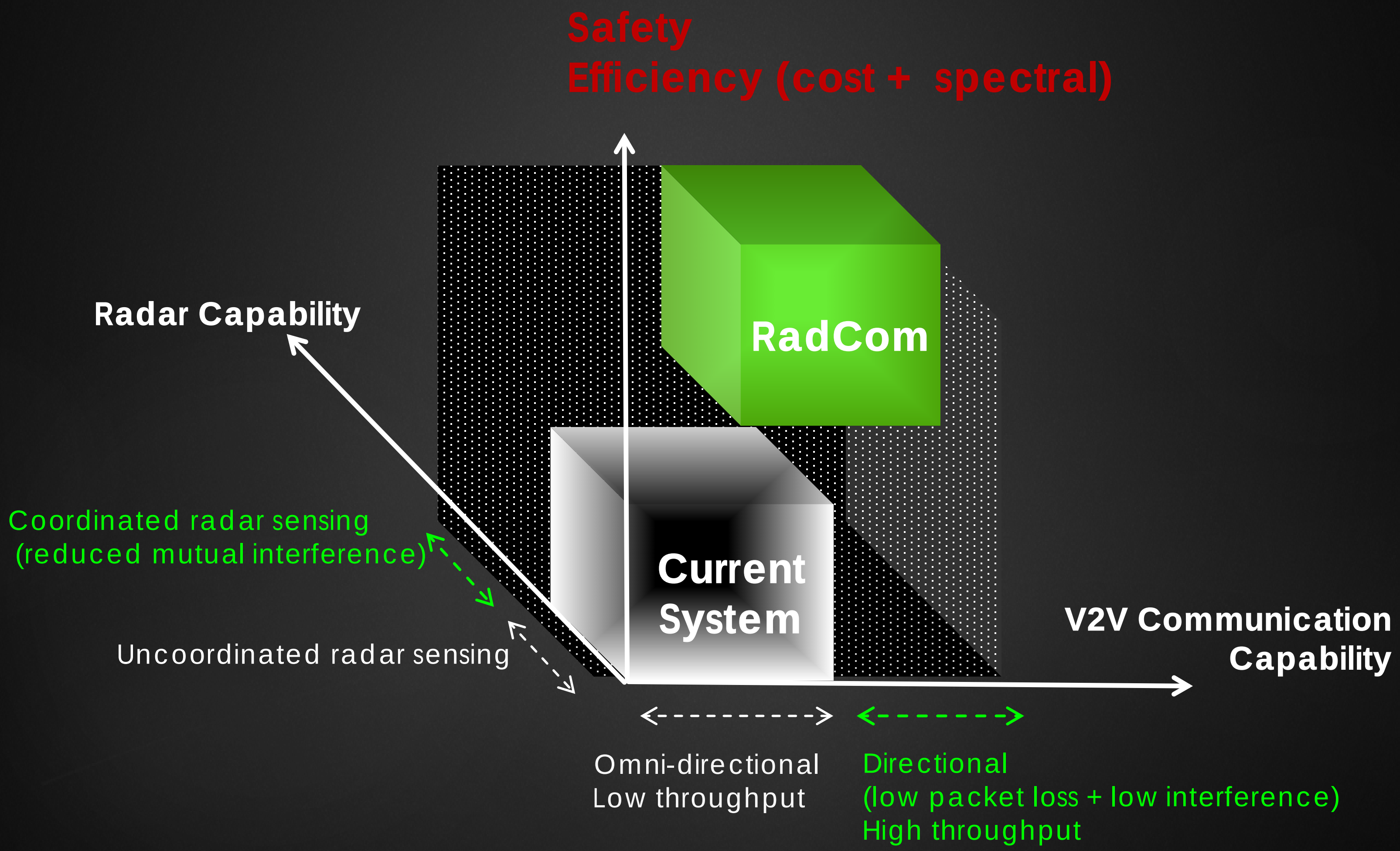
Results

- Probability of false alarm



- Vulnerable period is observed to be complaint to calculations

Conclusions



Future Work

- **FFI Project funded** (Traksäkerhet och automatiserade fordon) "Combined Radar-Based Communication and Interference Mitigation for Automotive Applications"
  - Chalmers (coordinator), Volvo Cars, Autoliv, SAAB, QamCom, Halmstad
  - 1 Jan. 2019- 31 Dec. 2020
- **Goal:** Hardware implementation of RadCom

Questions?

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