



Radar Communications: A solution for mitigating automotive radar interference

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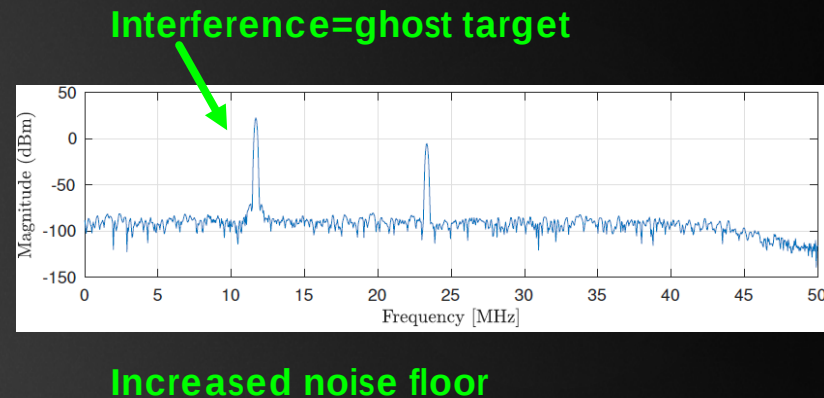
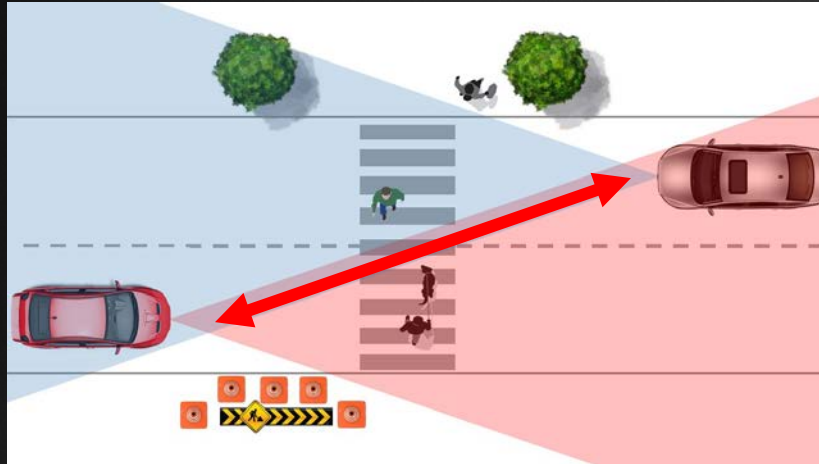
Outline



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

Problem

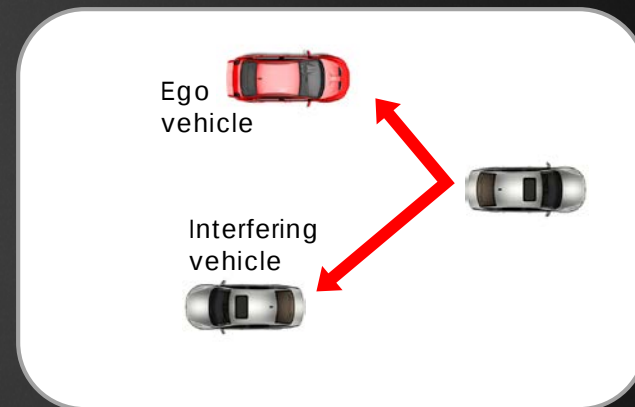
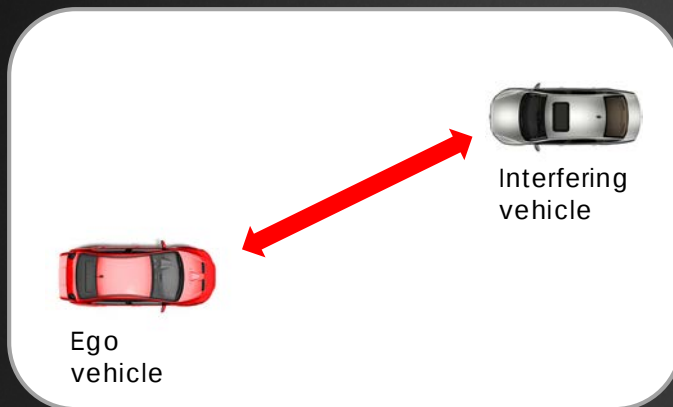
► Mutual radar interference



- 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)

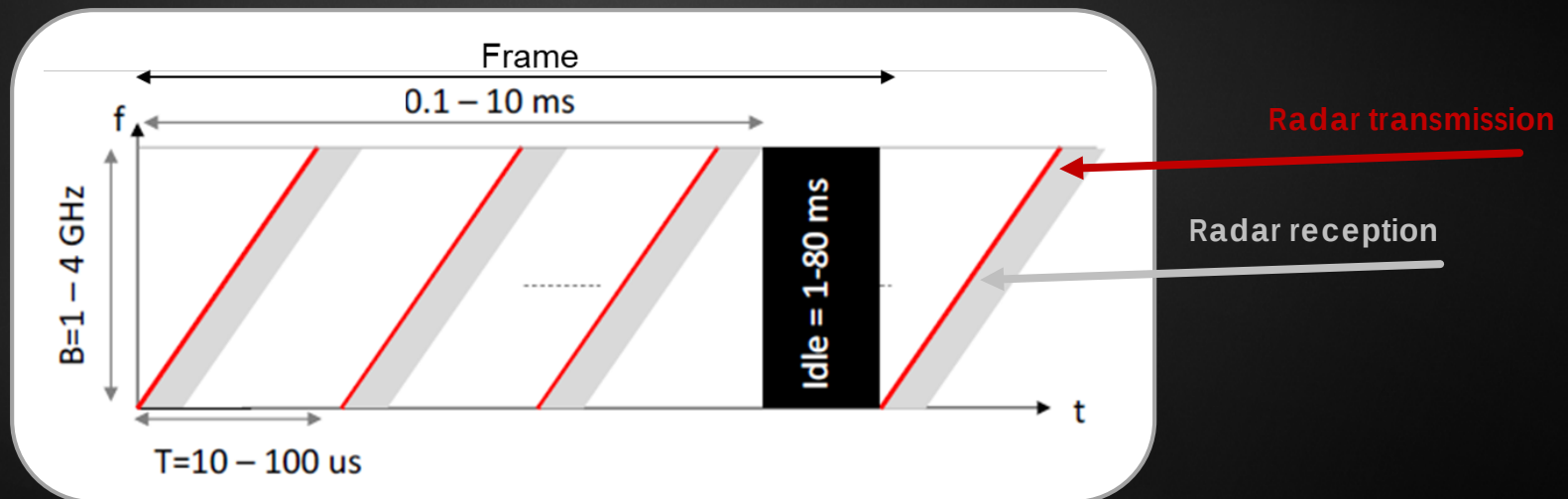


- Facing radars transmit during a 'vulnerable period'

Background

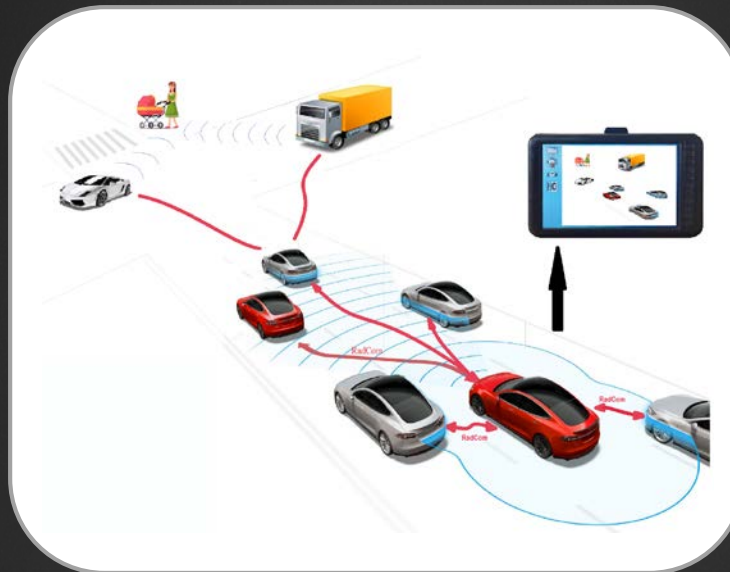
► Automotive radars

- 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

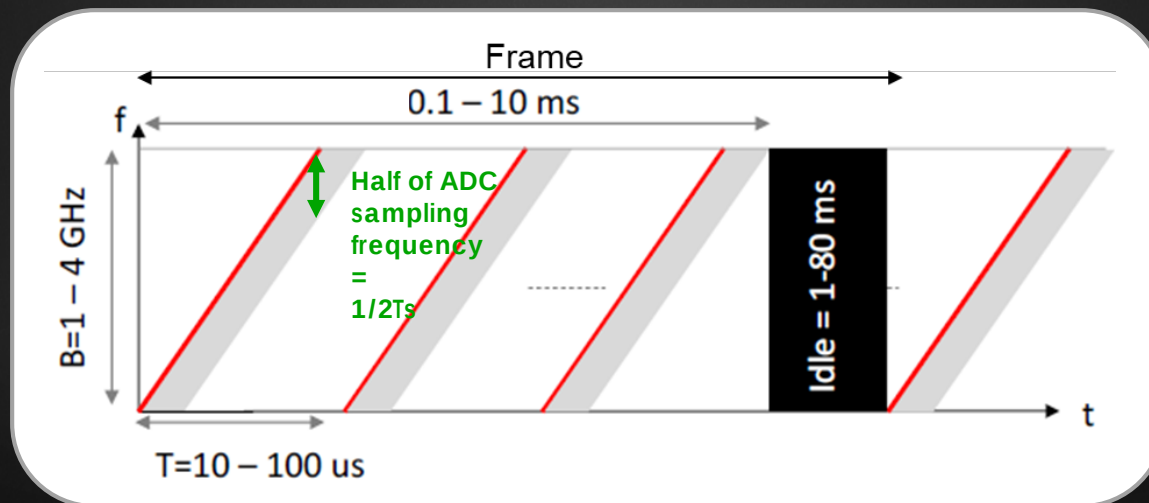
- ▶ **Radar Communications (RadCom)**
 - ▶ Single hardware for two functions



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

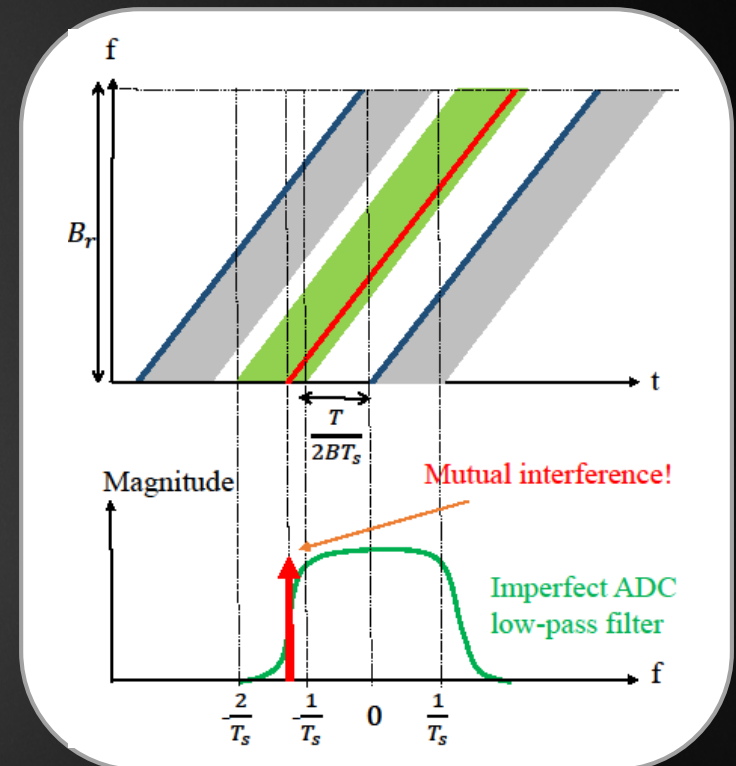
Radar Communications

- ▶ 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?



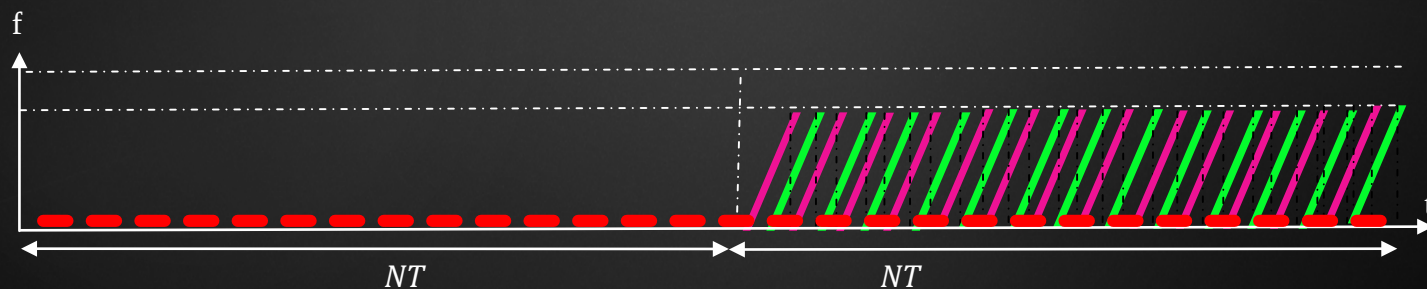
Vulnerable Period

- ▶ **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



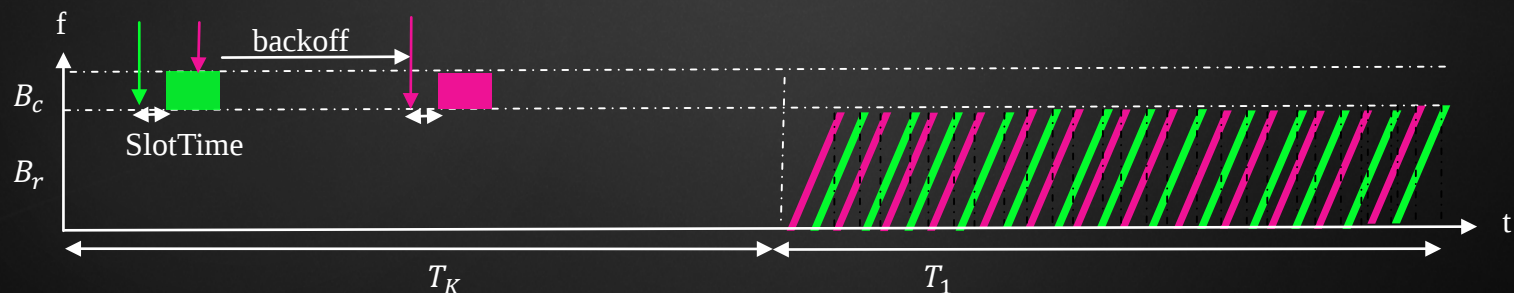
Radar Communications

- ▶ Vulnerable period:
 - ▶ $V = \frac{2T}{BT_s}$
- ▶ Extended vulnerable period:
 - ▶ $V_{ext} = 2NTV$, 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



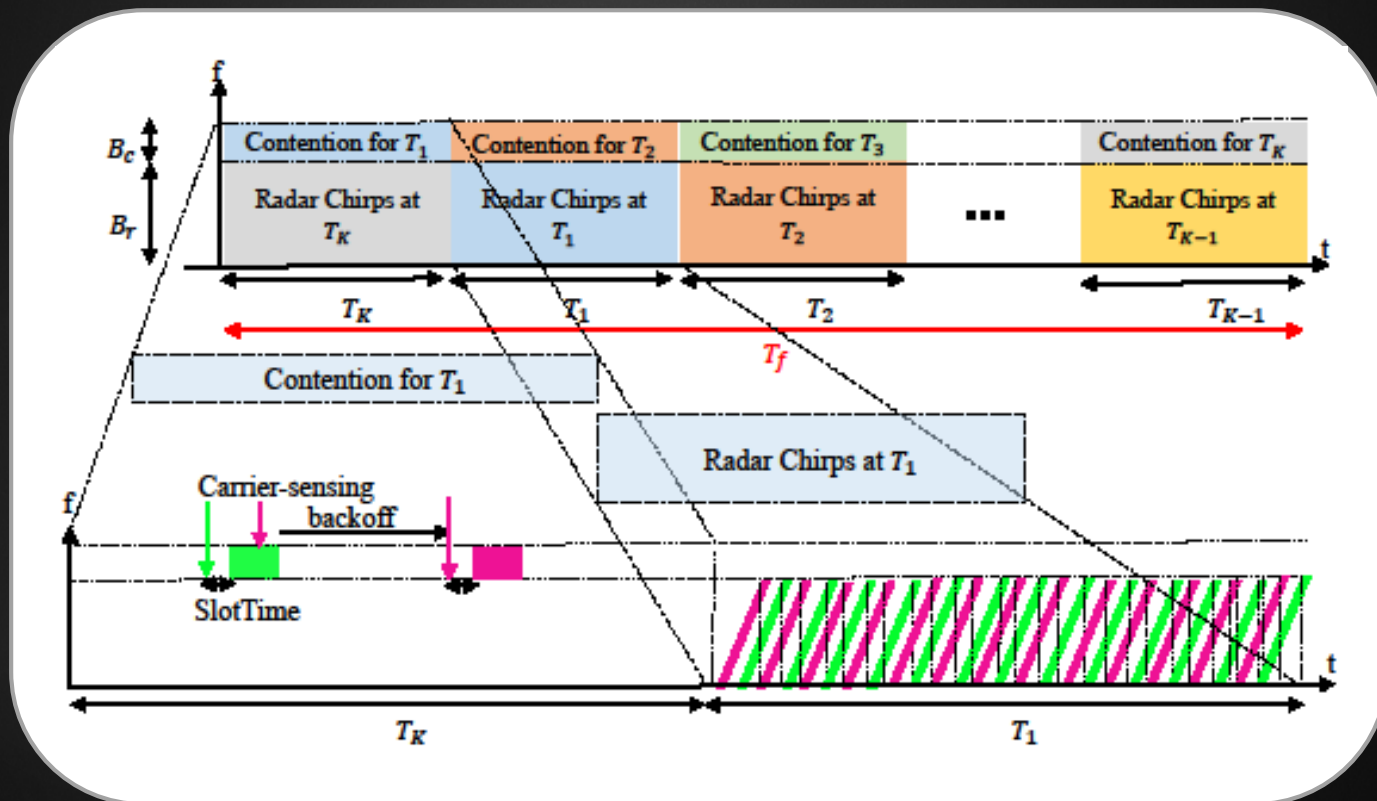
Radar Communications

- ▶ 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)**



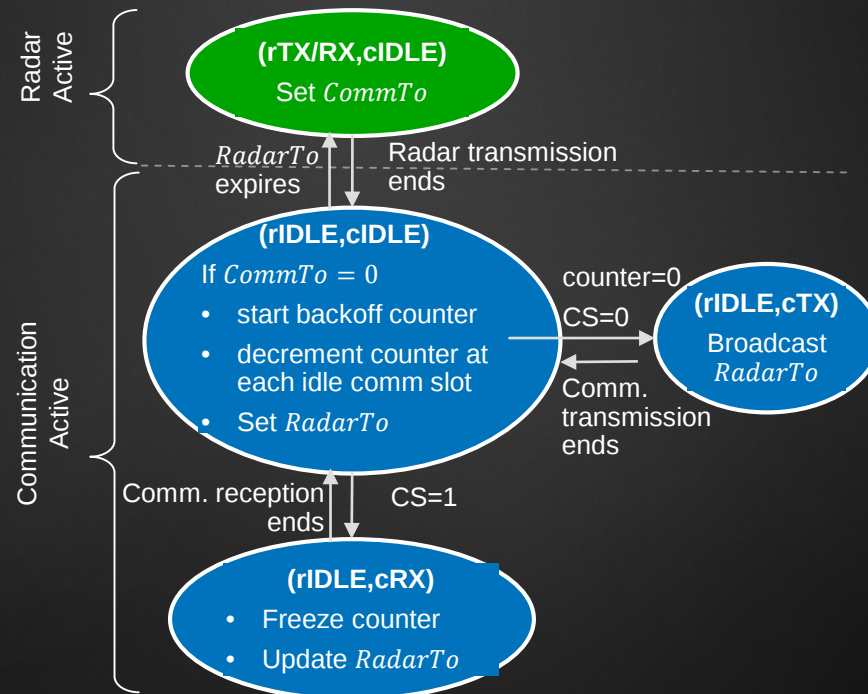
Radar Communications

- 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

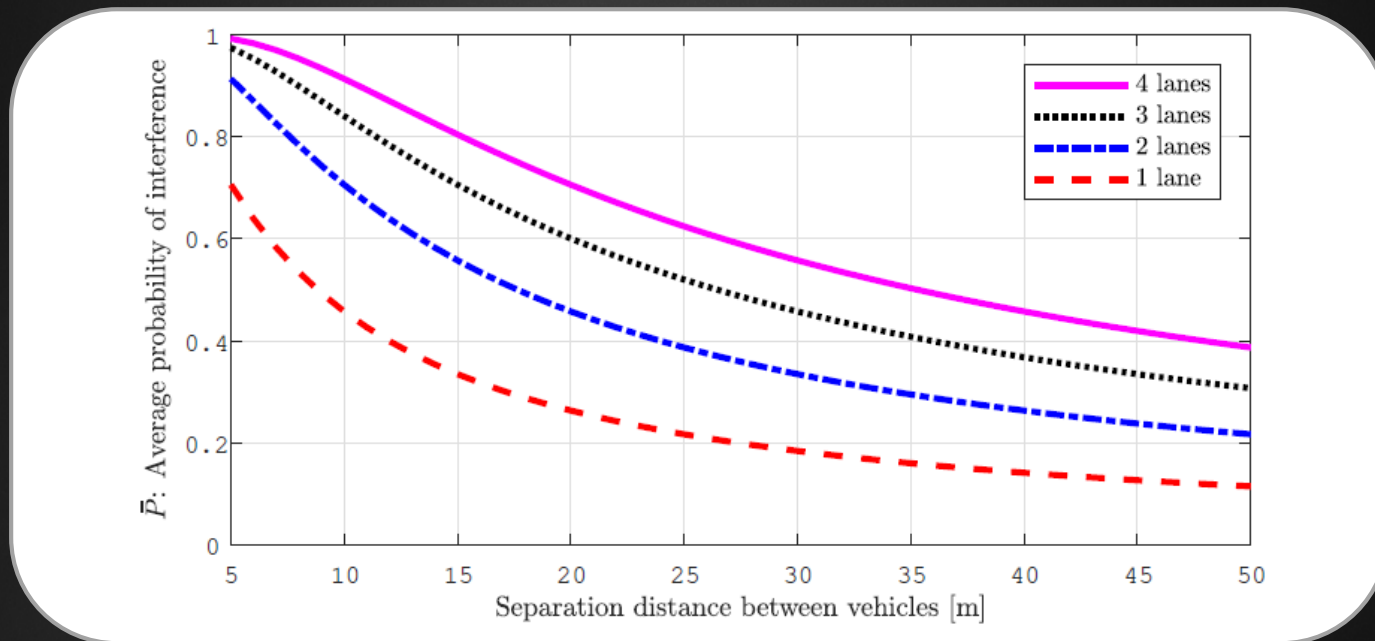
- ▶ Automotive radars
 - ▶ Homogeneous
 - ▶ FMCW
- ▶ Single-hop network

TABLE I
SIMULATION PARAMETERS.

	Parameter	Value
Radar	Chirp duration (T)	20 μ s
	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 μ s
	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 μ s
	Backoff window size	6

Results

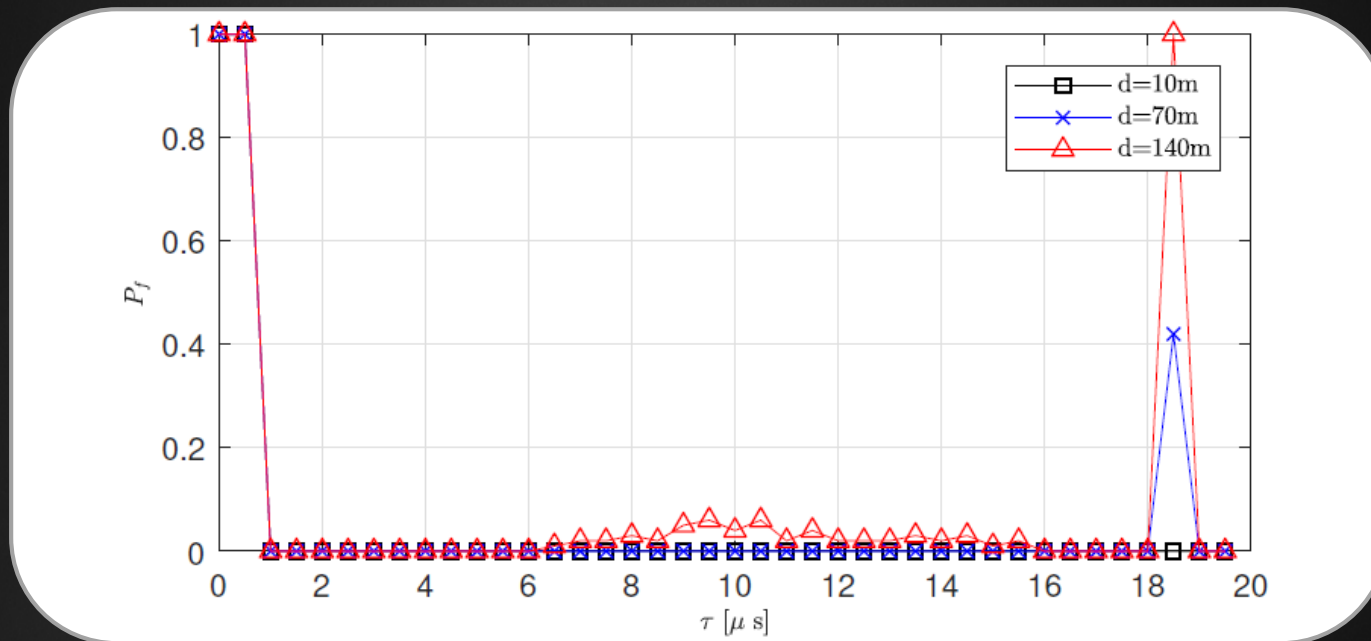
► Probability of interference without Radar Communications



► Mutual interference is not negligible for automotive radars

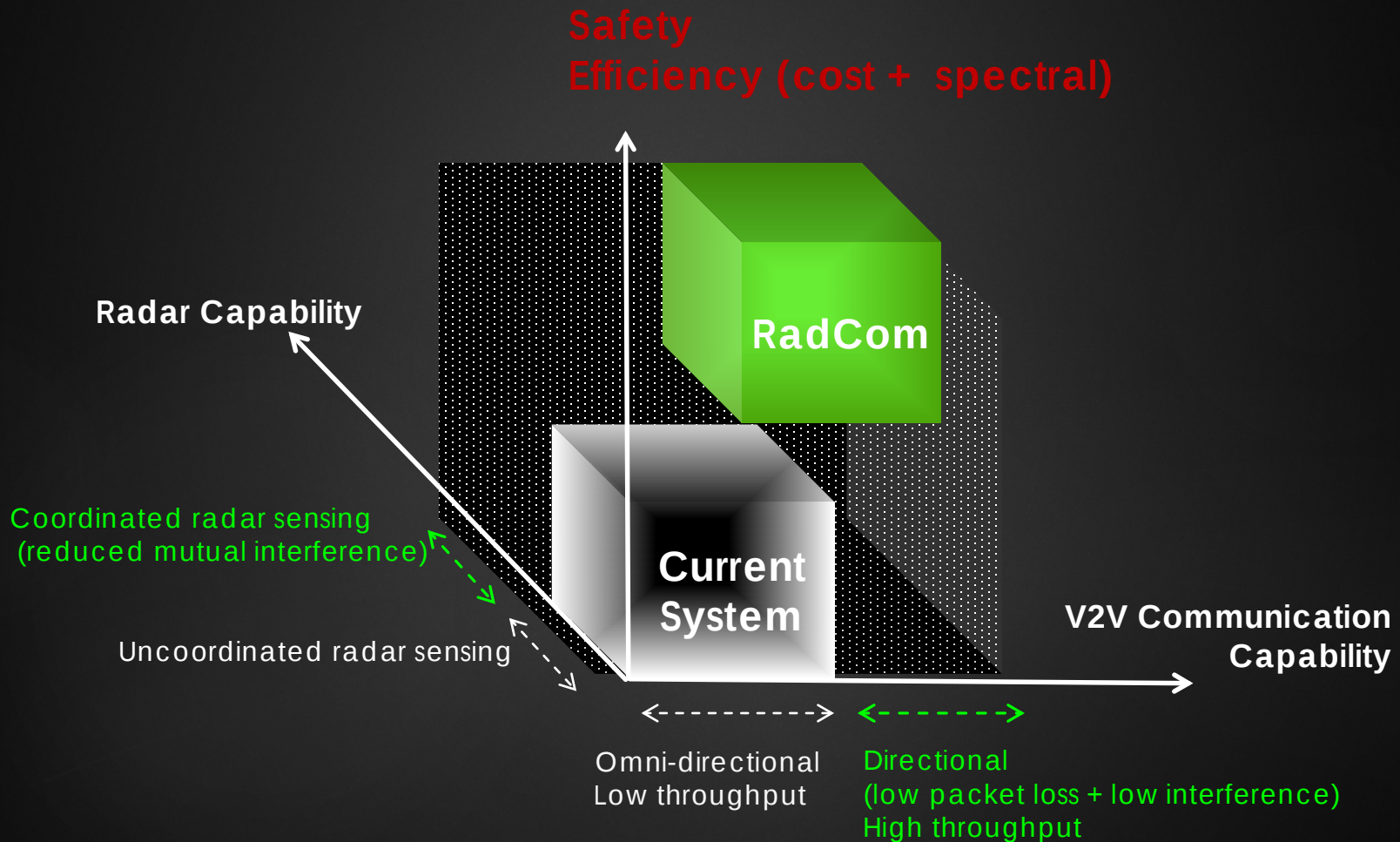
Results

► Probability of false alarm



► Vulnerable period is observed to be compliant 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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