Impact of a Truck as an Obstacle on V2V Communications in Rural and Highway Scenarios

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Contributions

- Vehicle-to-Vehicle
- Truck as obstacle
- Dynamic environment

Background

- V2V is beneficial when LOS is obstructed.
- Scattering enables reception in many cases.
- Building reliable transceivers is a challenge.
- New V2V channels models often disregard physical obstructions, except a few studies.
- Additional loss of ~10 dB has been observed previously.
- Previous studies considered single antenna - roof mounted systems or packet error rate (PER).
- Impact of OLOS on time-frequency selectivity on multi-antenna systems with diversity arrangement is yet to be investigated.

Measurement Setup

- Conducted outside the city of Lund, Sweden.
- GPS coordinates and videos were recorded from each vehicle.
- Two major measurement scenarios; rural and highway.
- LOS and OLOS measurements were performed.
- The channel transfer function $H(f,t)$ was collected for each antenna pair based on switched-array principle.

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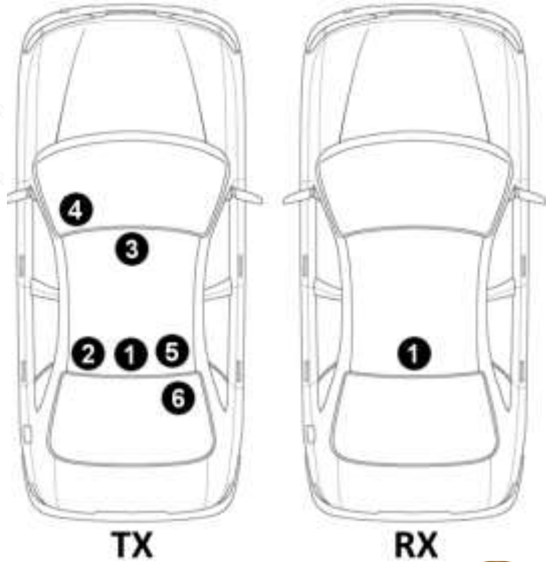
Measurement Setup

TABLE I: Measurement Parameters

Parameter	Value
Center frequency, f_c	5.75 GHz
Bandwidth, B	200 MHz
Test signal length, τ_{max}	3.2 μs
Time between snapshots, t_{rep}	268.8 μs (ST), 93 ms (LT)
Number of samples in time, N_t	65000 (ST), 120000 (LT)
Number of samples in frequency, N_f	641
Recording time, t_{rec}	18 s (ST), 563 s (LT)
Number of TX antennas	6
Number of RX antennas	1
TX antenna height	145 cm (roof), 135 cm (windshield)
RX antenna height	160 cm (roof)



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Rural Scenario

- Average speed of 70 km/h
- Reference measurements in an environment with few or no scatterers
- Major MPCs from LOS or diffraction around the truck

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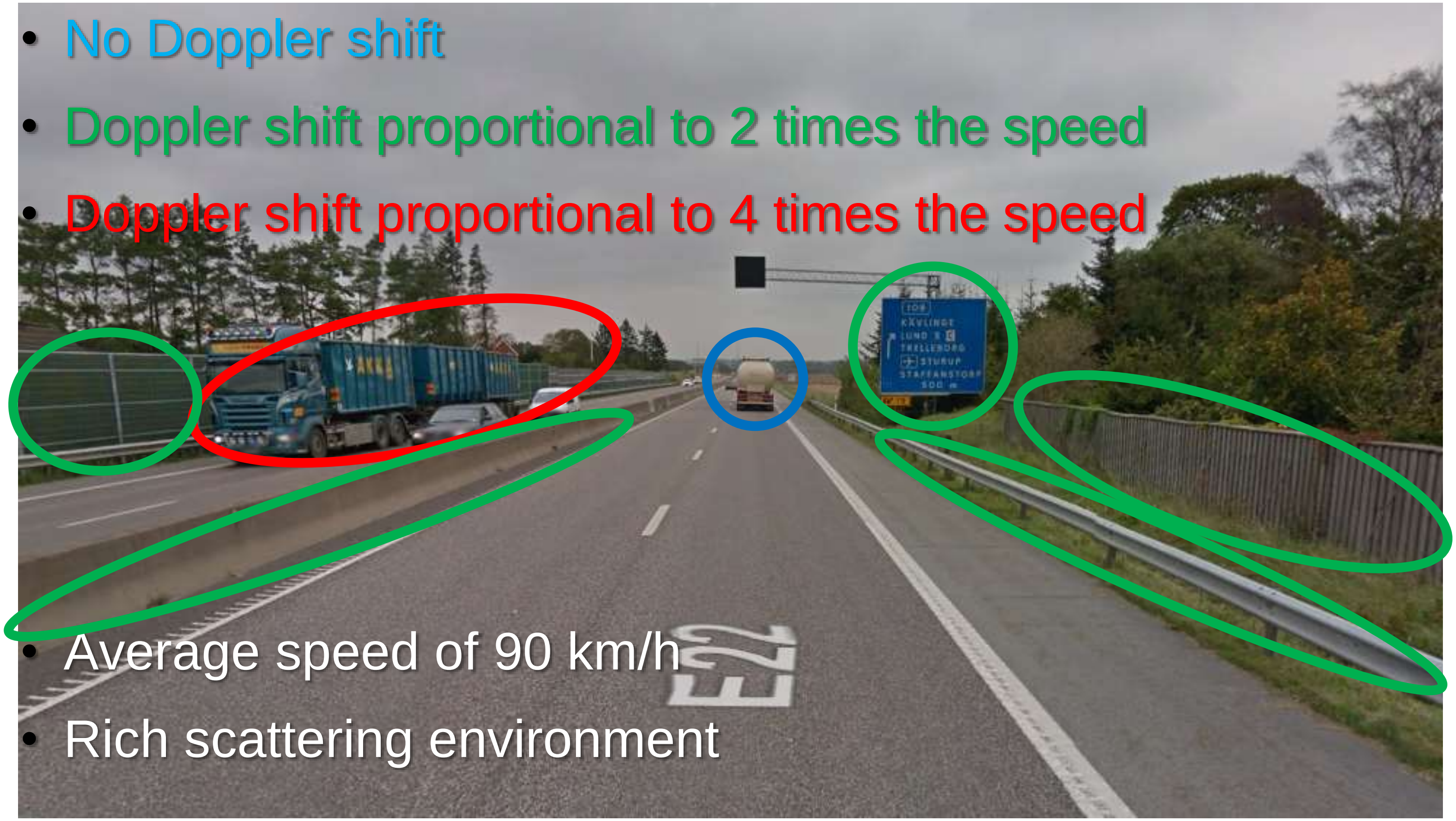
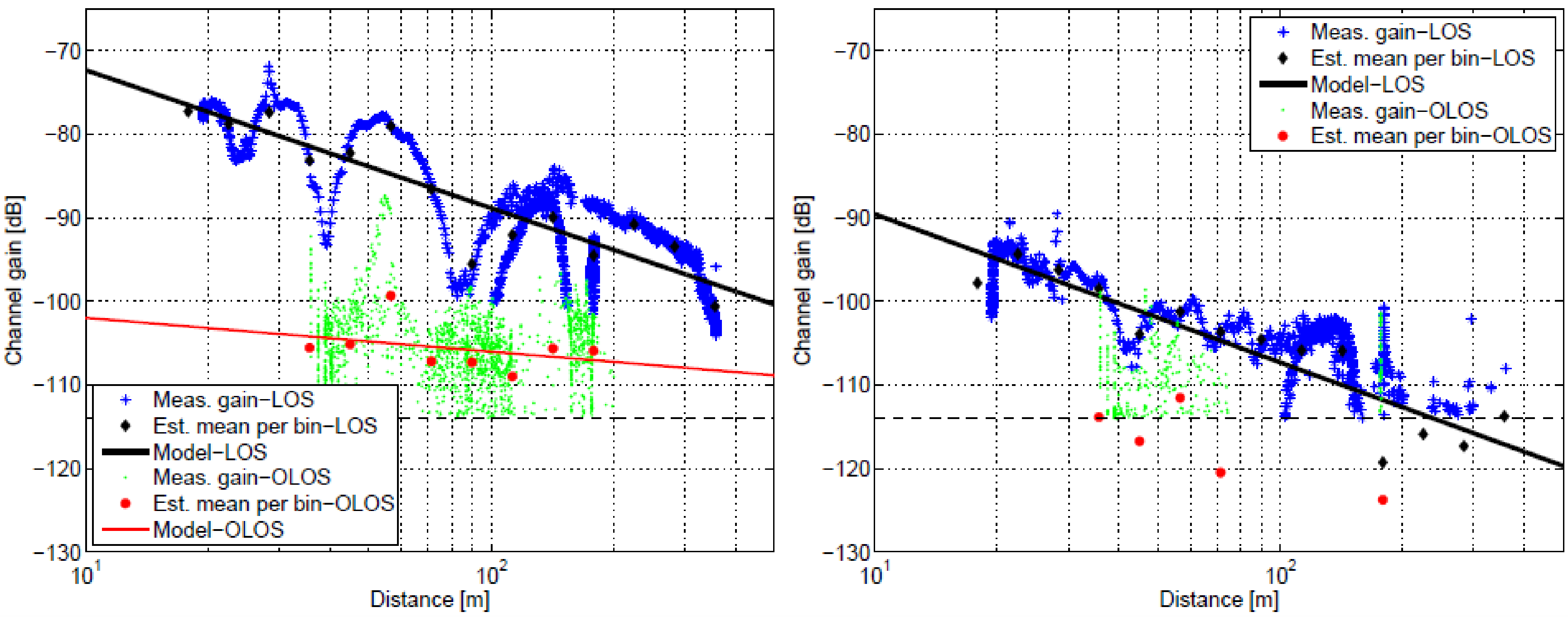
Highway Scenario



- No Doppler shift
- Doppler shift proportional to 2 times the speed
- Doppler shift proportional to 4 times the speed
- Average speed of 90 km/h
- Rich scattering environment

Pathloss



(a) Rural Scenario - Antenna 1 (b) Rural Scenario - Antenna 4

- Estimating incomplete data using the EM algorithm.
  T. Abbas et al., "Pathloss Estimation Techniques for Incomplete Channel Measurement Data" COST IC1004 10th Meeting, 2014.
- Rural scenario has higher loss for OLOS case.

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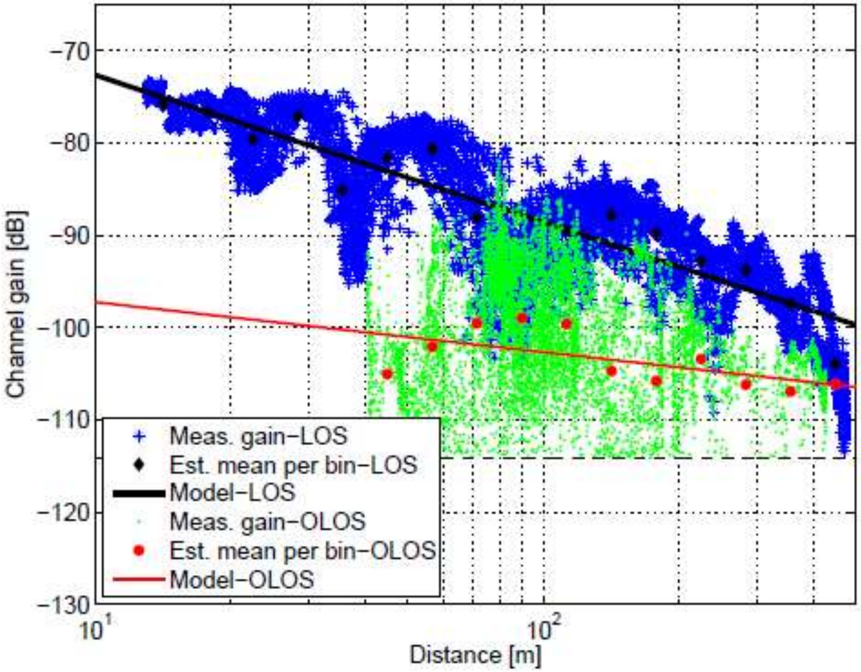
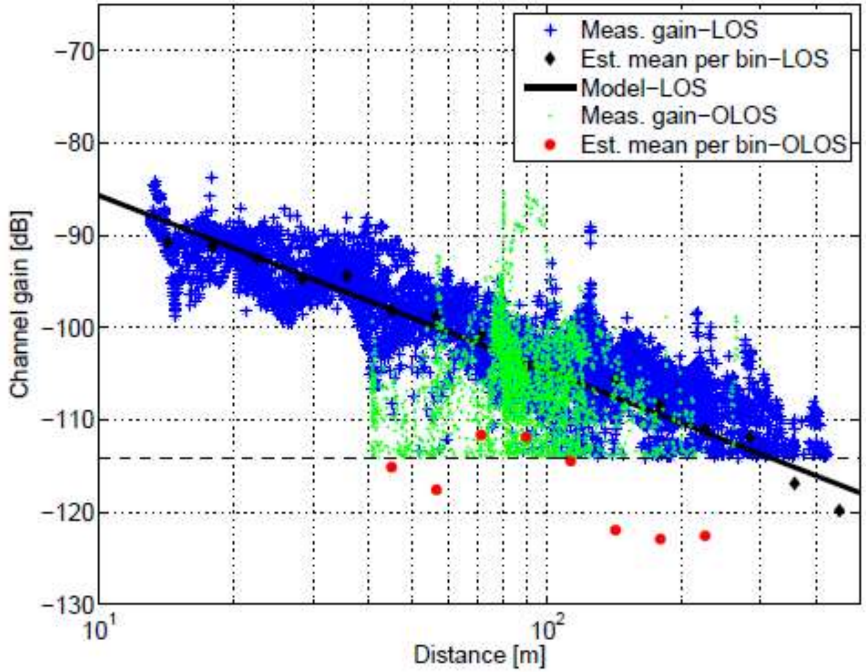
Pathloss



(d) Highway Scenario - Antenna 1



(e) Highway Scenario - Antenna 4

- Estimating incomplete data using the EM algorithm.
  T. Abbas et al., "Pathloss Estimation Techniques for Incomplete Channel Measurement Data" COST IC1004 10th Meeting, 2014.
- Rural scenario has higher loss for OLOS case.

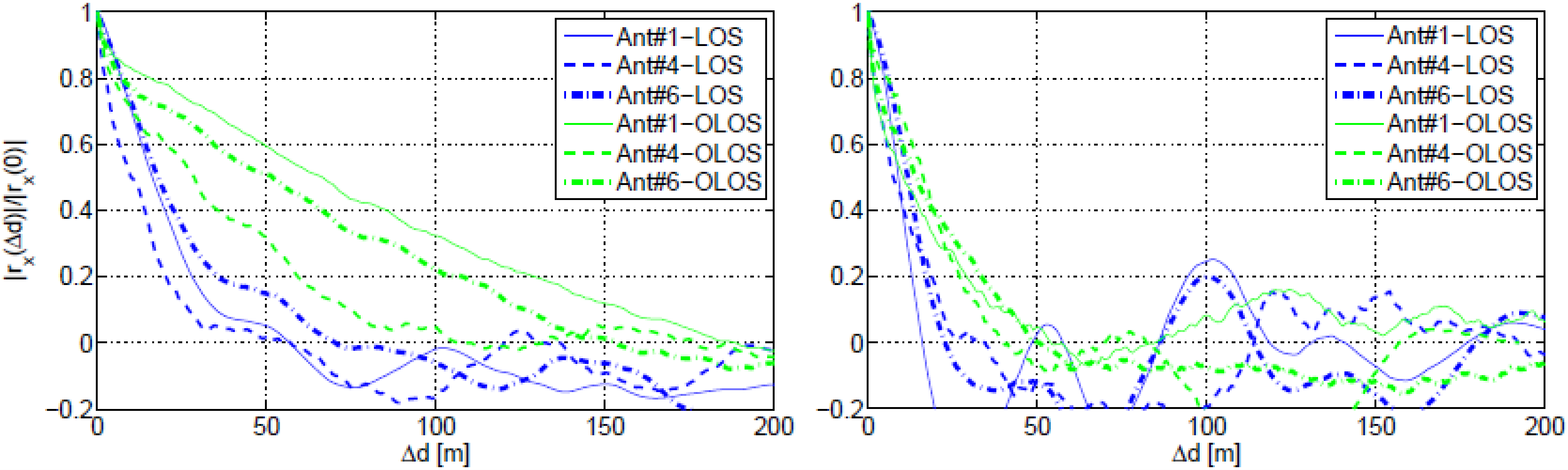
Pathloss

$$P(d) = P_{d_0} - 10nlog_{10}\left(\frac{d}{d_0}\right) + X_\sigma$$

		LOS			OLOS		
	Antenna	A1	A4	A6	A1	A4	A6
Rural	P_{d_0} [dB]	-72.3	-89.6	-68.9	-101.9	——	-95.6
	n	1.65	1.77	1.89	0.41	——	0.97
	σ [dB]	3.9	8.4	4.9	5.4	13.9	5.1
	d_c [m]	10.1	11.3	13.6	16.8	20.2	21.0
	$\mu_{\tau_{rms}}$ [ns]	8.0	8.0	8.0	23.1	23.1	23.1
	$max_{\tau_{rms}}$ [ns]	331.5	702.0	97.5	651.7	604.6	645.6
	$\mu_{\nu_{rms}}$ [Hz]	13.8	47.2	13.2	12.1	1.3	8.1
	$max_{\nu_{rms}}$ [Hz]	375.7	816.0	167.7	281.1	14.1	261.6
Highway	P_{d_0} [dB]	-72.6	-85.7	-68.0	-97.2	——	-92.1
	n	1.60	1.90	1.86	0.54	——	0.93
	σ [dB]	4.4	7.9	4.0	7.3	17.0	6.5
	d_c [m]	20.5	14.3	24.0	89.0	40.9	69.5
	$\mu_{\tau_{rms}}$ [ns]	9.9	9.9	9.9	24.7	24.7	24.7
	$max_{\tau_{rms}}$ [ns]	304.6	595.2	388.6	620.3	545.8	581.0
	$\mu_{\nu_{rms}}$ [Hz]	24.8	45.2	28.9	44.2	117.1	52.9
	$max_{\nu_{rms}}$ [Hz]	353.7	534.3	361.1	789.9	737.4	712.6

Large Scale Fading

$$r_x(\Delta d) = E\{X_\sigma(d)X_\sigma(d+\Delta d)\}$$
$$r_x(\Delta d) = e^{-|\Delta d|/d_c}$$



(b) Highway scenario. (a) Rural scenario.

Shadowing Loss

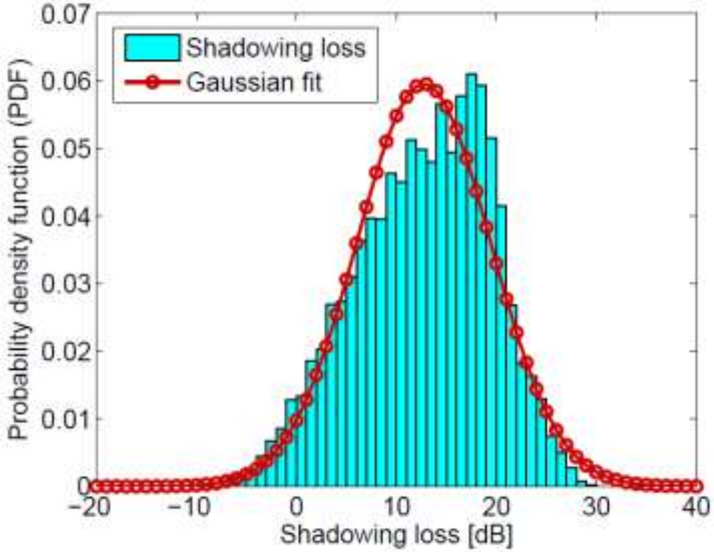


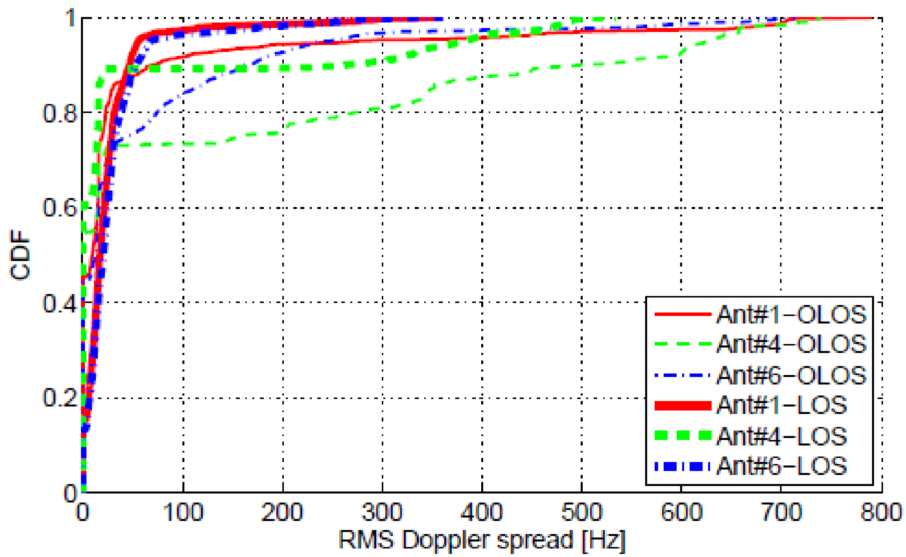
Fig. 5: Shadowing loss due to the truck for antenna 1 in the highway scenario.

TABLE II: Shadowing Loss, $L_{shadow} \sim \mathcal{N}(\mu_{loss}, \sigma^2_{loss})$

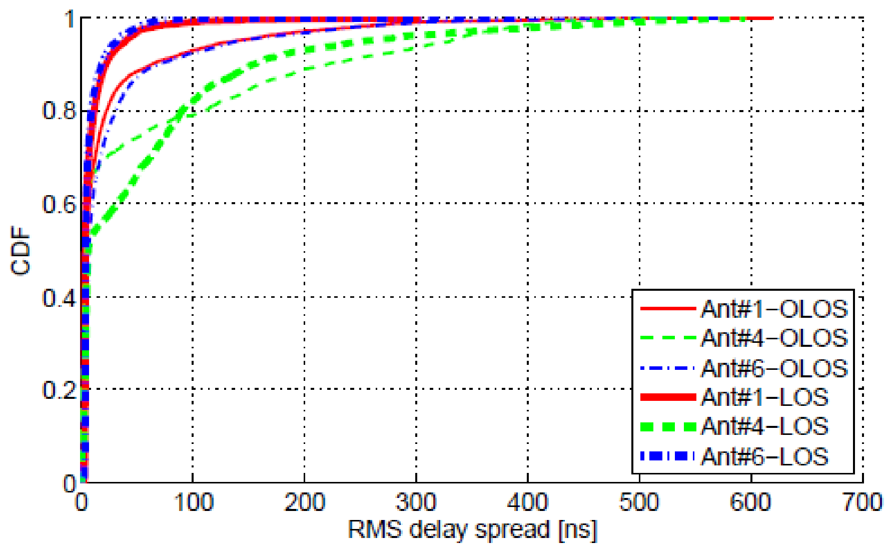
	Rural			Highway		
Antenna	A1	A4	A6	A1	A4	A6
μ_{loss} [dB]	11.9	10.0	8.9	12.7	10.7	10.8
σ_{loss} [dB]	5.2	6.2	5.0	6.7	6.0	6.0

RMS Delay and Doppler Spreads

- Both RMS Doppler and Delay spreads increase for the OLOS case.
- Front antenna (4) behaves differently due to shadowing from the car body which changes the antenna pattern.



(b) RMS Doppler Spread



(a) RMS Delay Spread

Summary

- Truck as a obstacle in a highly dynamic environment.
- Switched array 1x6 SIMO measurements with RUSK LUND channel sounder.
- 3 different antenna placements were considered; front, roof and rear.
- Pathloss was modeled using log-distance power law.
- Large Scale Fading was modeled as a zero-mean Gaussian variable. Spatial auto-correlation was shown.
- RMS delay and Doppler spreads were given. Dispersion in both domains increased for the OLOS case.
- **Additional losses of 12 dB and 13 dB for rural and highway scenario respectively, due to truck blockage.**

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