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Millimeter-wave channel measurement and modeling at USC

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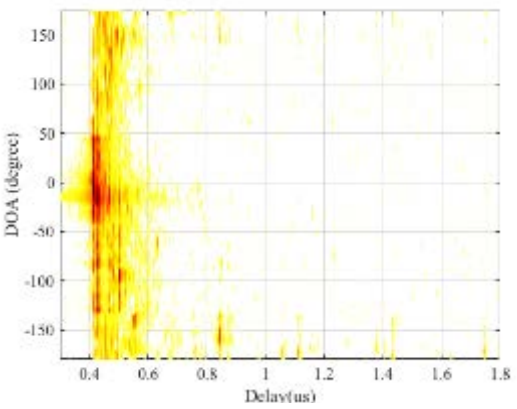
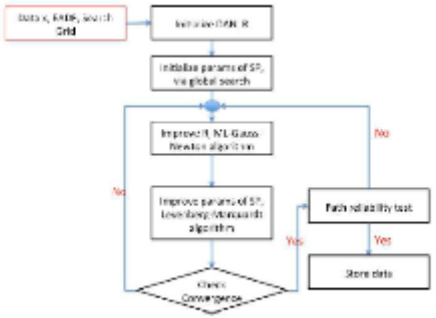
About the WiDeS group

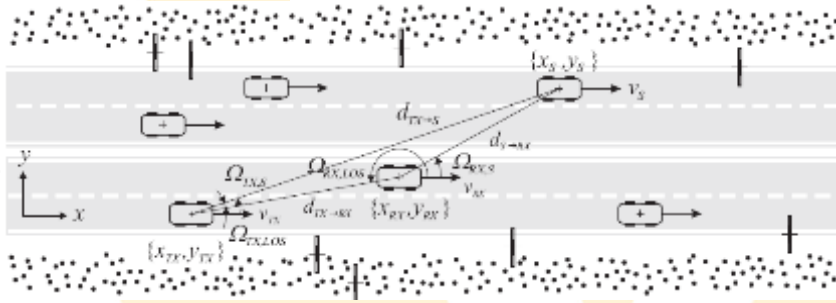
- "Bridge the chasms"
  - Communication Theory vs. Antenna/Propagation
  - Theory/Simulation vs. Experiment
  - Academic vs. industrial/standardization
- Main research topics:
  - Propagation channel measurement and modeling
  - Wireless system design
    - Multi-antenna systems
    - Ultrawideband localization and communication
    - Wireless Video
  - Interaction between channels and systems
    - Can't design a good system without understanding the channel
    - Can't measure/model the channel in a meaningful way without understanding the systems operating over it

Components of channel research

- Building and calibrating channel sounders
  - Mm-wave sounder
  - MIMO sounder for device-to-device and vehicle-to-vehicle
  - Ultrawideband (0 - 10 GHz) distributed MIMO sounder
  - 2-15 GHz SISO sounder (Extendable to higher frequencies)
  - Wideband (500 MHz) massive MIMO sounder @ 2.5 and 5 GHz
  - Calibration in own anechoic chamber
  - Careful planning of measurement campaigns is critical
- Designing extraction algorithms
  - Use of high-resolution parameter extraction (10x more accurate)
    - Rimax for single-snapshot
    - Extended Kalman Filters for tracking
  - Clustering algorithms as basis for models
- Creating channel models
  - Based on double-directional or GSCM approaches
  - Constant innovation needed to incorporate new effects
  - Close interaction with standardization







ALL COMPONENTS INTERACT

The USC mm-wave sounder

- Joint work with Samsung
- Electronically switched beam
- Enables real-time, dynamic measurements with directional resolution
- Enough phase stability for high-resolution evaluation
- 160 dB dynamic range

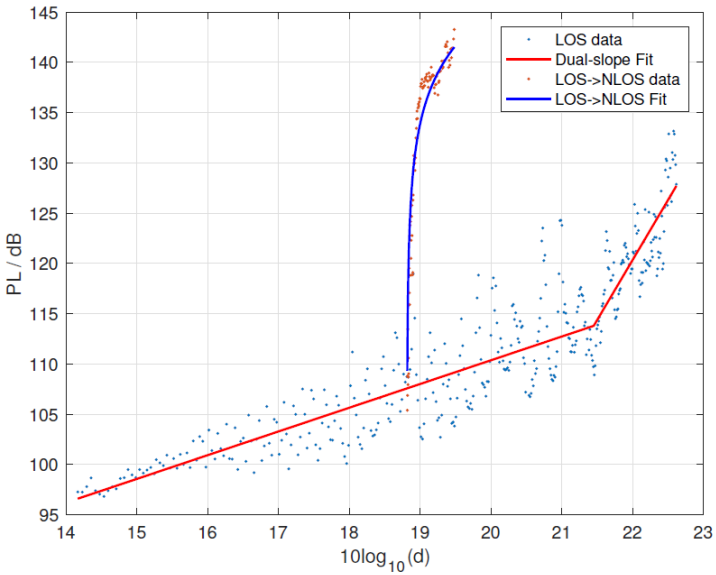
Hardware Specifications	
Center Frequency	27.85 GHz
Instantaneous Bandwidth	400 MHz (max 1 GHz)
Antenna array size	8 by 2 (for both TX and RX)
Horizontal beam steering	-45 to 45 degree
Horizontal 3dB beam width	12 degrees
Vertical beam steering	-30 to 30 degree
Vertical 3dB beam width	22 degrees
Horizontal/Vertical steering steps	5 degrees
Beam switching speed	$2\mu s$
TX EIRP	57 dBm
RX noise figure	$\leq$ 5 dB
ADC/AWG resolution	10/15-bit
Data streaming speed	700MBps
Sounding Waveform Specifications	
Waveform duration	2 μs
Repetition per beam pair	10
Number of tones	801
Tone spacing	500 kHz
PAPR	0.4 dB
Total sweep time[1]	14.44 ms (min 1.44ms)

[Bas et al. 2017]

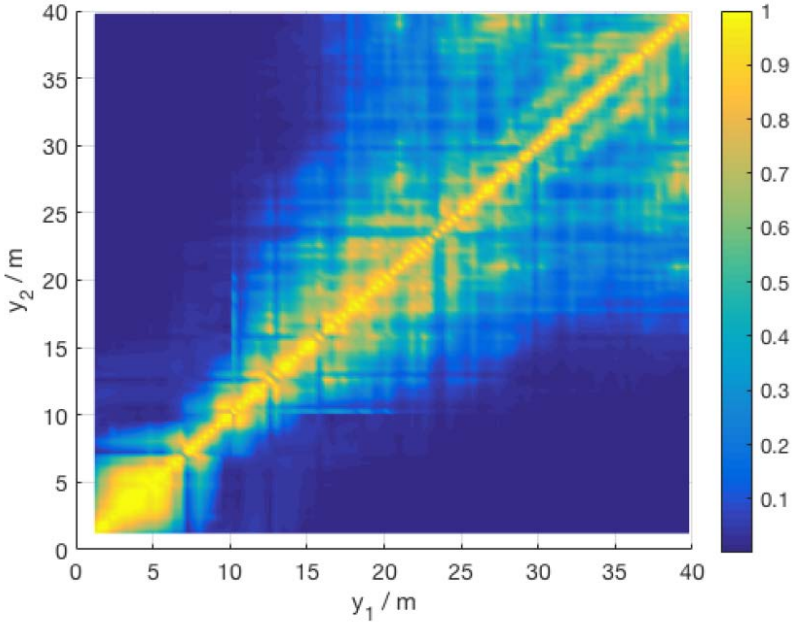
Measurement of stationarity region

- Exploit possibilities of dynamic sounder;
- 29 million impulse responses in a few hours

Pathloss/shadowing



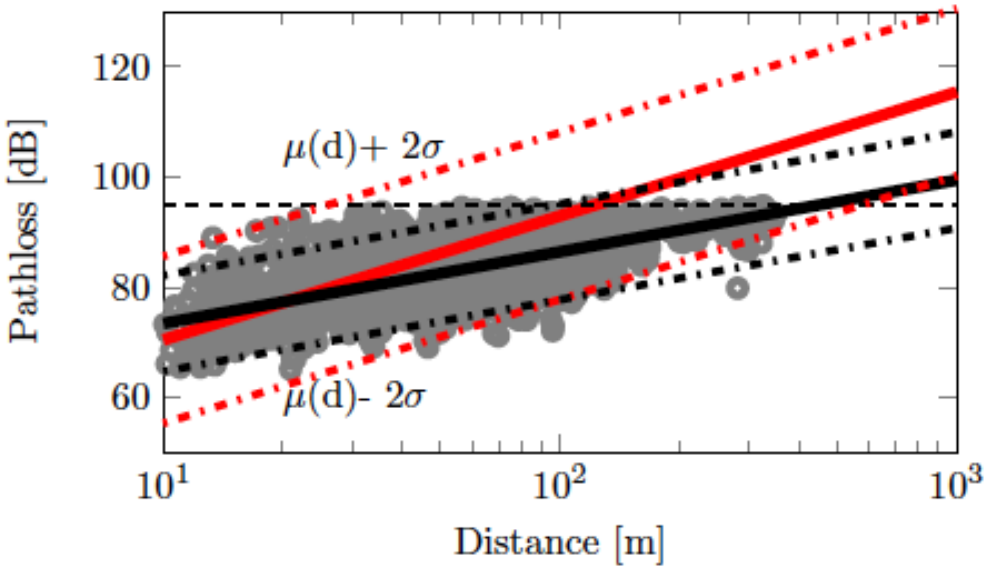
Collinearity of PDP



[Wang et al. 2017]

Pathloss extraction pitfalls

- Measurements
  - Selection bias: when only measurement locations are used where we can get signal
  - Leads to underestimation of pathloss coefficient
  - Compensate by model for *truncated* pathloss

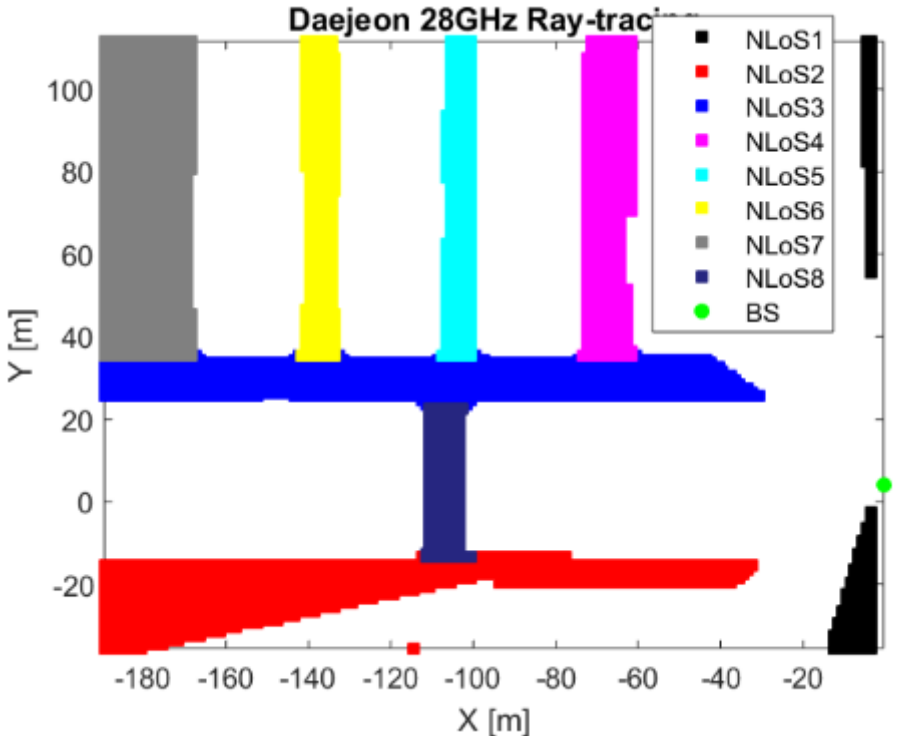


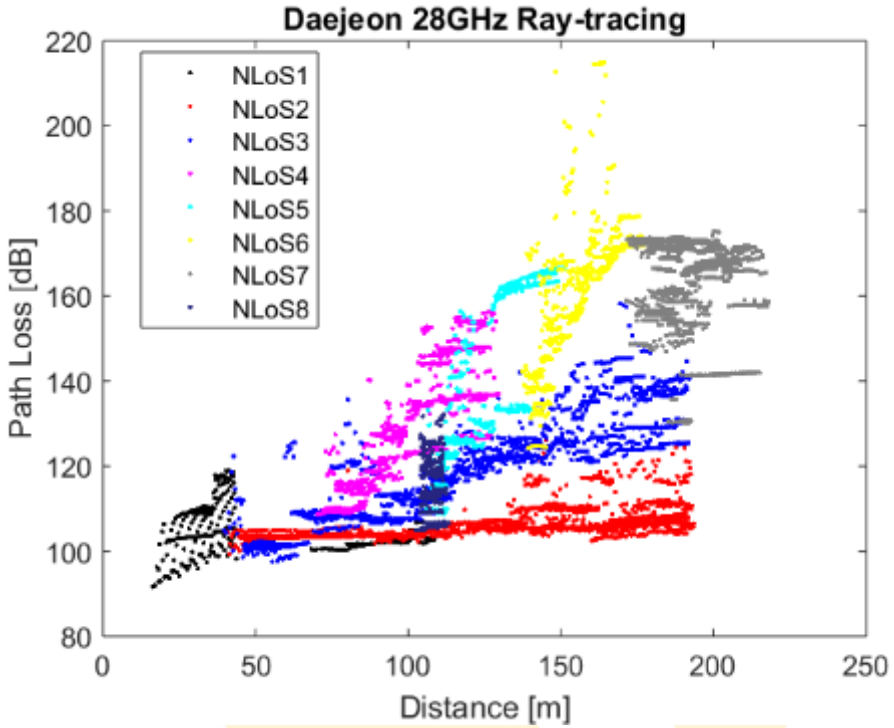
	$\hat{n}$	$\hat{\sigma}$
ML	2.2	7.6
OLS	1.3	4.4

[Gustafsson 2014]

Impact of street canyon

- Cause for spreading of pathloss different streets have different slopes





[Molisch et al. 2016]

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