Project: IEEE P802.15 Working Group for Wireless Personal Area Networks

Submission Title: [Propagation Model Using Circular Polarized Antennas]
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Abstract: [Update of activities in the channel modeling sub-group and call for participation]

Purpose: [Contribution to 802.15 TG3c conference call on channel model]

Objective & Motivation

Objective

Develop a channel model for pulse transmission in support of applications in office and residential environments

Motivation

Reduction of multipath simplifies system design for high data rate applications using circular polarized directional antennas

Advantages of Circular Polarization

Summary of Manabe and Sato's Work [2]

A

Estimated RMS Delay Spread

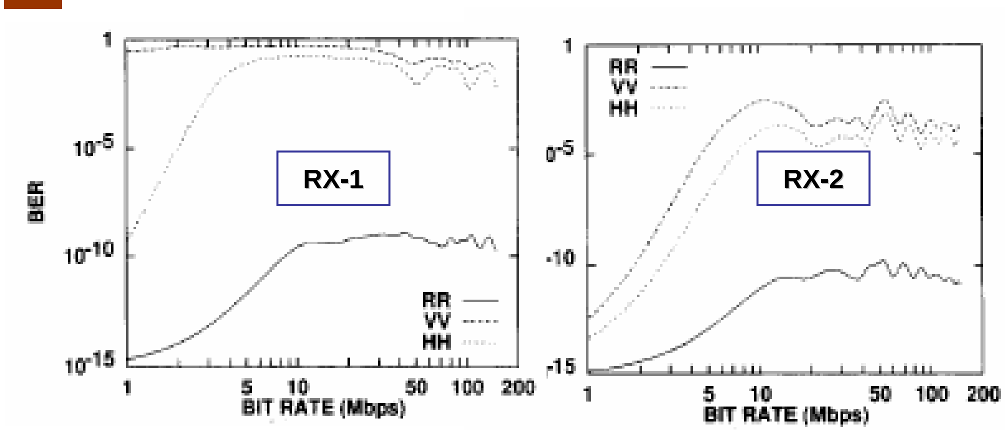
Rx Location	Vertical	Horizontal	Right Hand
RX-1	11.02 ns	9.96 ns	5.66 ns
Rx-2	11.08 ns	10.07 ns	4.68 ns

B

Reported that the circular polarization suppressed multipath up to 30 dB.

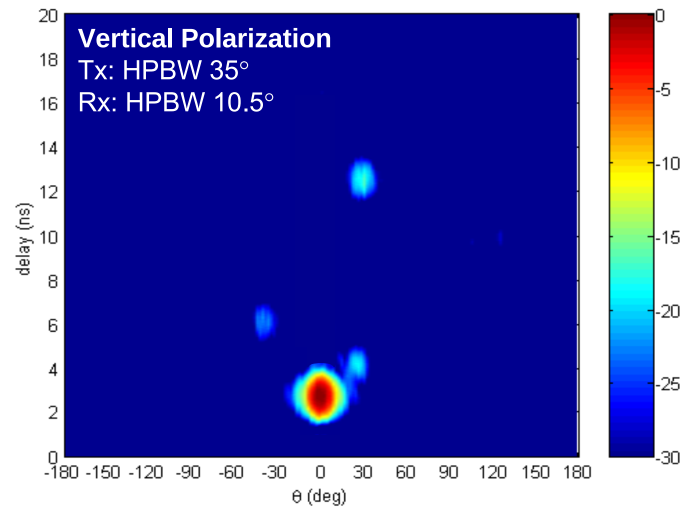
C

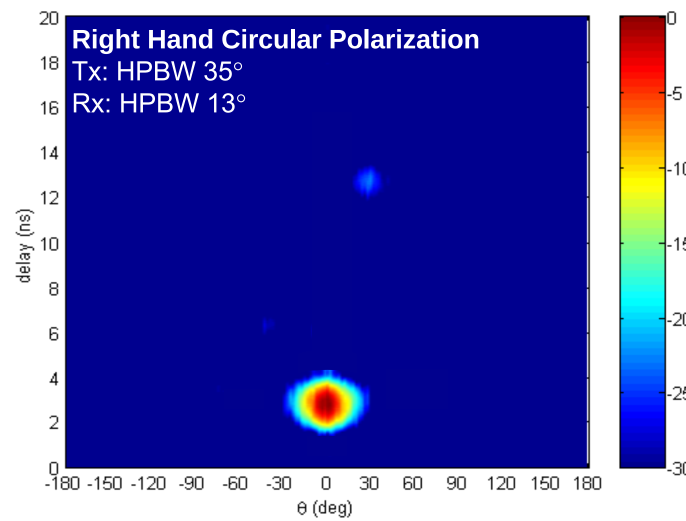
Dependency of BER on Polarization



Estimated for 150 Mbps BPSK transmission with SNR of 15 dB

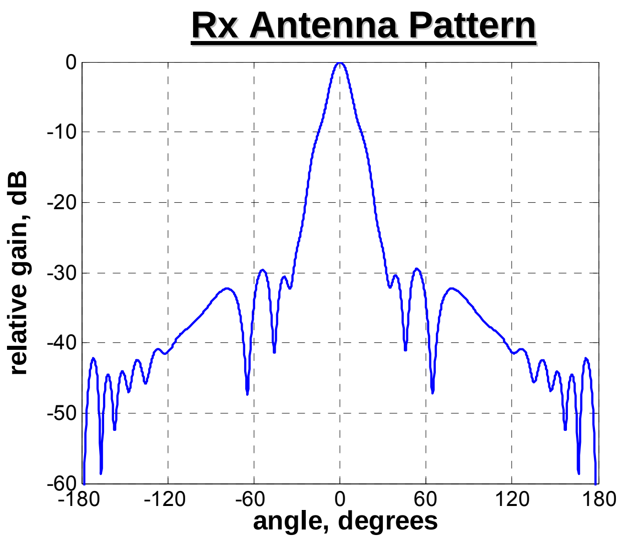
NewLANS' Office Measurement



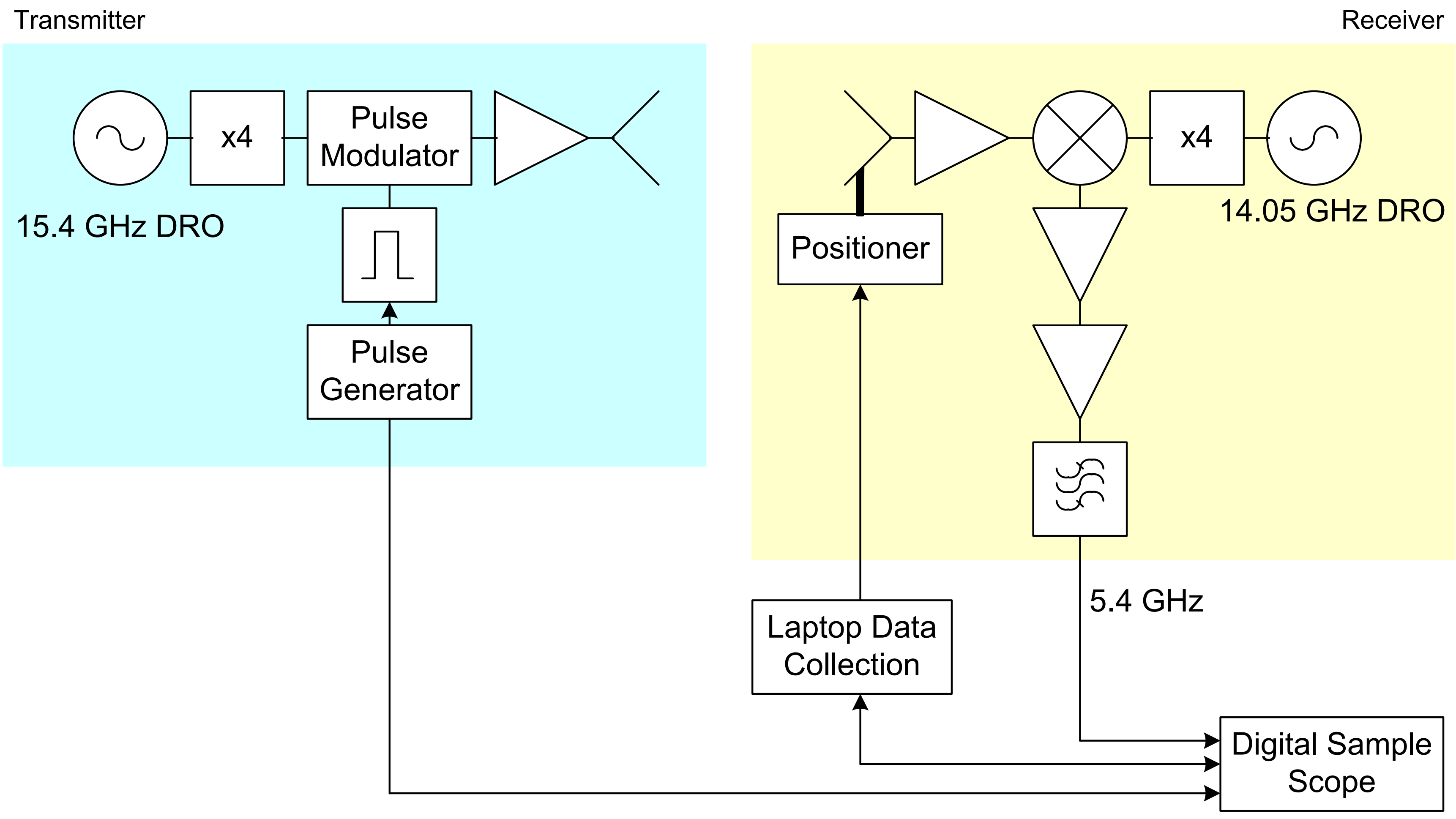


Measurement Information

- Office and residential environments
  - Office → cubicles, conference room and hallway/corridor
  - Residential → Family/living room, dining room and kitchen
- ~60 GHz center frequency
- Pulsed measurement (~1 ns pulse width)
- Tx Antenna
  - Fixed
  - Directional, HPBW of 35°
- Rx antenna
  - Rotated in step of ~2°
  - Directional, HPBW of 13º
- Right hand circular polarization



60 GHz Pulsed Measurement Set-Up

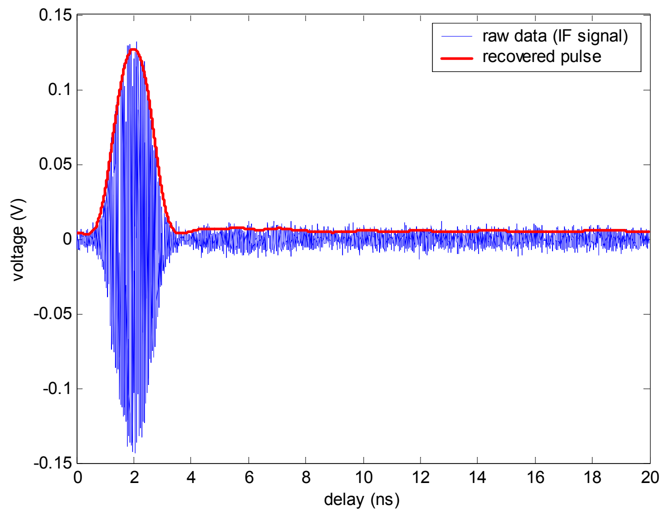


Environment

Environment	Number of Locations	Number of Measurements
Office	34	6,188
Residential	31	5,642
Total	**65**	**11,830**

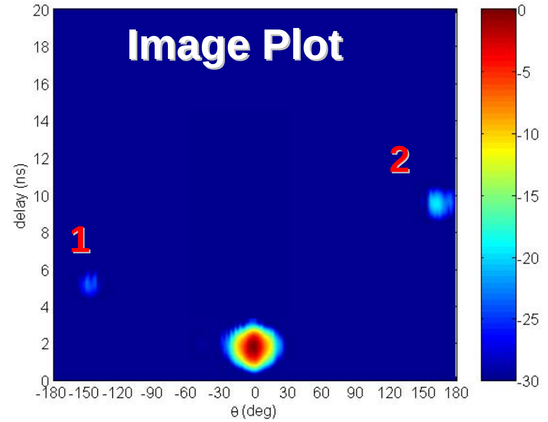
Data Processing & Analysis

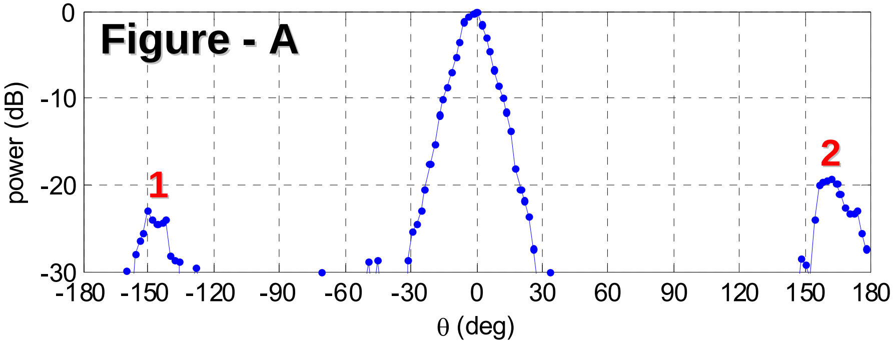
- Time domain impulse response measured as Rx rotated through 360°
- Envelope detector digitally implemented in Matlab to recover baseband pulses
- Multipath information collected from processed data and layout of each environment

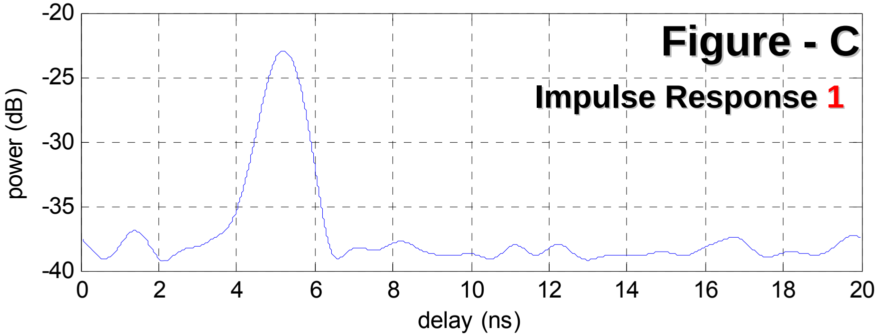


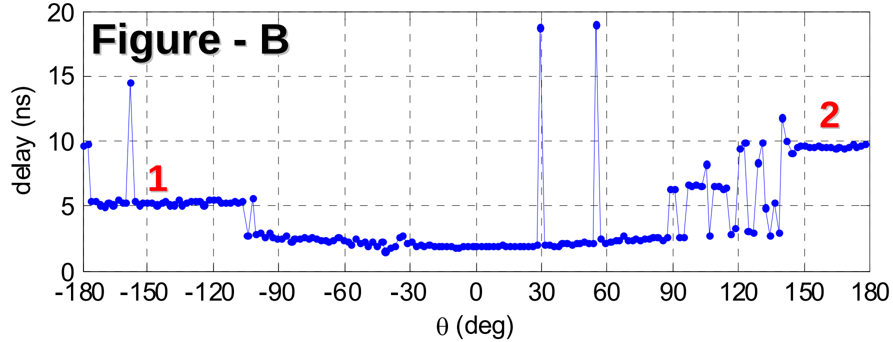
Received Pulse (LOS With No Reflections)

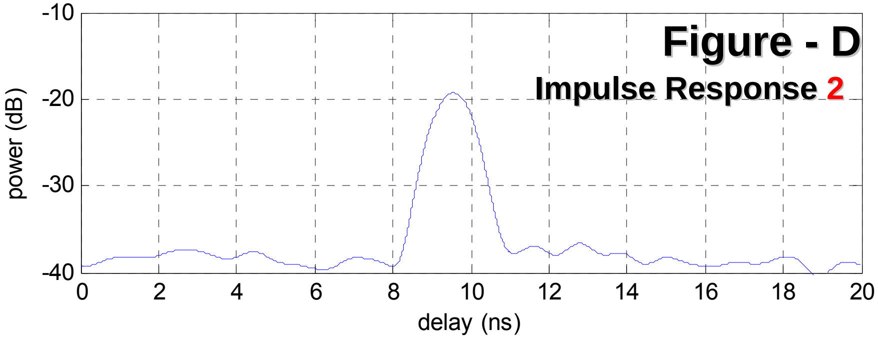
Example – Office Environment



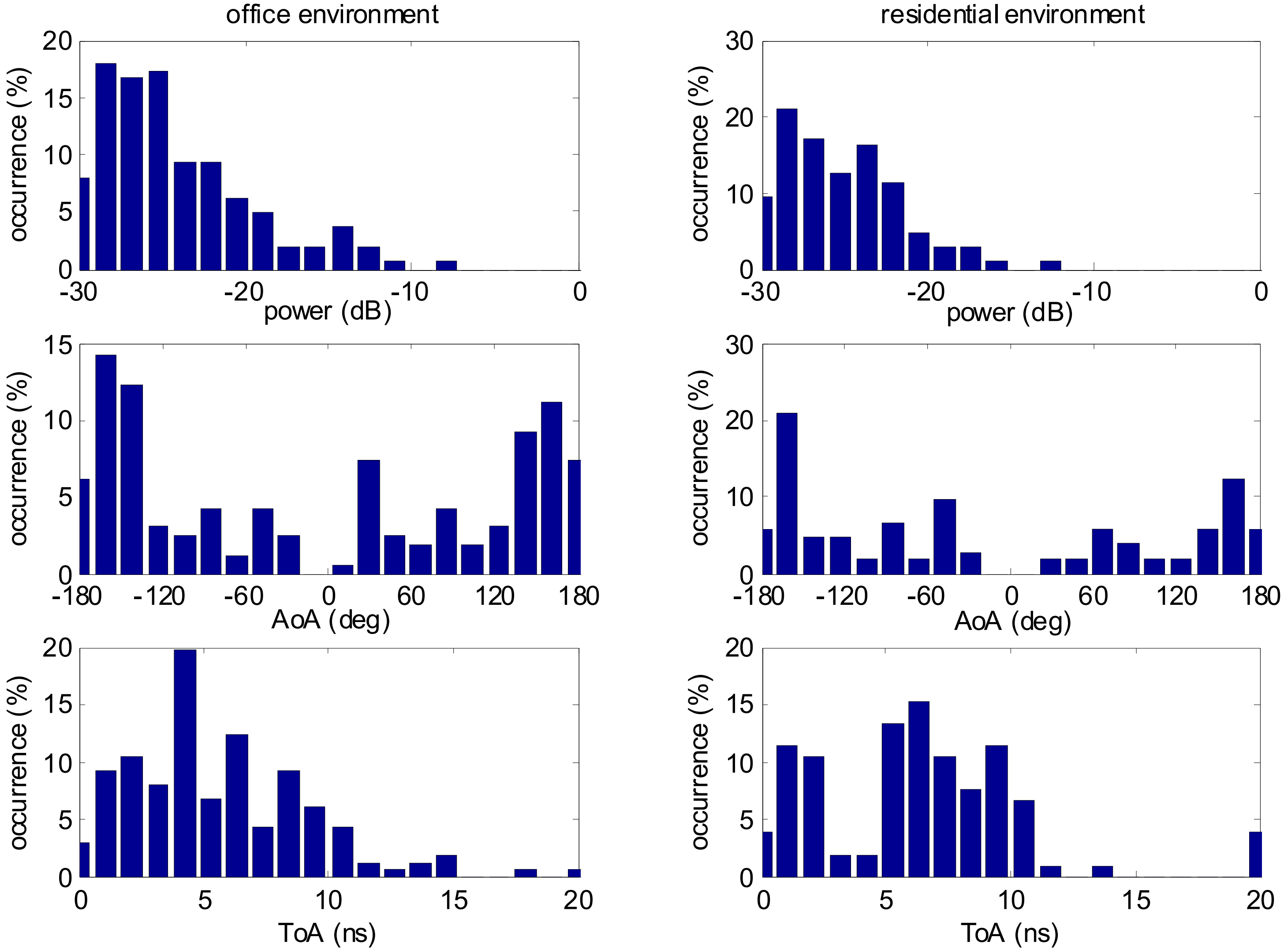




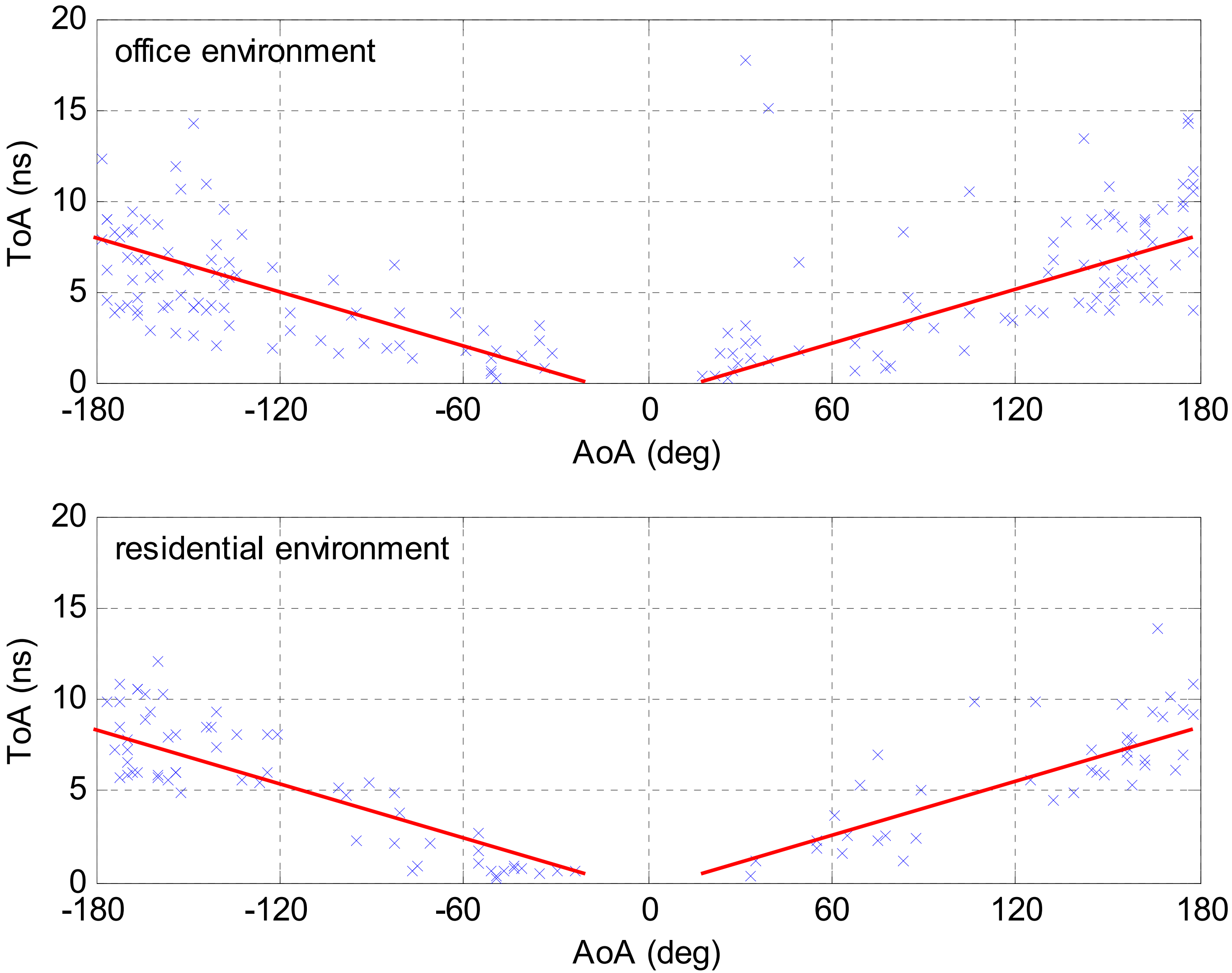




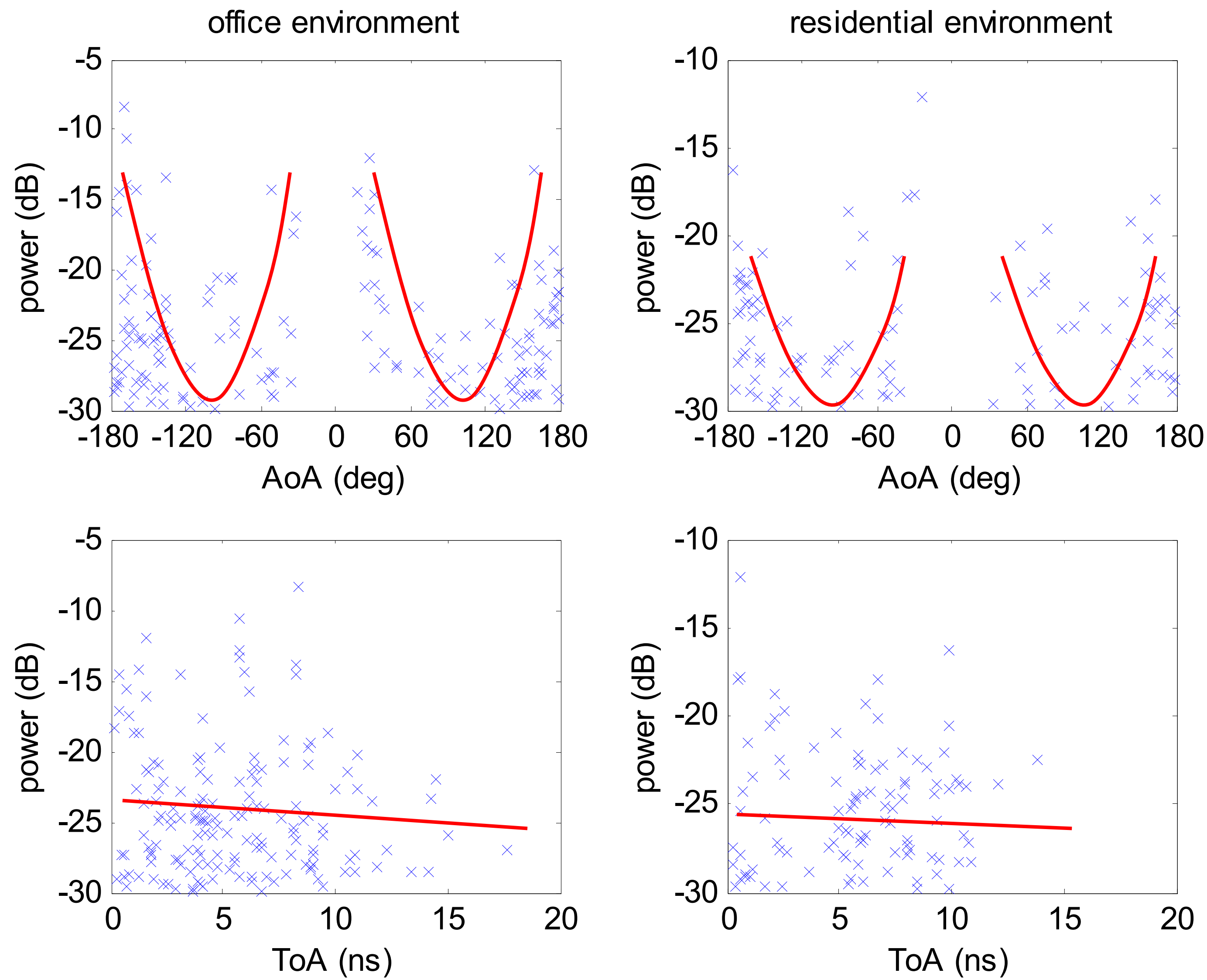
Power, AoA, and ToA Histograms



Scatter Plots of ToA vs AoA



Scatter Plots of Power vs AoA/ToA



Proposed Channel Model

$$h(t,\theta) = K\Bigg[\overbrace{\delta(t - t_{\mathrm{LOS}},\theta)}^{\text{LOS}} + \overbrace{\sum_{l=1}^{L}\alpha_l\,\delta\big(t - t_{\mathrm{LOS}} - t_l,\theta - \theta_l\big)}^{\text{multipath}}\Bigg]$$

where:

K = normalization factor

L = number of arrivals

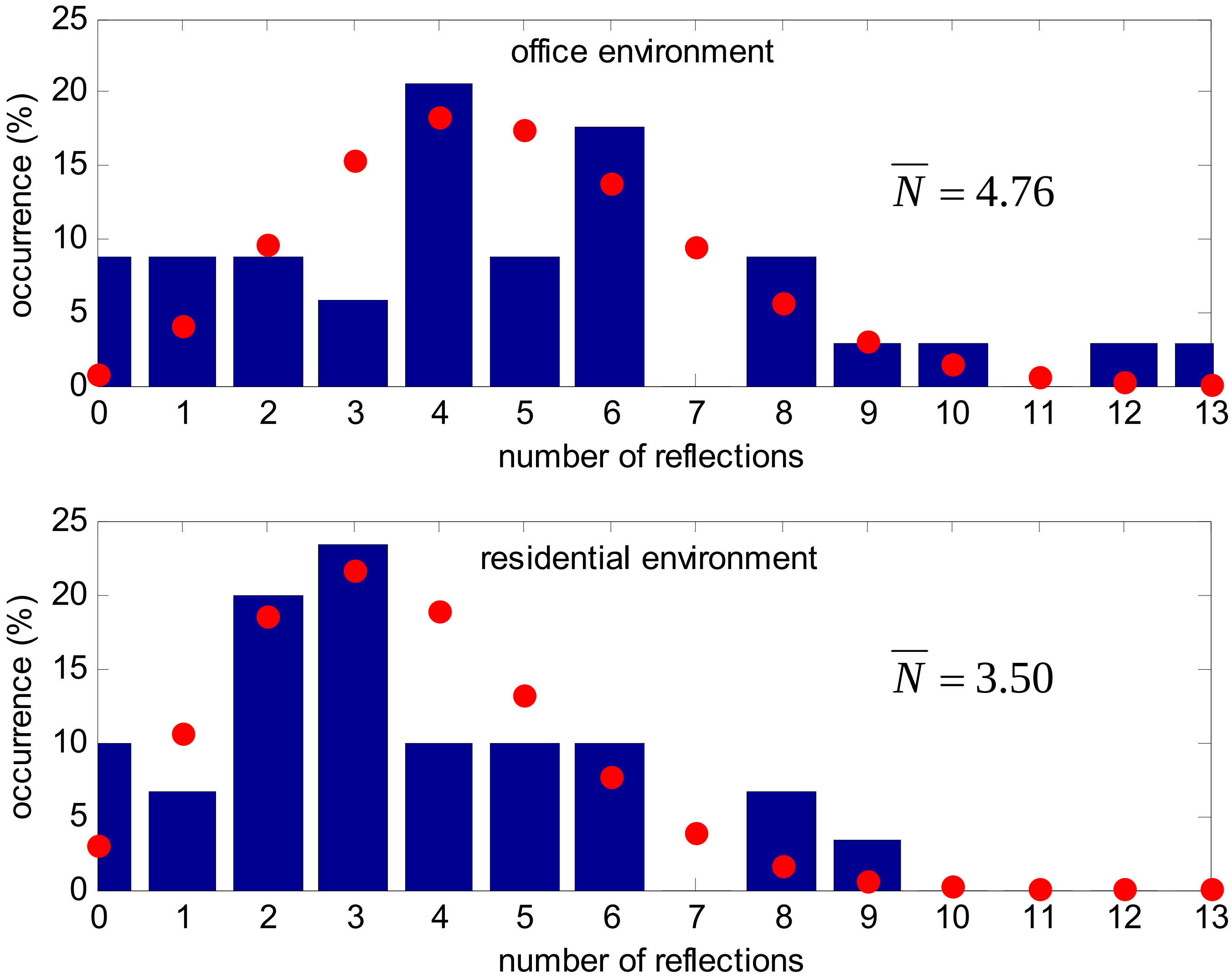
α_l = multipath gain of the l^{th} arrival

t_{LOS} = delay for line-of-sight signal

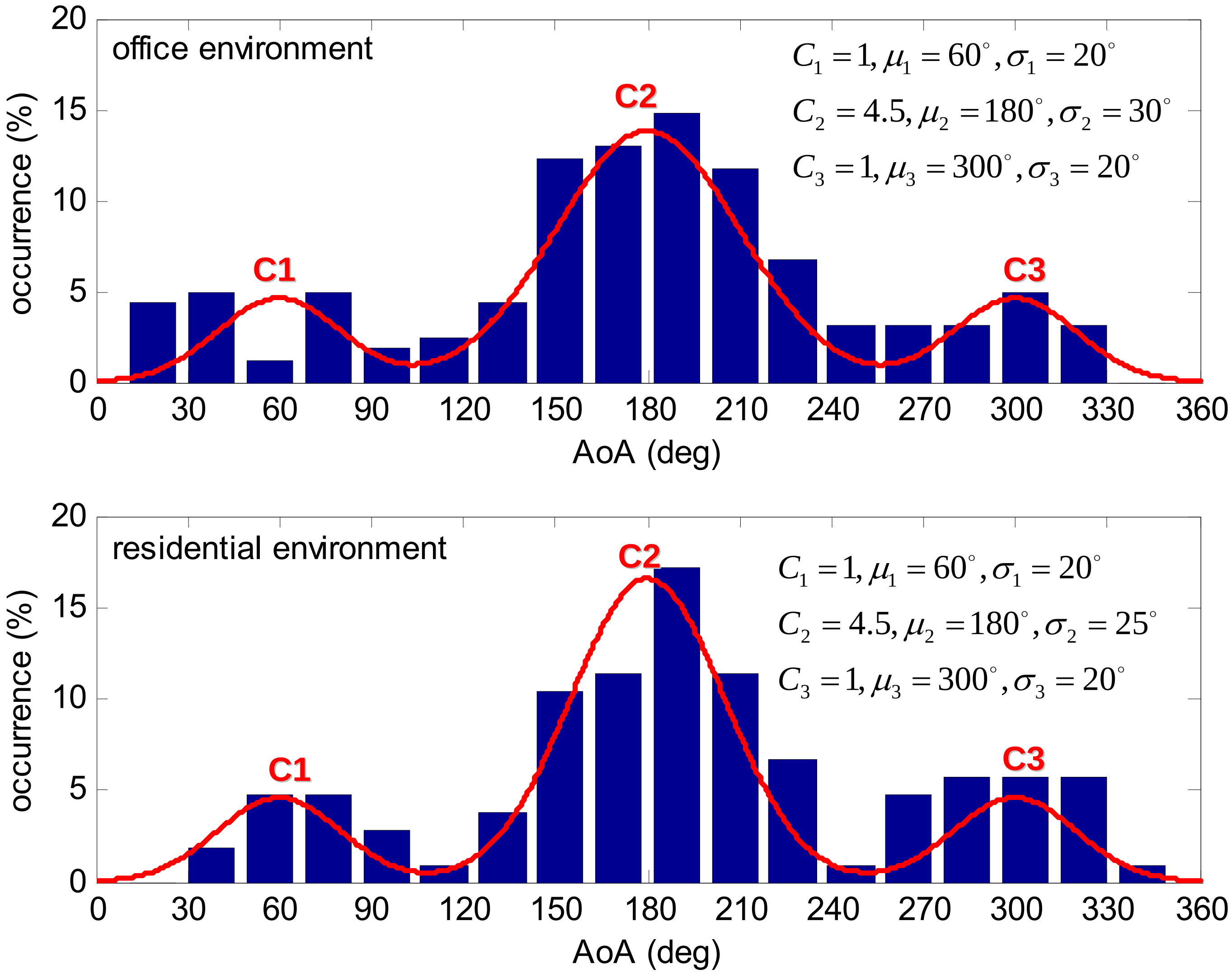
t_l = time of the l^{th} arrival

θ_l = angle of the l^{th} arrival

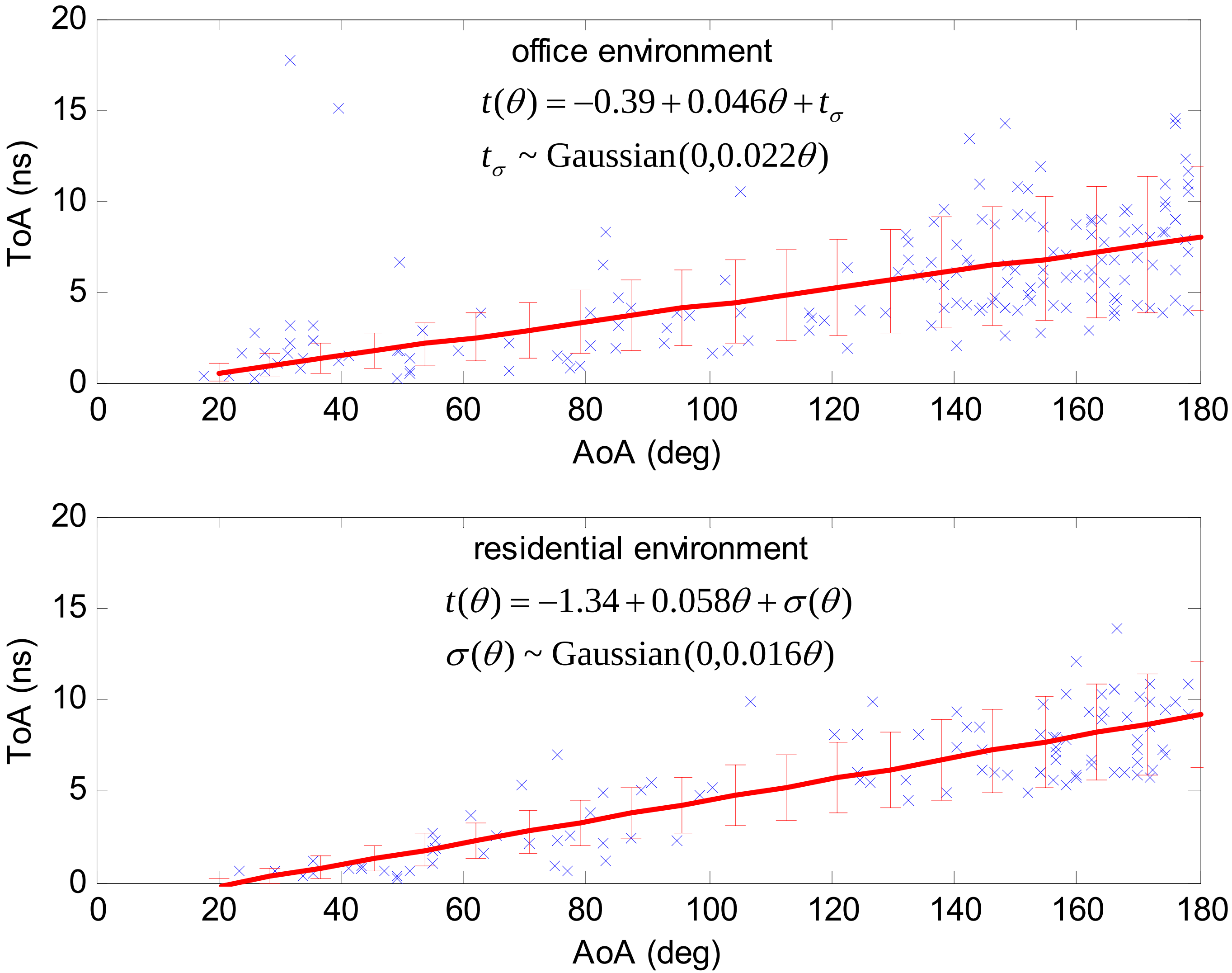
Number of Reflections – Poisson



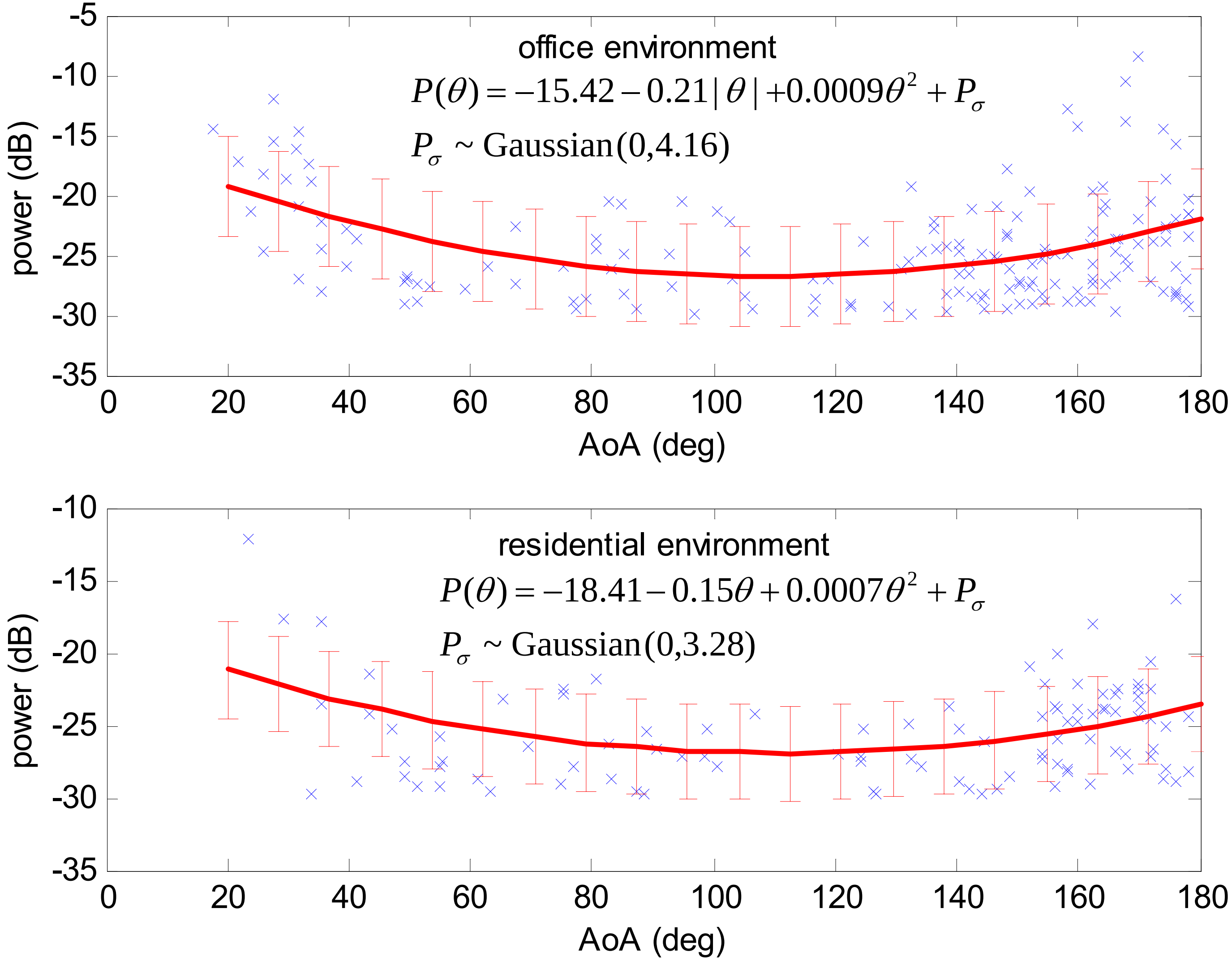
Angle of Arrival – Triple Gaussian



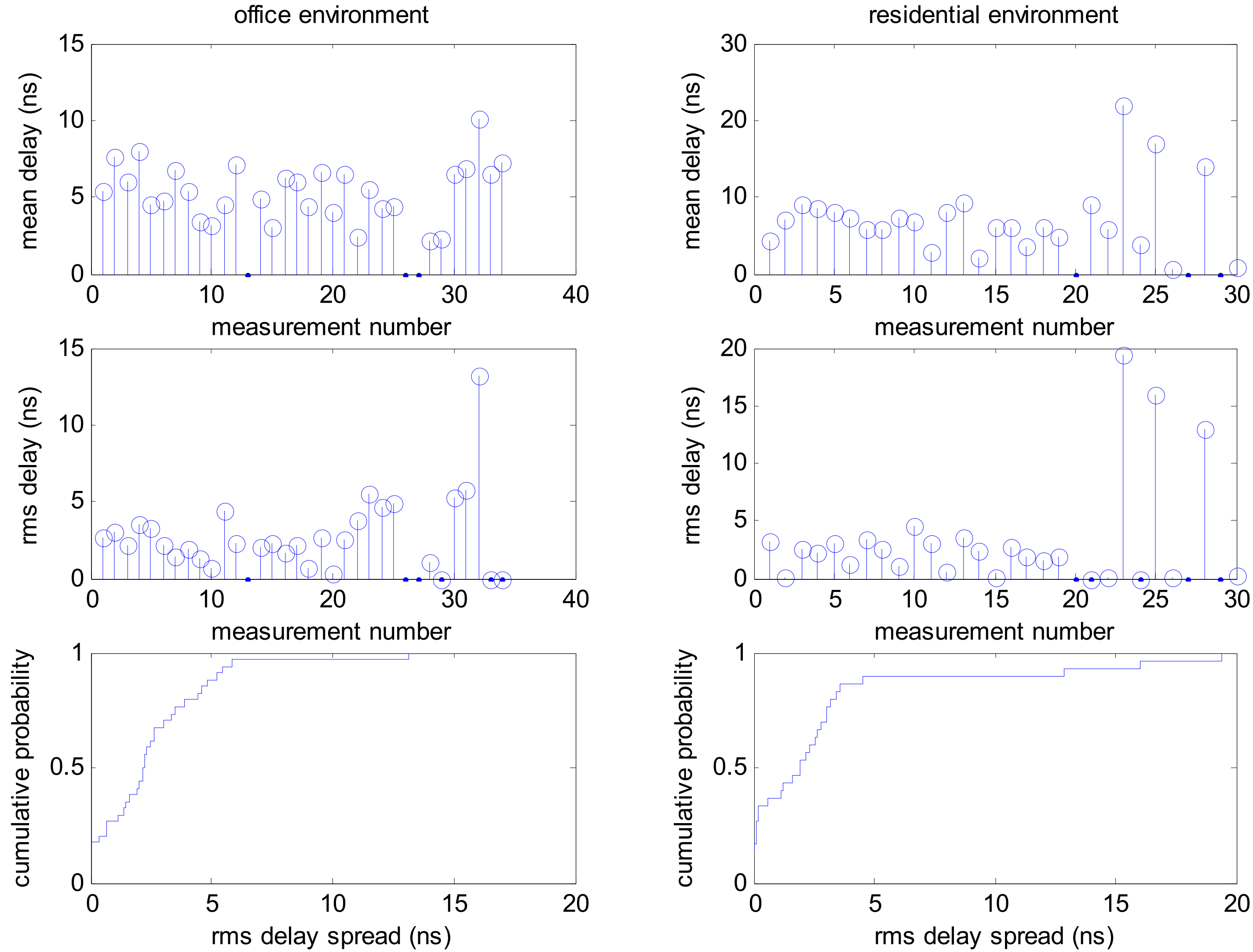
ToA vs AoA – Linear Regression



Power vs AoA – Quadratic Regression



Delay Spread



Extracted Parameters

$$h(t,\theta) = K\left[\delta(t - t_{\mathrm{LOS}}, \theta) + \sum_{l=1}^{L} \alpha_l \delta\left(t - t_{\mathrm{LOS}} - t_l, \theta - \theta_l\right)\right]$$

	Values		Unit
	Office	Residential	
Number of reflections	4.8	3.5	-
Mean power	-24.3	-25.3	dB
Power standard deviation	4.5	3.5	dB
Mean AoA	175	192	degrees
AoA standard deviation	75	74	degrees
Mean delay	5.4	7.1	ns
RMS delay spread	2.8	3.4	ns

Summary and Conclusions

- About 50% of the reflections have a relative power of -25 dB or less (85% for -20 dB) compared to the line-of-sight signal for both environments.
- No reflection observed within ±20 degrees for office environment and ±30 degrees for residential environment, and the majority of the reflections occur near 180 degrees.
- Number of reflections follows Poisson distribution.
- The arrival time of multipath components is highly correlated with the angle of arrival (well fitted to a linear model), while the angle of arrival follows a “triple” Gaussian distribution.

References

1. T. Manabe, *et*. *al*., Multipath measurement at 60 GHz for indoor wireless communication systems, *IEEE 44th Vehicular Technology Conference*, 905-909, June 1994.

2. T. Manabe, *et*. *al*., Polarization dependence of multipath propagation and high speed transmission characteristics of indoor millimeter channel at 60 GHz, *IEEE Transaction on Vehicular Technology*, **Vol**. 44, **No**. 2, 268-274, May 1995.

3. K. Sato, *et*. *al*., Measurements of reflection and transmission of office building in the 60 GHz band, *IEEE Transaction on Antennas and Propagation*, **Vol**. 45, **No**. 12, 1783-1792, December 1997.