UWB Channel Measurements for the Home Environment

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updated 1/24/02 by David Cheung

Outline

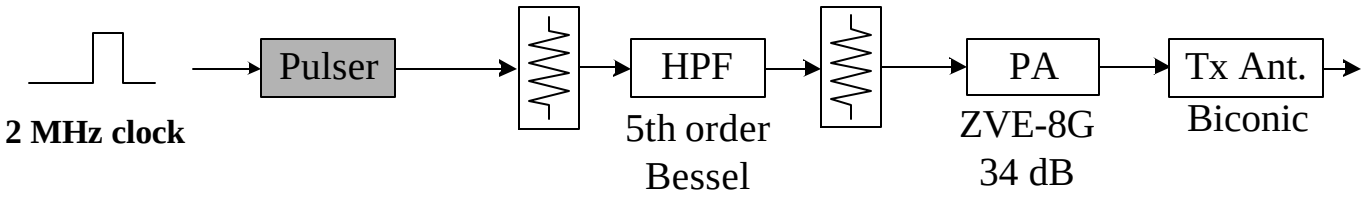
- Motivation
- Measurement Setup & Data Analysis
  - Equipment; Antennas; Calibration
  - Windowing
  - Baseband vs. Passband
- Channel Statistics
  - Pathloss & Delay Spread
  - Multipath Intensity Profile
  - Water Occultation
  - Dual antenna correlation
- Proposal: Central Database of UWB Channel Soundings

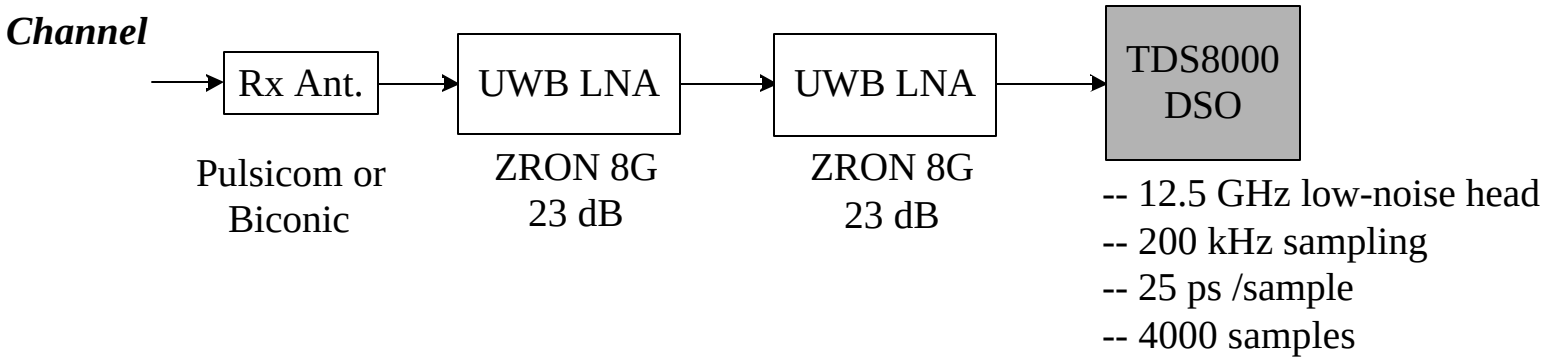
Impact of Channel Model

- **UWB Receiver design**
  - **Low power system – need to exploit multipath energy**
  - **Accurate characterization of the multipath**
  - **Narrowband channel**
    - Exponentially decreasing multipath channel
    - Single parameter for the channel – mean excess delay
  - **Impact of regulatory decisions**
- **Decision to make our own measurements**
  - **Gather experience with the UWB channel and pulses**
  - **Collect "live" data to be used in testing receiver structures**
  - **Model the channel on the frequency bands under consideration by FCC**
- **Other Results in Channel Modeling**
  - **Hashemi (1993) – 0.9–1.3 GHz network analyzer with 801 points**
  - **Rappaport series (1990-1998) – mostly narrowband**
  - **USC, Time Domain (1999) – 1-3 GHz pulsed**
  - **AT&T (2001) – concurrent measurements, 2.5GHz centered on UNII band**

Channel Measurements of Pulsed Signal

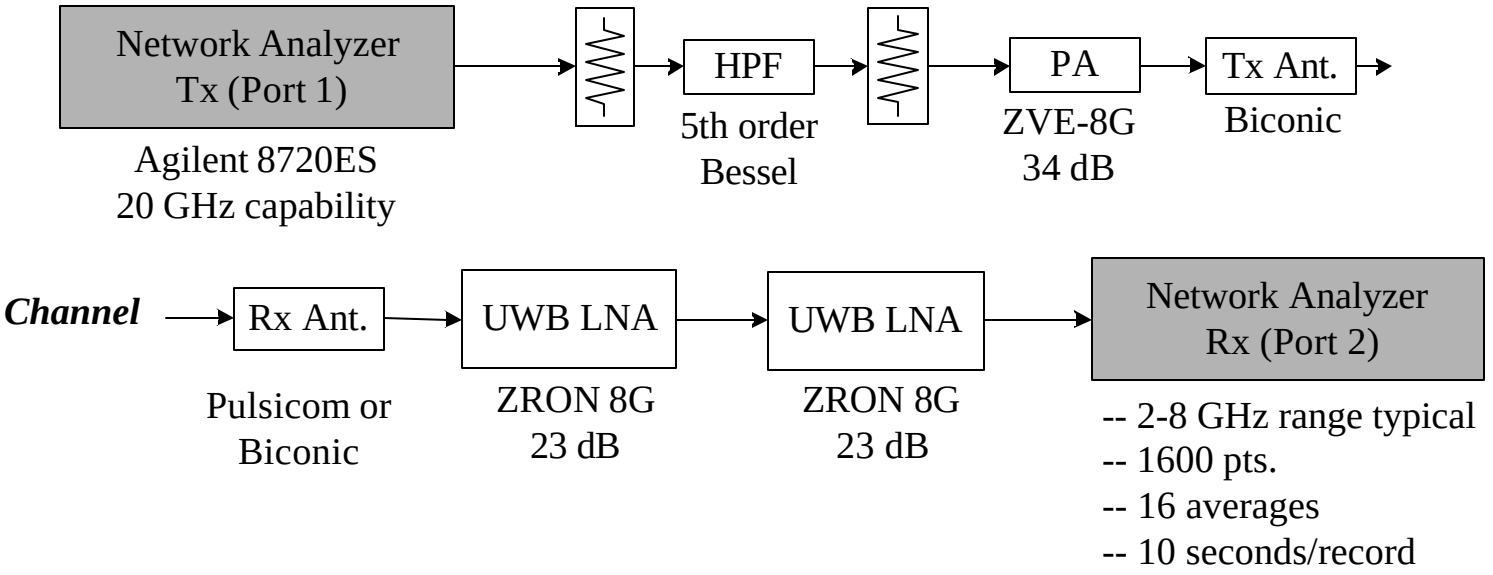
- **Pulser obtained from Hyperlabs**
- **Filter from an in-house design by Bud Nation**
- **Gain blocks, cable, adapters procured off-the-shelf**
- **Digital Sampling Oscilloscope (DSO) obtained on lease**





Network Analyzer (NWA)

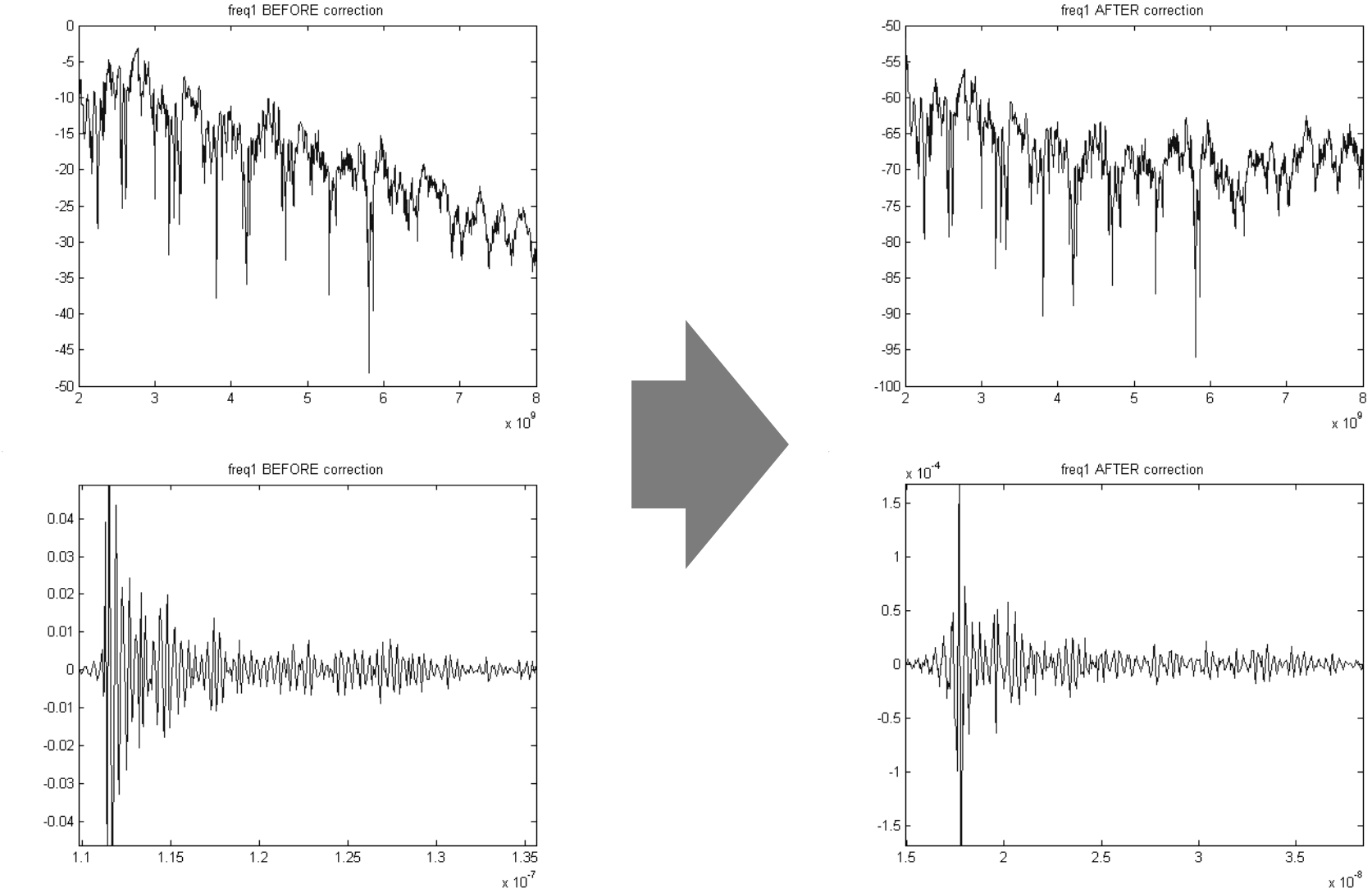
- **Direct sounding of the time-varying channel transfer function**
- **Key test equipment was the Agilent 8720 network analyzer leased by IAL**
- **Various gain stages were incorporated to improve sensitivity**
- **Various filters were used with the goal of providing measurements equivalent to pulse measurement using the oscilloscope**



Measurement Resolution

- **Time Domain measurements**
  - **25ps between samples; 4000 samples; 100ns “sampled” interval**
  - **PRF 2 MHz; sampling rate 200kHz; 20 ms per sweep;**
  - **16 sweeps per measurement ? .32 s of observation**
  - **62.5ps Nyquist so ~2.5X oversampling**
- **Frequency Domain measurements**
  - **2-8 GHz, 1601 samples, 3.75 MHz between samples**
  - **Passband & Complex Baseband Analysis**
    - Zero pad from 0-2 GHz, FFT of size 4267 (including conjugate reflection)
  - **62.5ps time between samples; 267 ns**
  - **Time resolution truly ~ 83ps corresponding to 1601 samples**
  - **Hamming window ? Time resolution truly ~ 167 ps**

Compensated Data

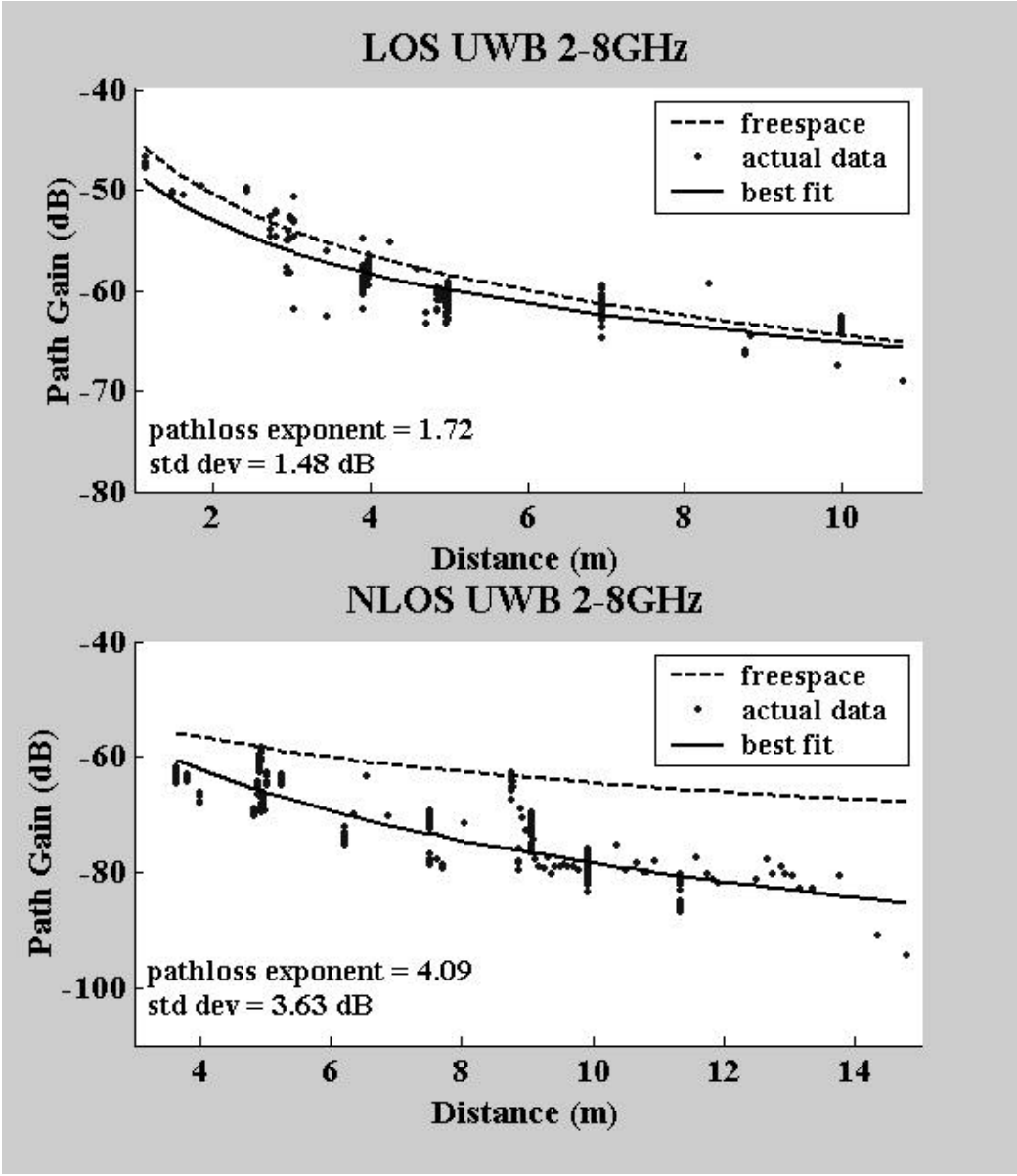


LOS example

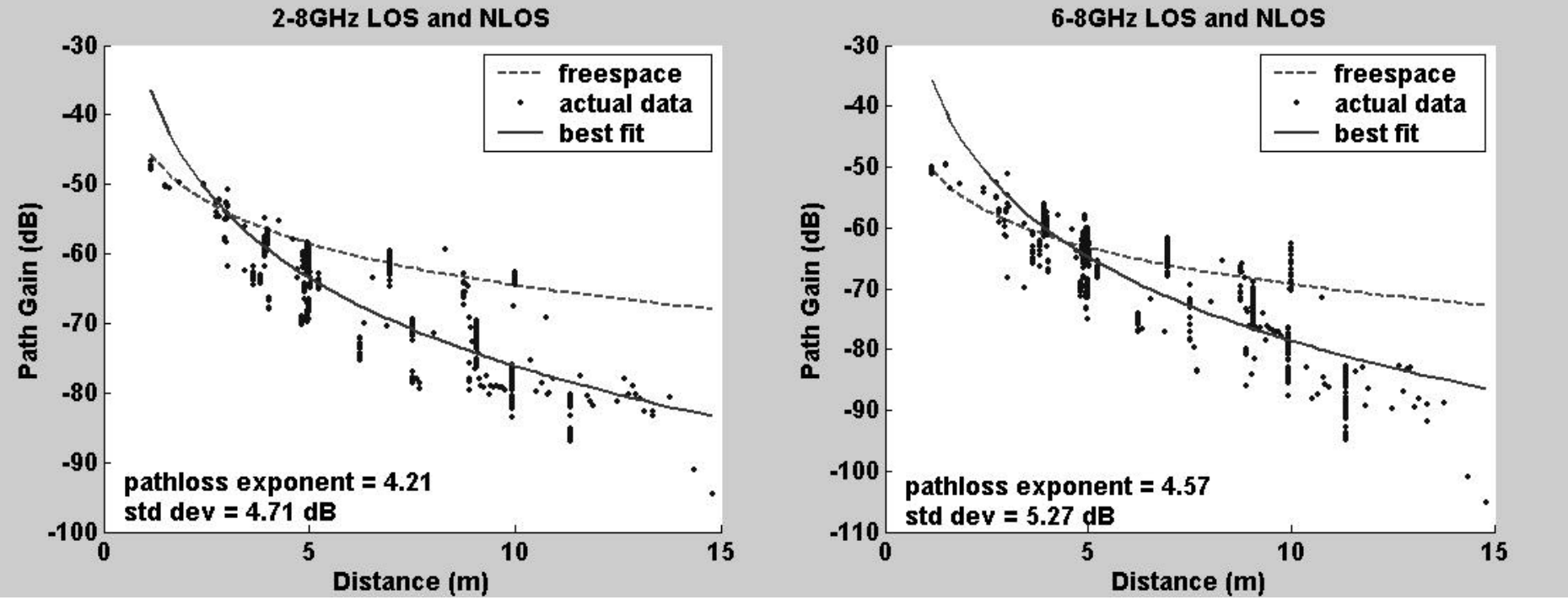
Antenna Characterization

- **UWB omni-directional antennas were used**
  - **Microwave Electronics Company biconic**
    - not characterized by the vendor so the Intel OSEL anechoic chamber was used for characterization measurements
  - **Room had conductive floor**
  - **Took data on elevation behavior of the antenna at one azimuth, and of the azimuthal behavior at one elevation.**

Pathloss at 2-8 GHz



Pathloss Variation

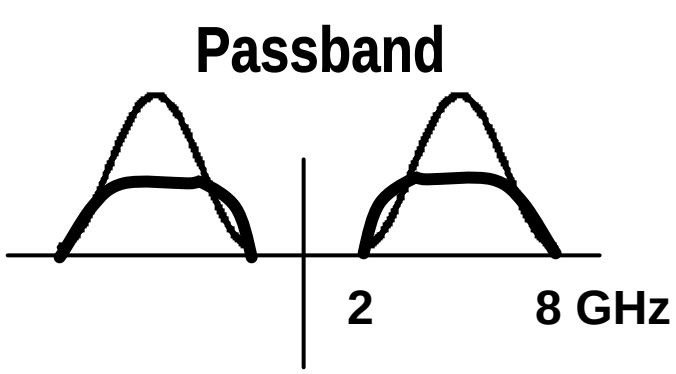


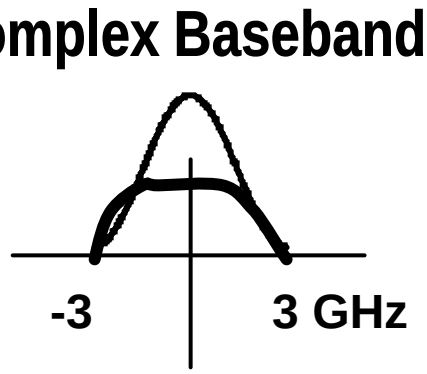
Path Loss Exponent

	NLOS (458 files)	LOS (378 files)	All (836 files)
UWB (2-8GHz)	n = 4.09 ? = 3.63 dB	n = 1.72 ? = 1.48 dB	n = 4.21 ? = 4.71 dB
UWB (6-8GHz)	n = 4.69 ? = 4.81 dB	n = 1.99 ? = 1.79 dB	n = 4.57 ? = 5.27 dB
ISM	n = 3.73 ? = 4.35 dB	n = 1.91 ? = 3.15 dB	n = 3.81 ? = 4.79 dB
UNII(I)	n = 4.70 ? = 4.55 dB	n = 1.83 ? = 3.17 dB	n = 4.76 ? = 5.90 dB

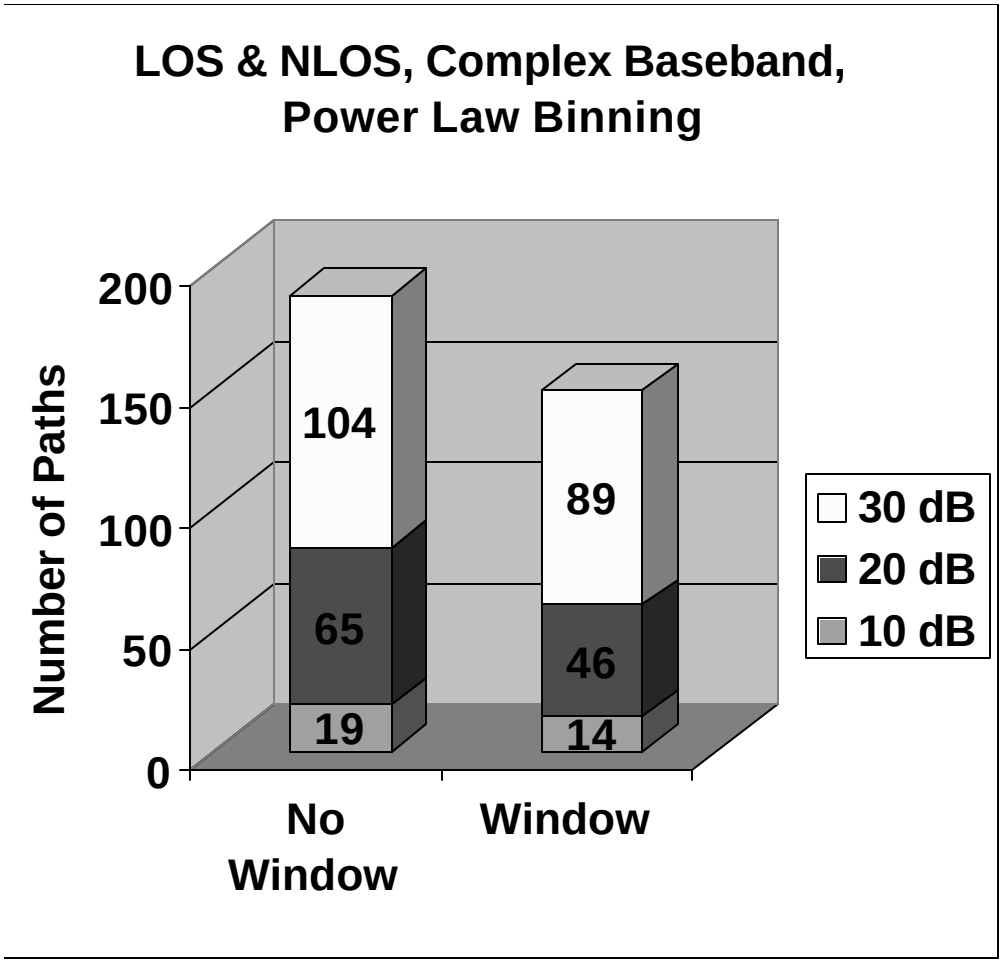
Multipath Bin Size

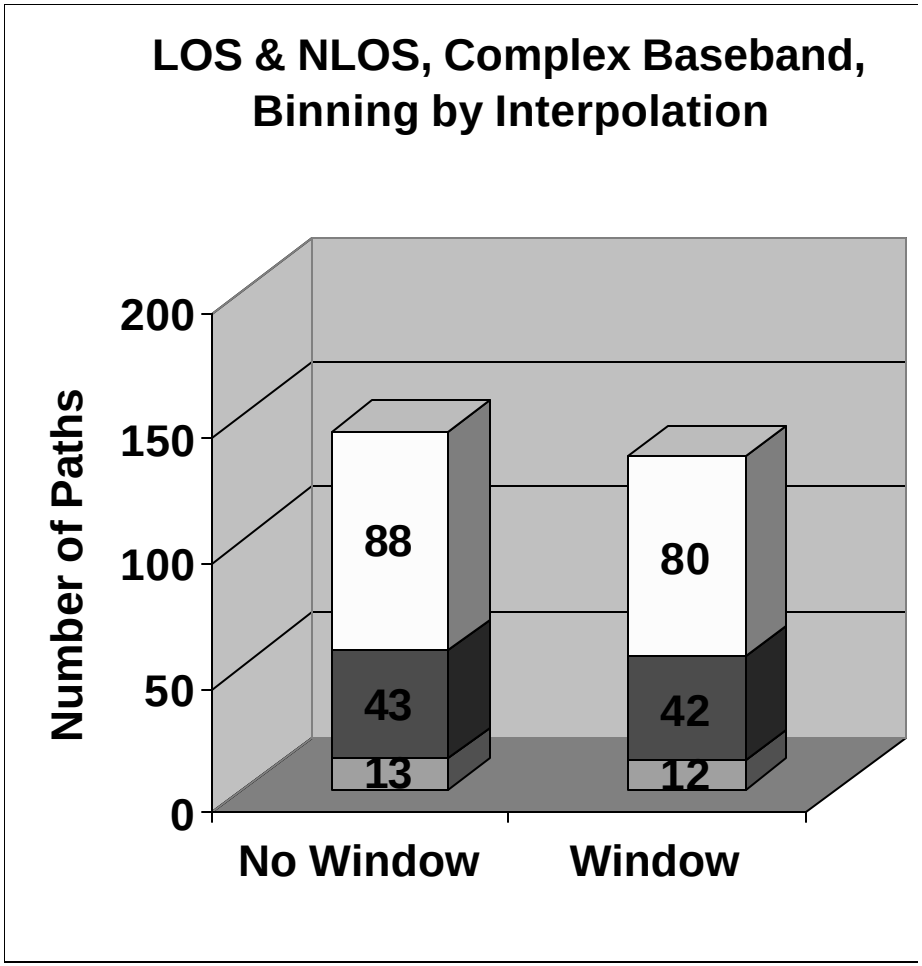
- **Finest Resolution**
  - **167 ps resolution with windowing, 83 ps without windowing**
  - **May be too fine to be practical for simulations**
- **Determined by Pulse Width**
  - **Receivers using a correlator and/or RAKE structure**
  - **Paths in a bin combined by square law or interpolation**
  - **Pulse widths considered: .33 ns (6 GHz); .67 ns (3 GHz); 1.6 ns (1.25 GHz)**





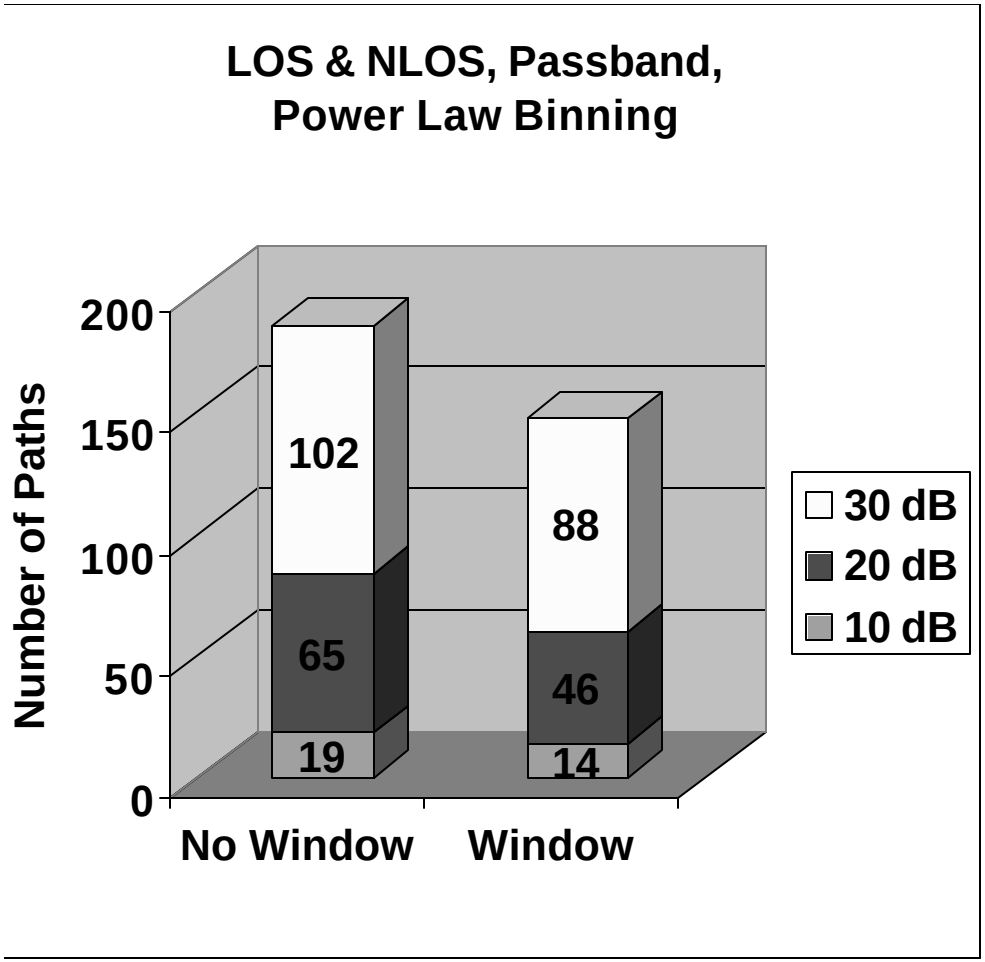
Windowing Effects

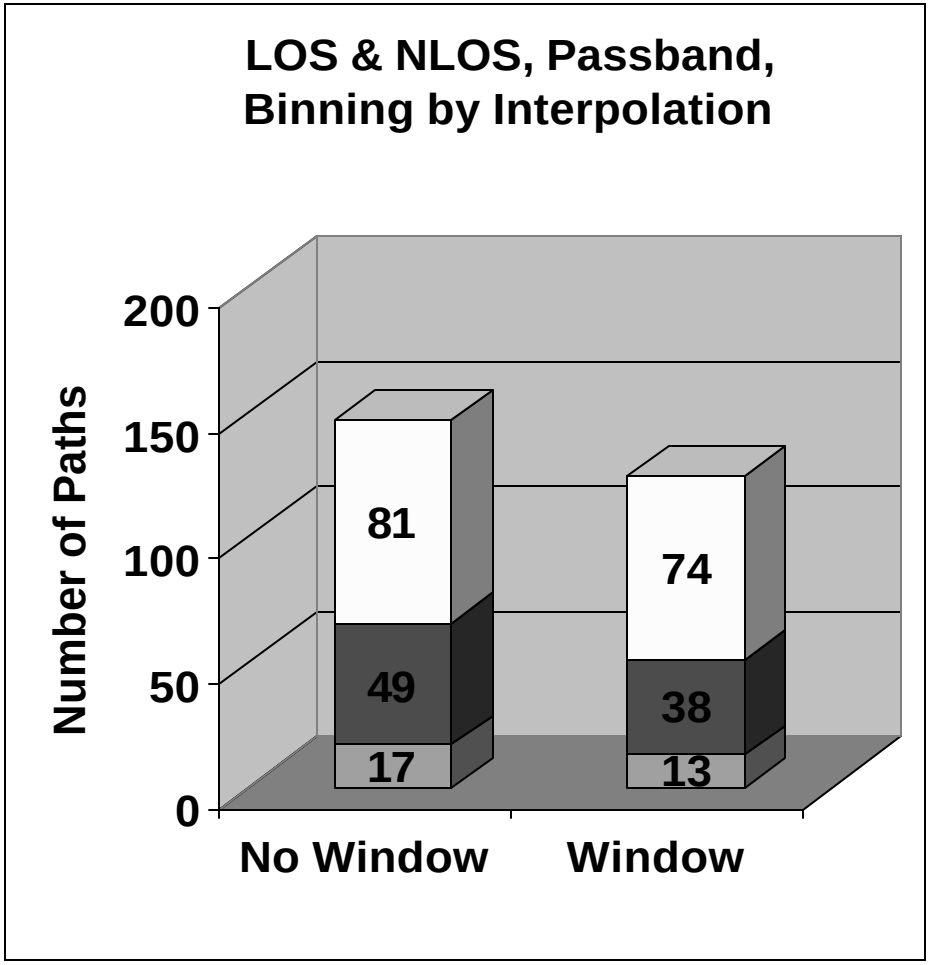




not updated (1/24/02, dbc)

Windowing Effects





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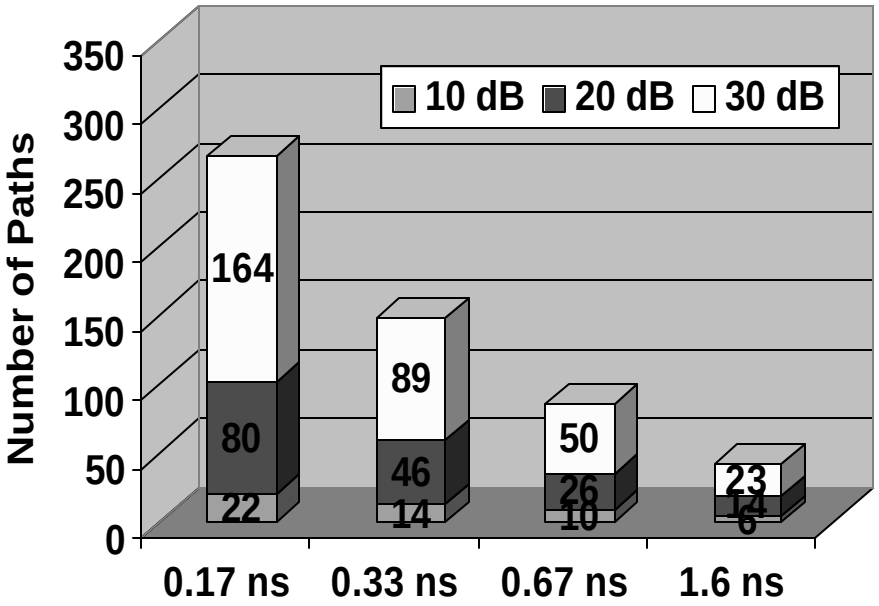
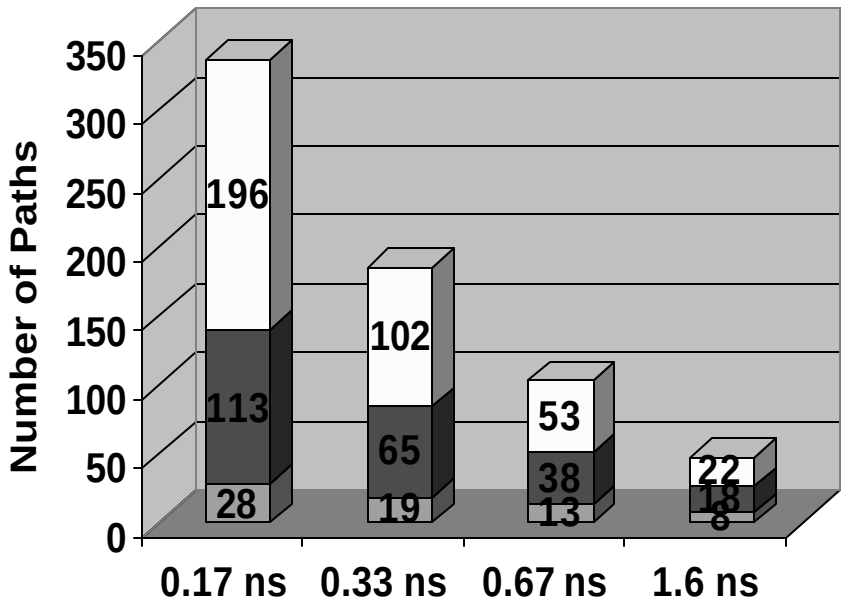
Number of Paths
Passband vs. Baseband

LOS & NLOS, Complex Baseband, Power Law Binning



LOS & NLOS, Passband, Power Law Binning



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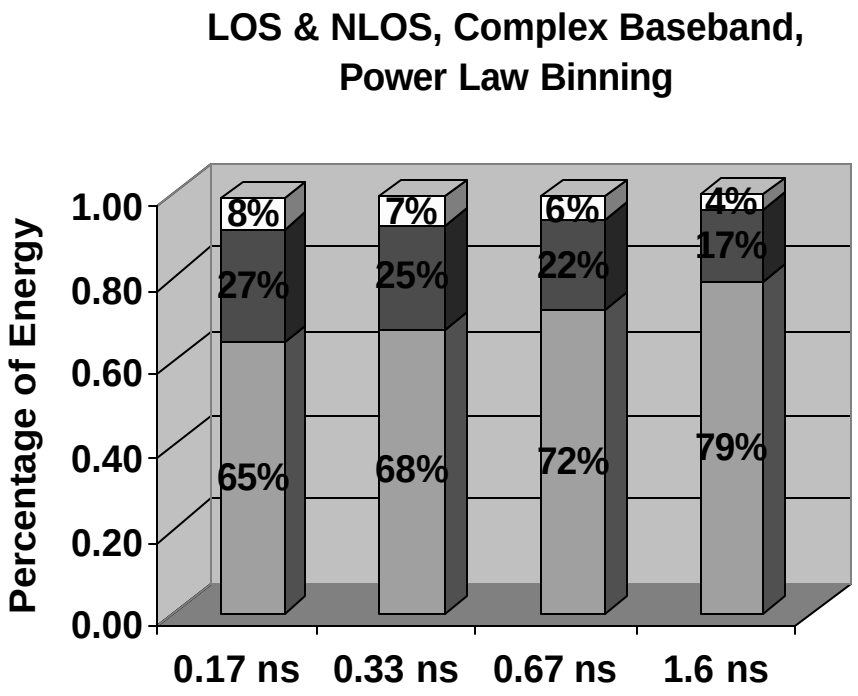
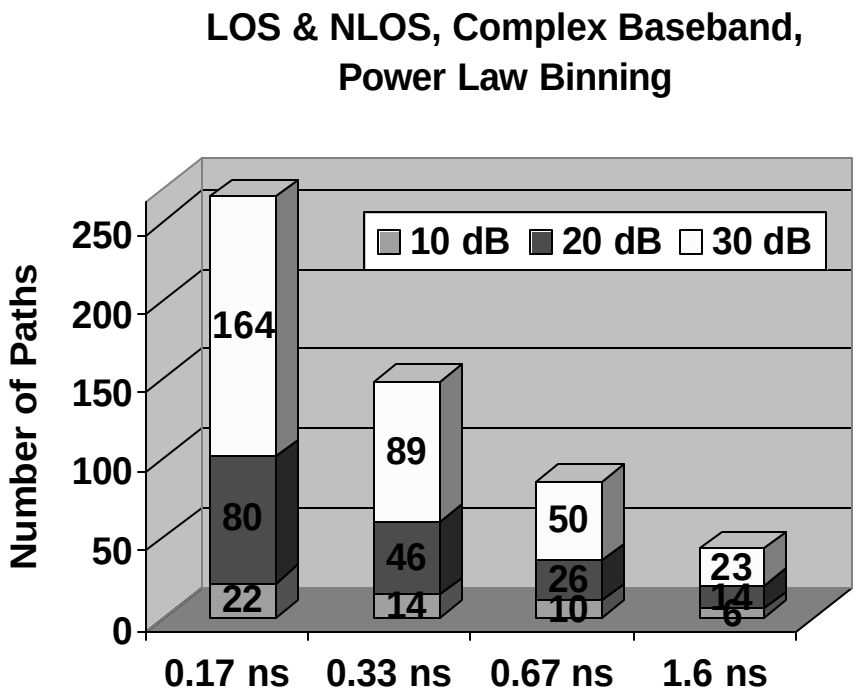
Percentage of Energy





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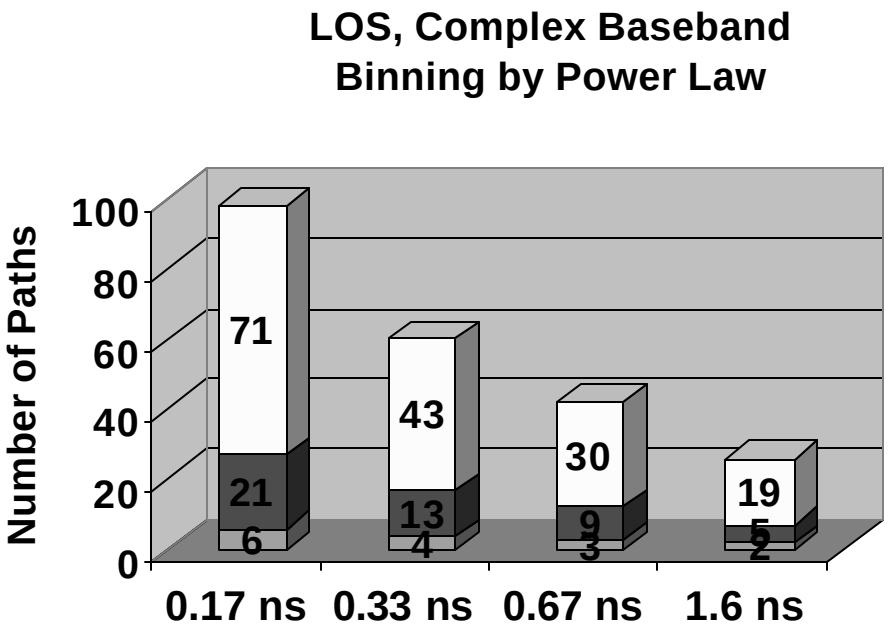
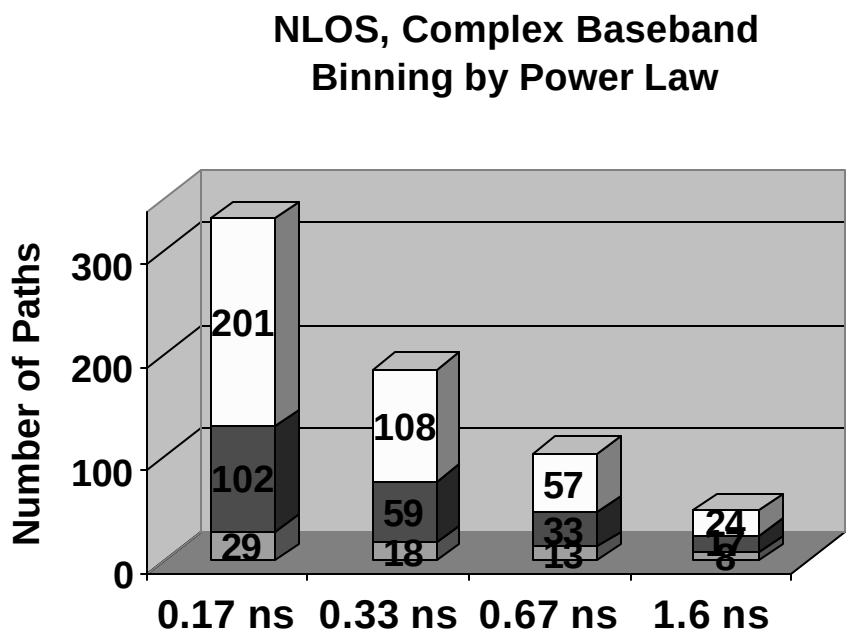
LOS vs. NLOS





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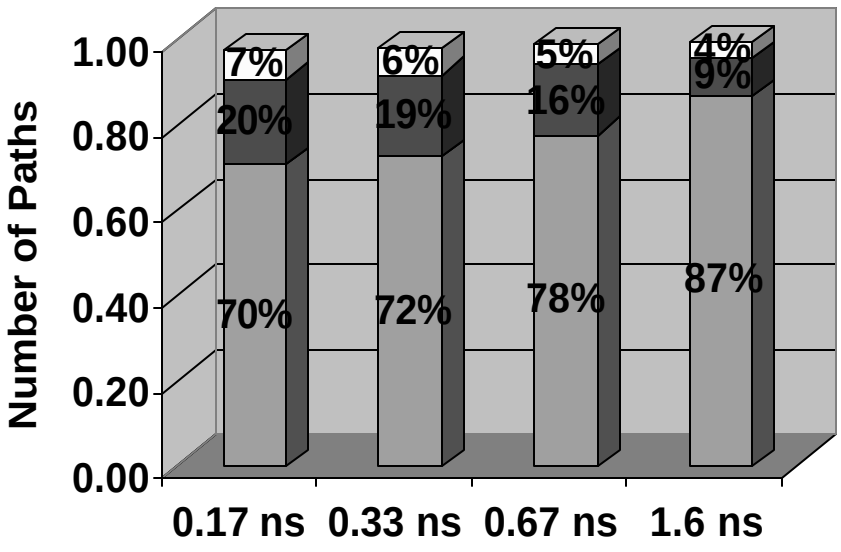
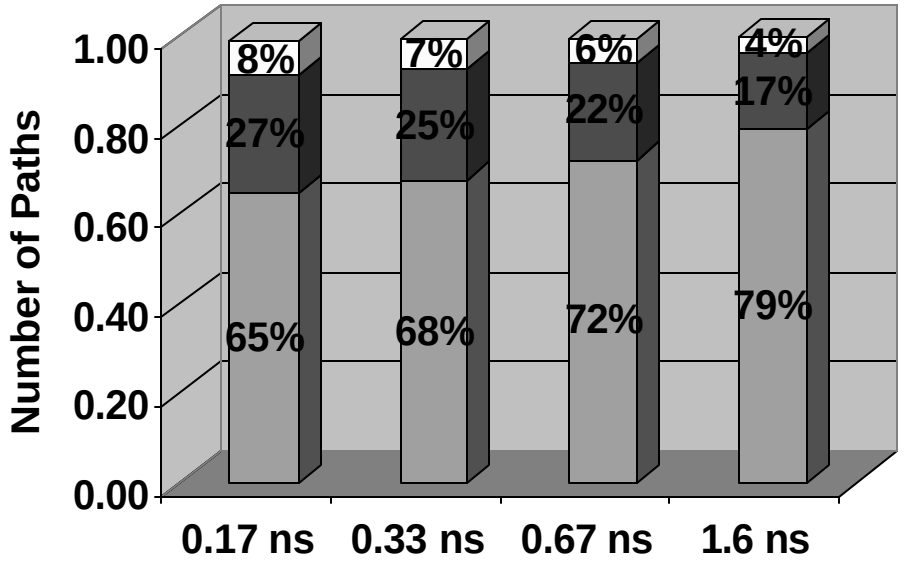
LOS vs. NLOS

LOS, Complex Baseband, Power Law Binning



NLOS, Complex Baseband, Power Law Binning



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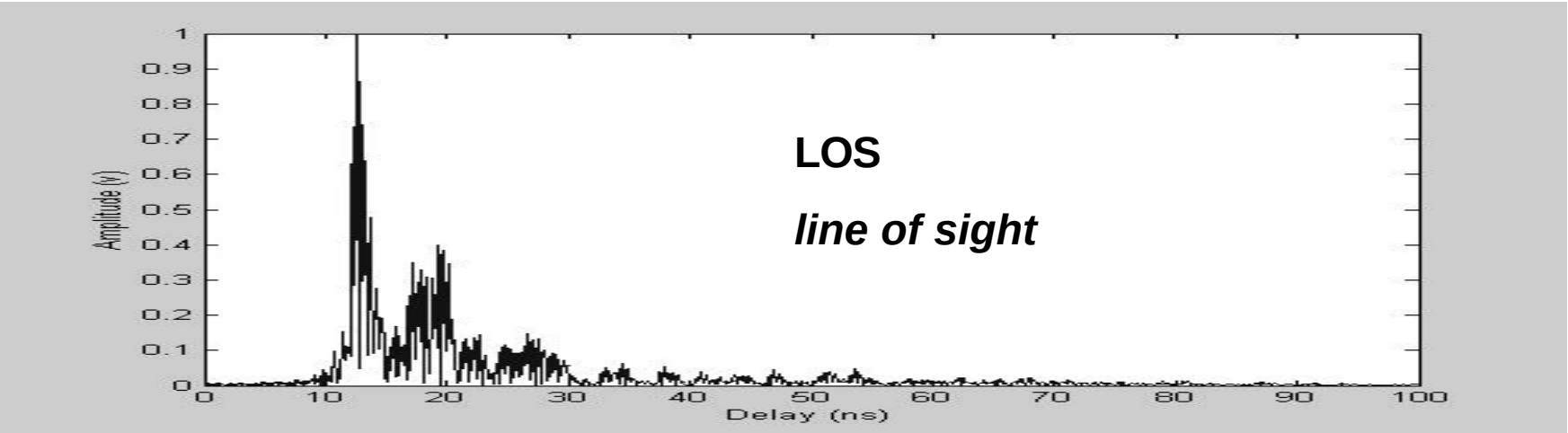
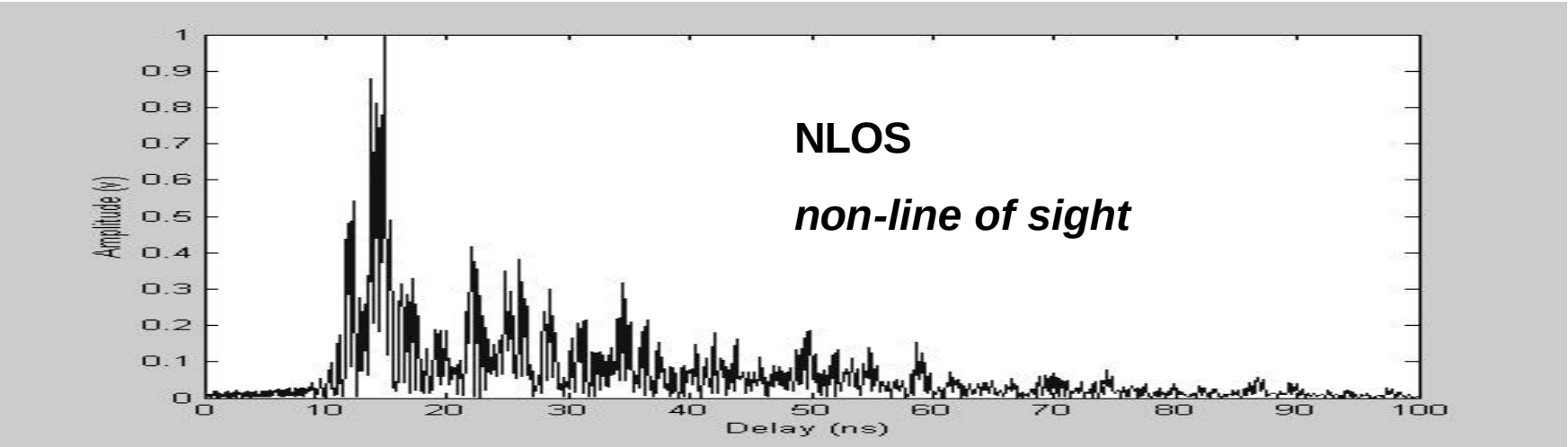
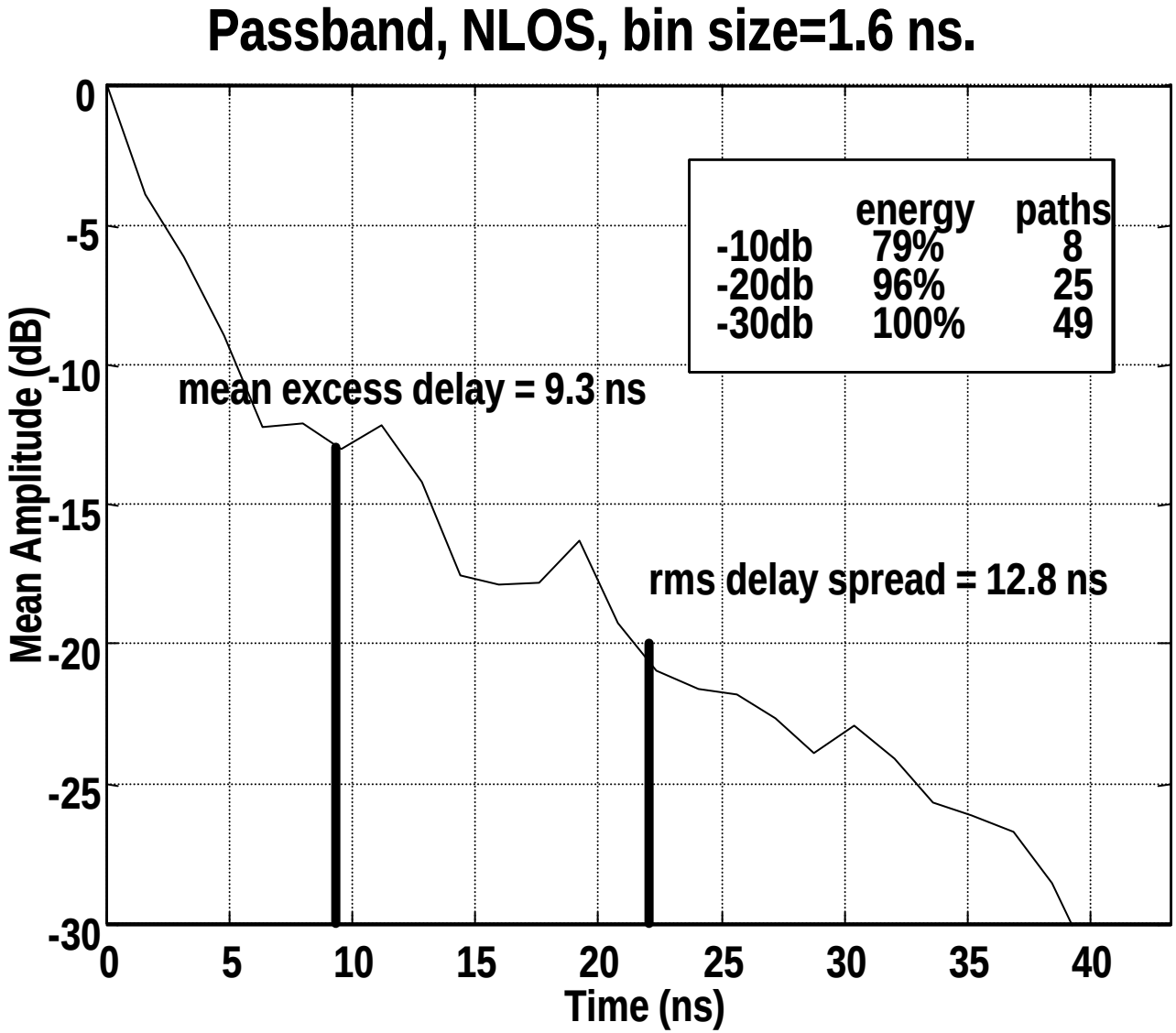
UWB Typical Multipath Profiles

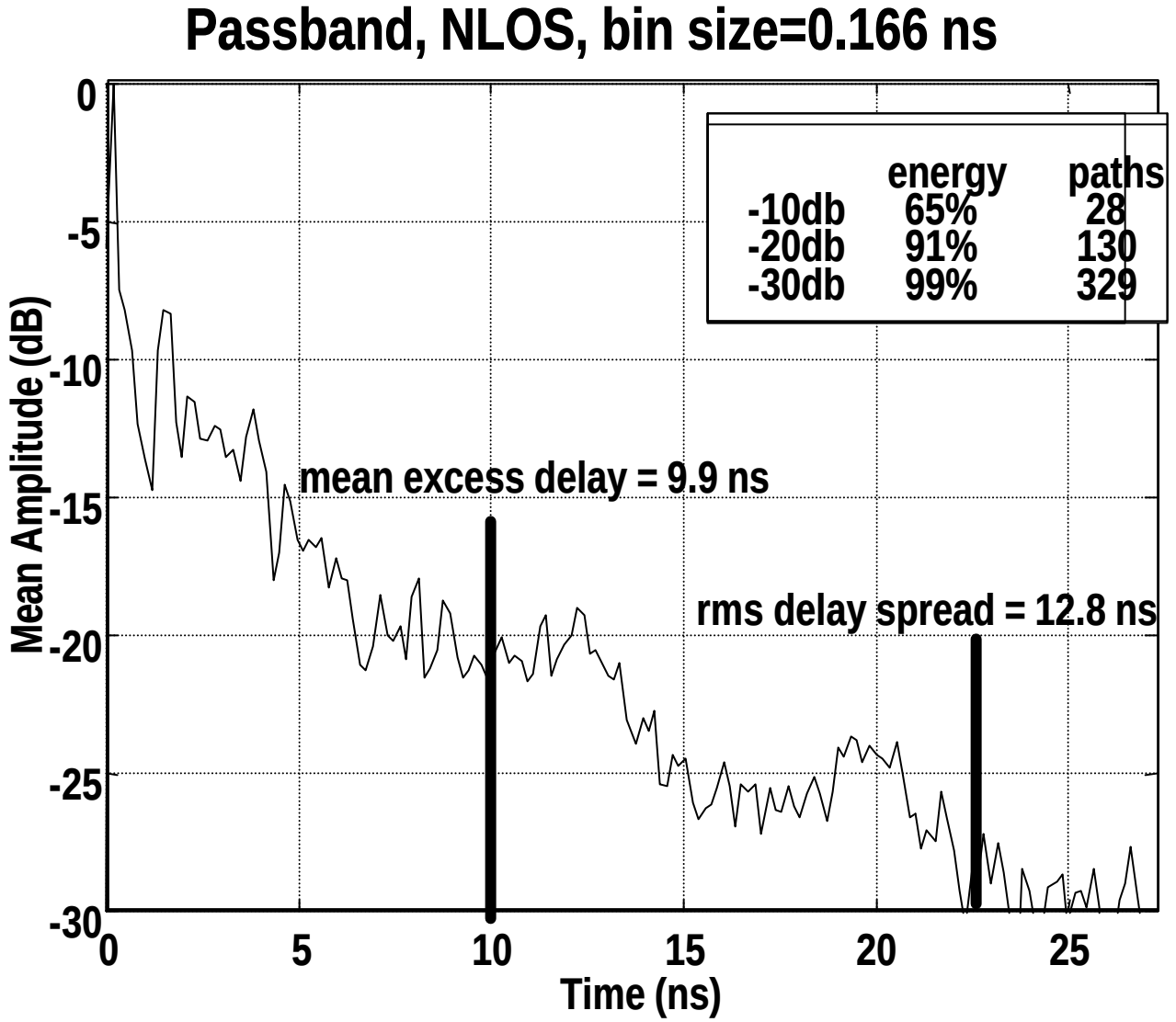




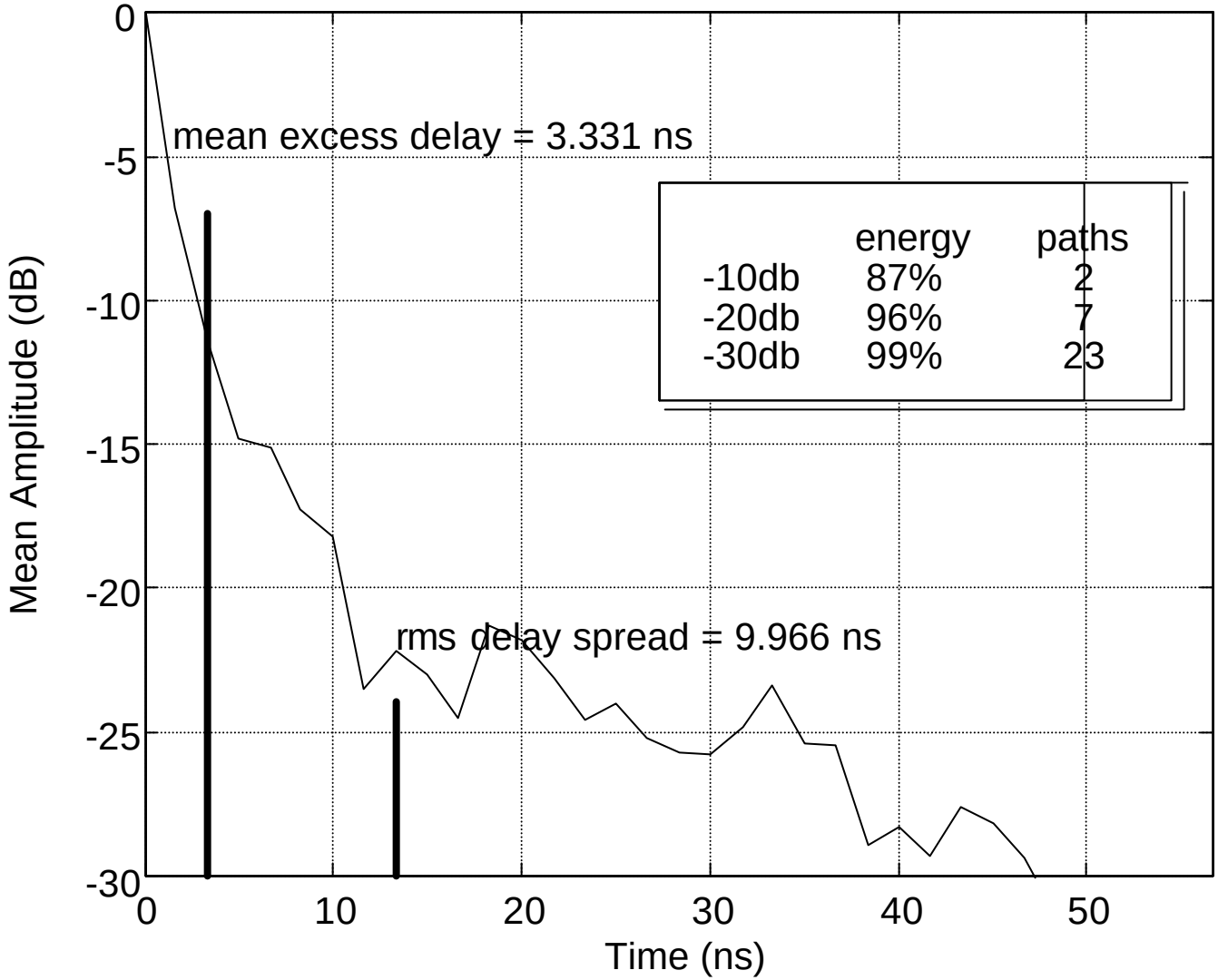
Multipath Intensity Profile



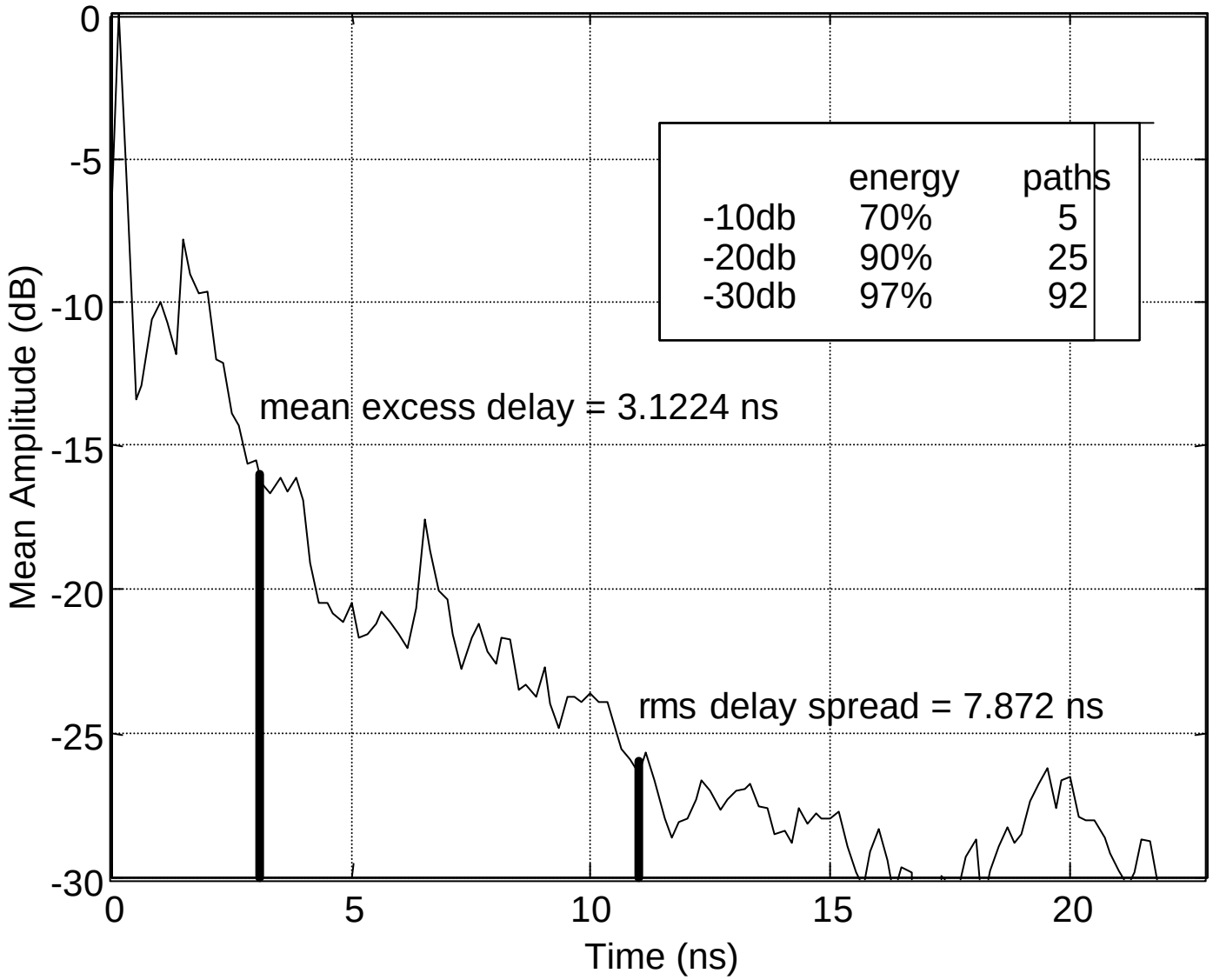
Multipath Intensity Profile



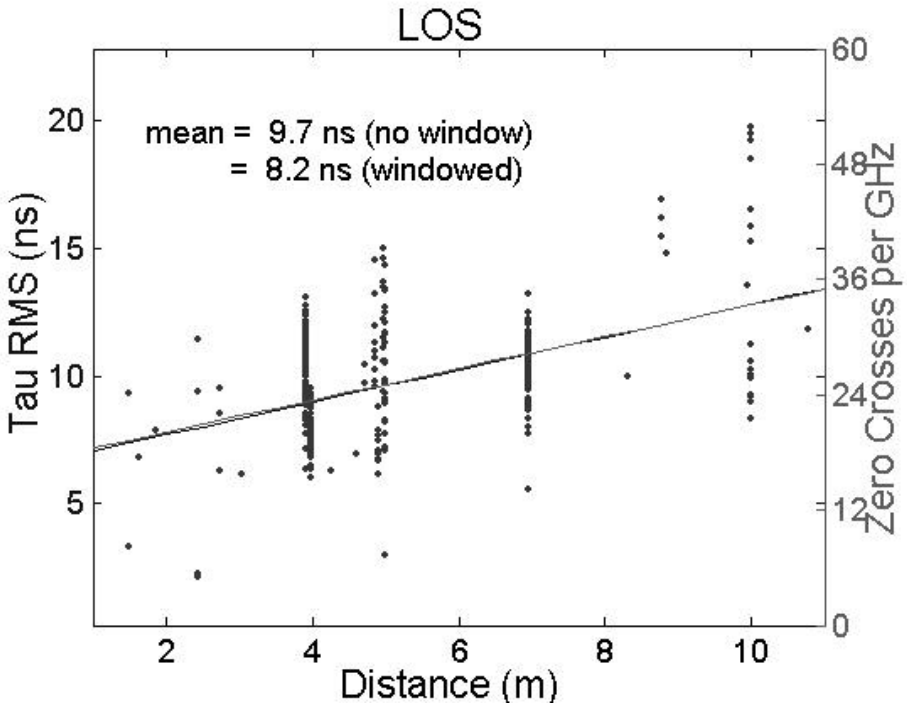
Complex Baseband, LOS, bin size=1.67 ns

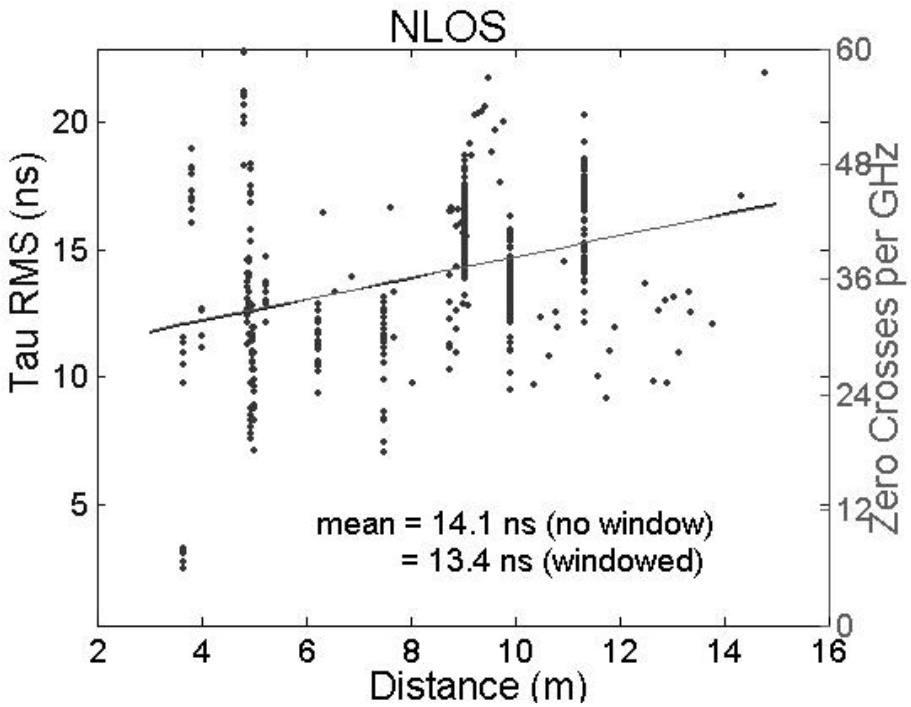


Complex Baseband, LOS, bin size=.167 ns



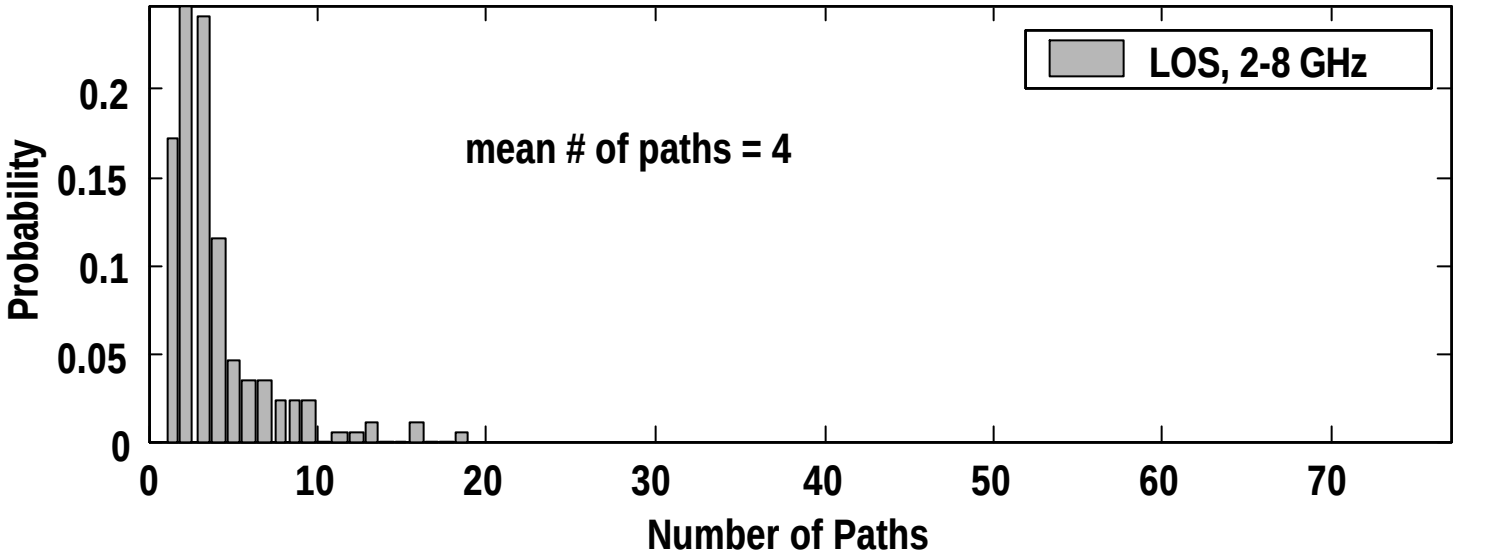
Spectral Level Crossings

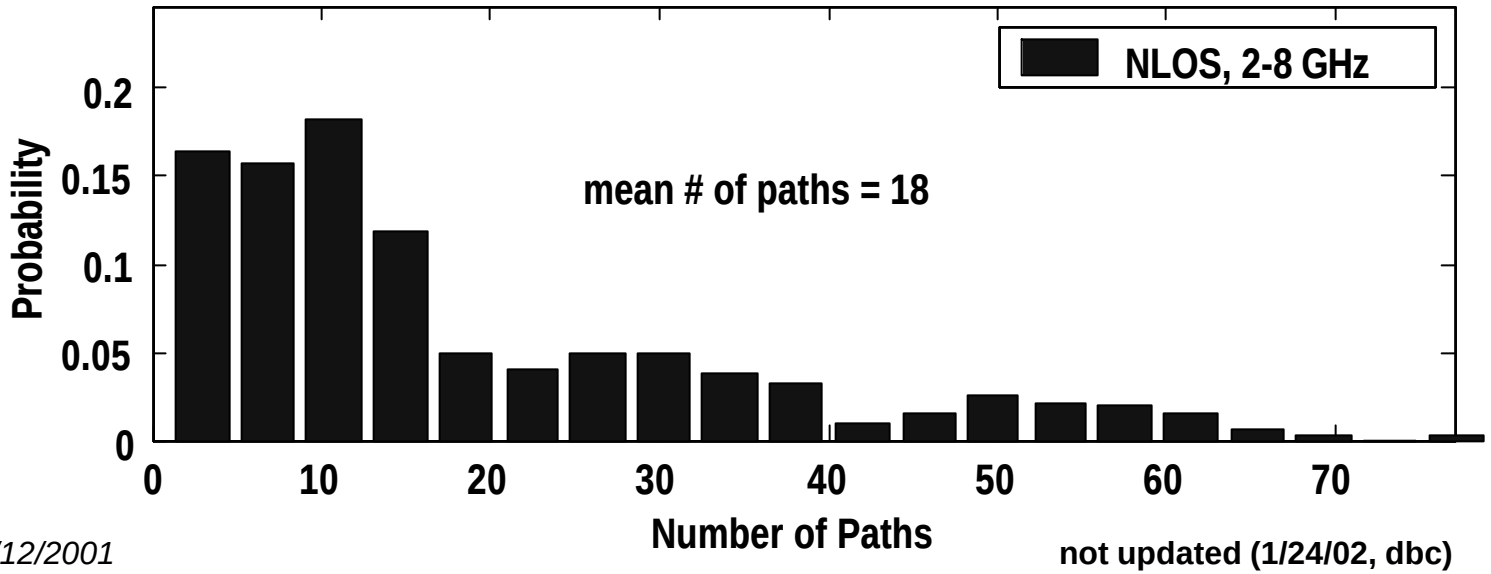




based on Witrisal,
July 2001

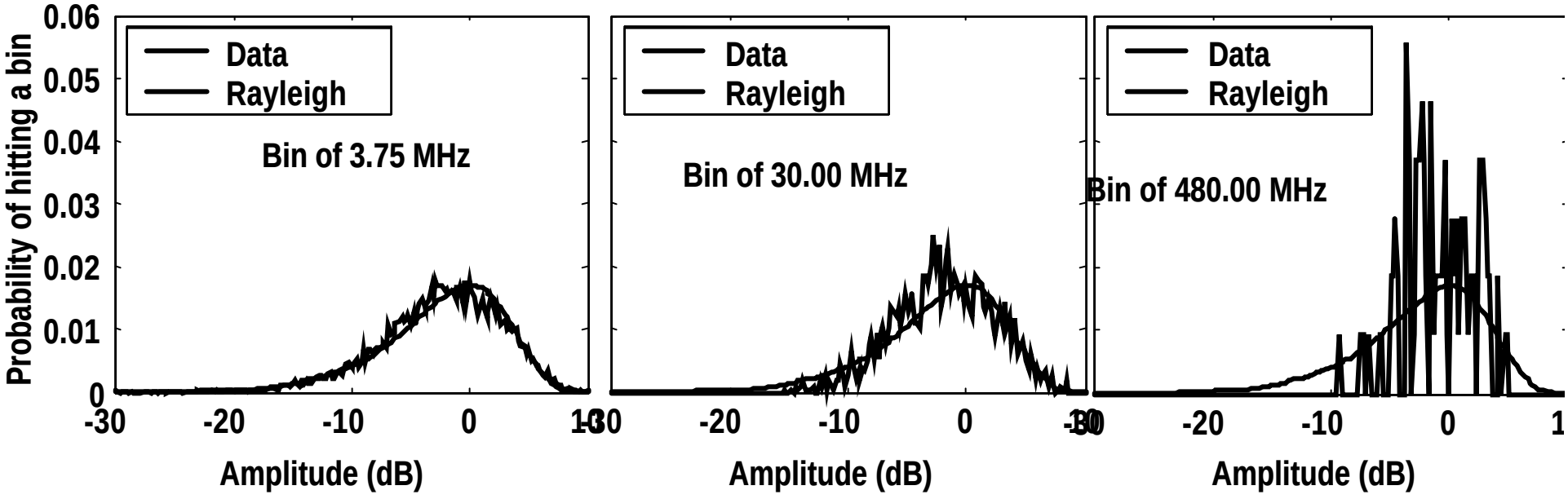
Distribution of Number of Paths
.33 ns resolution



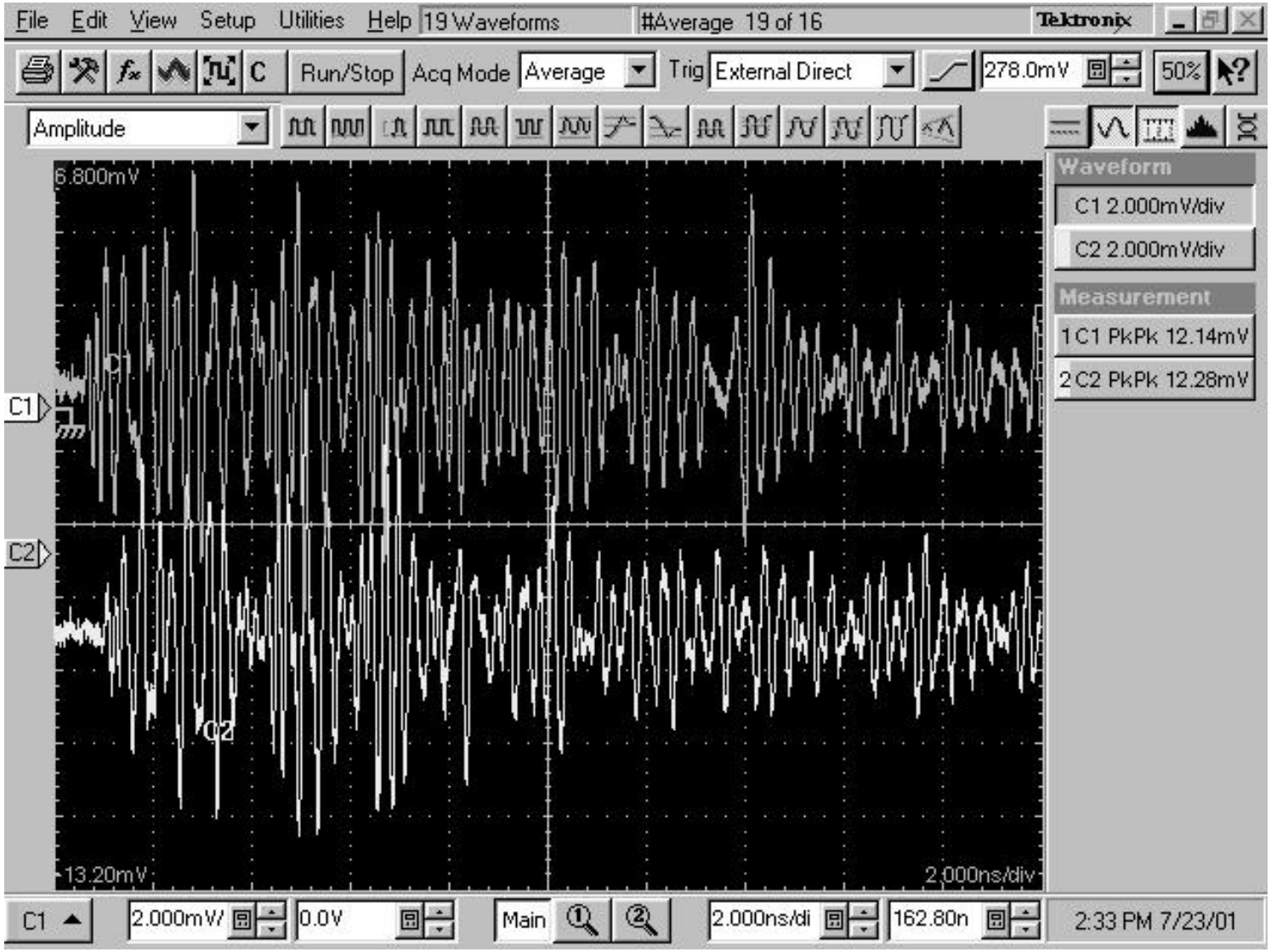


Narrowband Fading

- Examine narrowband bins in the frequency domain and find fading (relative energy) among these bands
- As bin size increases, fading veers away from Rayleigh

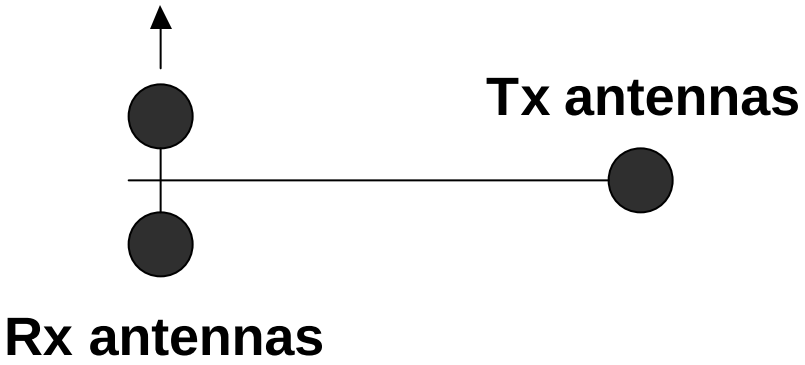


Received Pulser Waveforms

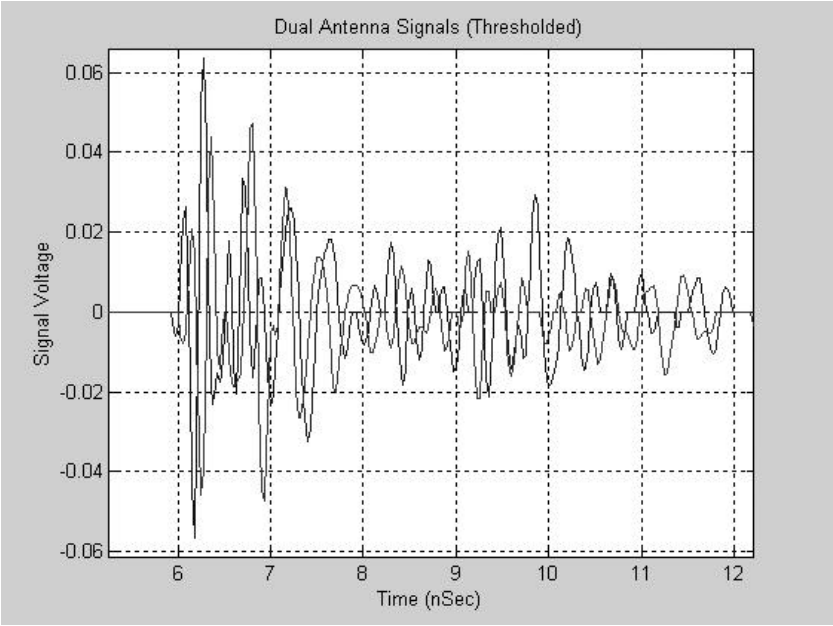


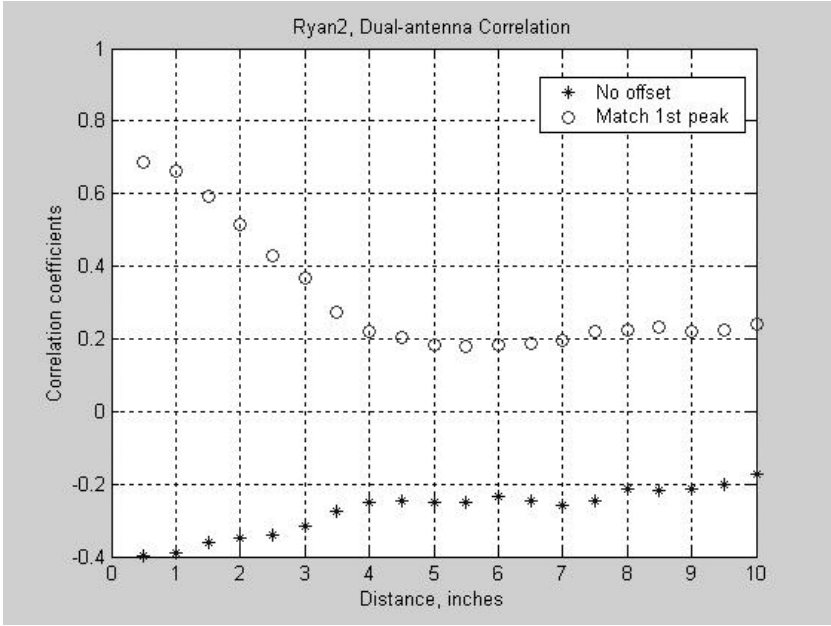
Dual-Antenna Correlation

- **Narrowband signals**
  - **Correlation between antennas**
    - Angular spectrum of incoming wave
    - Antenna separation (in wavelengths)
  - **Example**
    - Uniform illumination
    - Antenna separation of ?/2
- **UWB signals**



Dual-Antenna Data





- **Measurement characteristics**
  - **Townhouse positions**
  - **Oscilloscope data over time**
  - **4000 points over 100 nsec**
  - **Stable timing reference**
- **Average distance ~ 4 inches**

Conclusion

- Significant number of paths that increases with time resolution
- Even within 10 dB, we get ~30 NLOS paths at .16 ps resolution
- 70-80% of pulse energy within 10 dB of peak for all time resolutions
- Delay spread
  - ~ 15 ns for NLOS, 8 ns for LOS,
  - 20 ns for NLOS using frequency domain technique
- Future analysis
  - Distribution of multipath intensity
  - Statistical model for UWB channel
- Database of UWB Channel Soundings
  - Intel encourages pre-competitive sharing of data
  - University may be best location