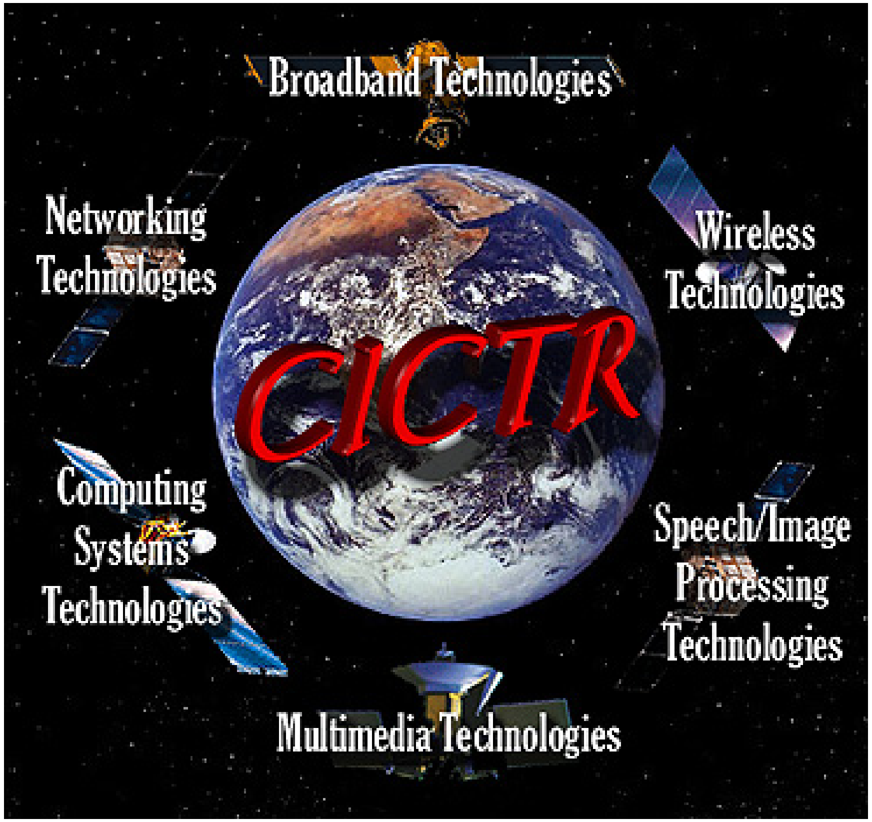
Architecture and Predicted Performance of an IEEE 802.11b-like Wireless Metropolitan Area Network Transceiver at 5.8 GHz

Center for Information and Communication Technology Research



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Outline

- Anntron Inc.'s WMAN System Architecture
  - Network Topology
  - Components:
    - UNII-Link Transceiver, Multibeam Antenna Assembly, Intelligent Hub Access System
  - Predicted Performance Analysis
  - Benefit of Adaptive Rate-Switching
- Narrowband Channel Sounding at 5.8 GHz
  - RSS Data Reduction Methodology
  - RSS Data Histogram and CDF
  - Minimum Fade Margin Analysis
  - Minimum Chi-Square (X^2) Analysis
  - Level Crossing Rate and Average Fade Duration

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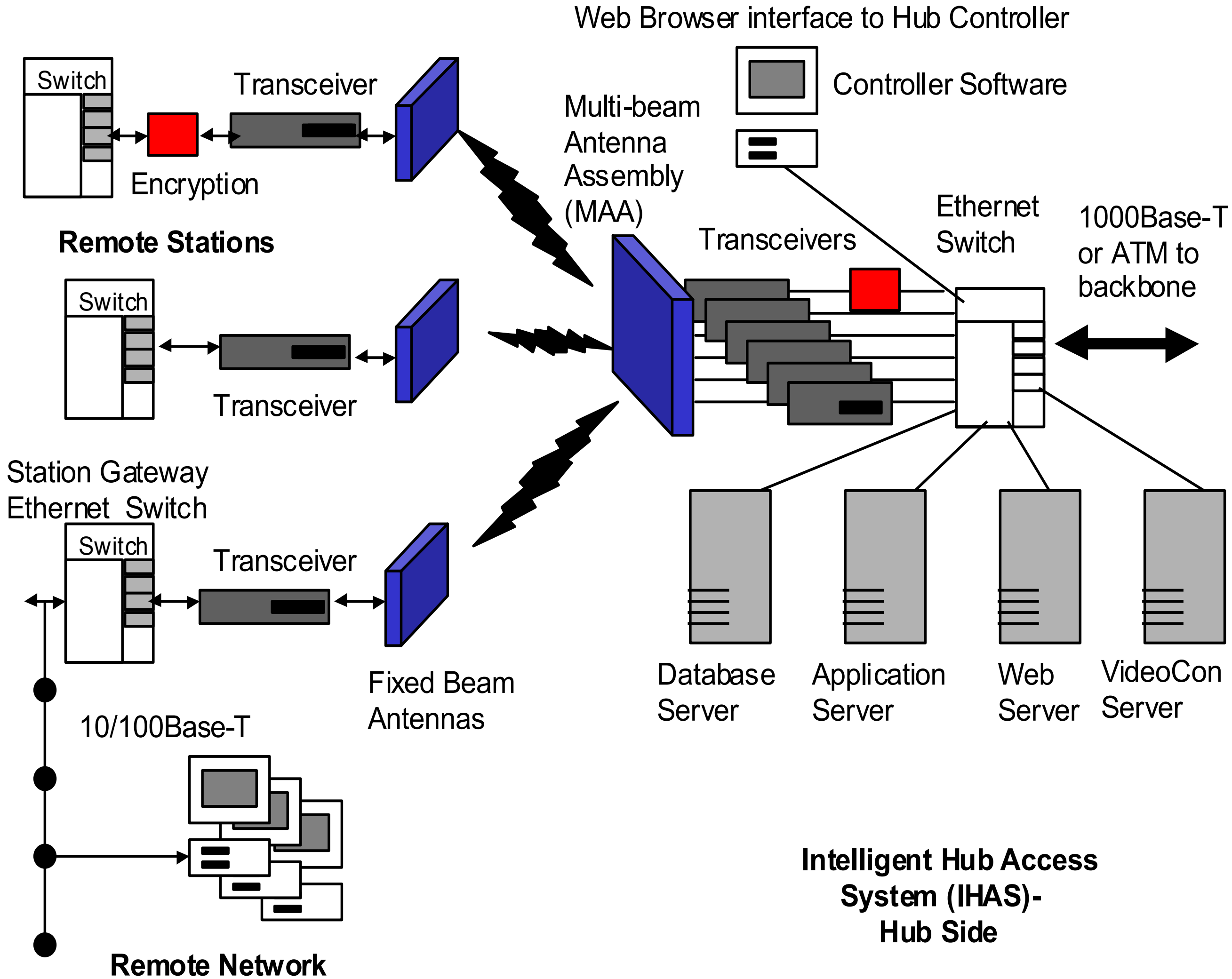
WMAN Architecture



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Anntron's WMAN Components

- Wireless Metropolitan Area Network (WMAN)
  - UNII-Link - point-to-point wireless LAN bridge
    - Based on IEEE 802.11b WLAN standard
    - Intersil's PRISM II chipset
    - Custom Medium Access Controller (MAC) optimized for outdoor, point-to-point LAN bridging
  - MAA - Multibeam Antenna Assembly
    - 6 main lobes over 90 degrees
    - Angular and antenna polarization diversity
  - IHAS - Intelligent Hub Access System
    - Contention-free medium access through switched Ethernet LAN microsegmentation
    - Pause packets provide full-duplex flow control

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UNII-Link WMAN Transceiver

- MODEM: Intersil's PRISM II
  - Baseband Processor (HFA3863)
    - DSSS Modulation: 1, 2, 5.5, and 11 Mbps rates
    - Rake Receiver and Decision Feedback Equalizer
  - I/Q Mod/Demodulator (HFA3783)
    - Baseband to IF conversion with 70 dB of AGC
- MAC optimized for outdoor, point-to-point LANs
  - Rate-Switching algorithm reduces probability of packet errors (adaptive modulation)
  - Removed inherent latency of IEEE 802.11b's Distributed Coordination Functions (DCF)
  - Prevent buffer overflow through MAC layer flow control

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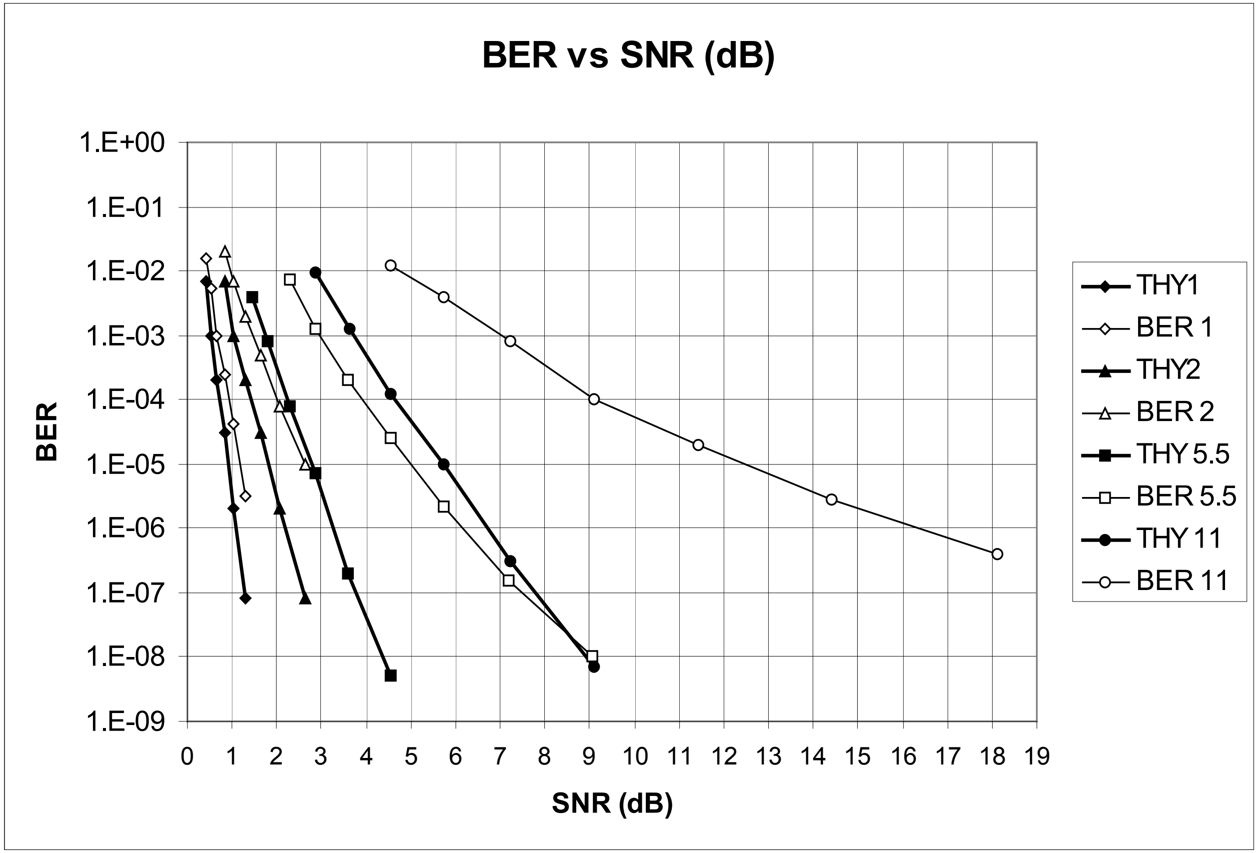
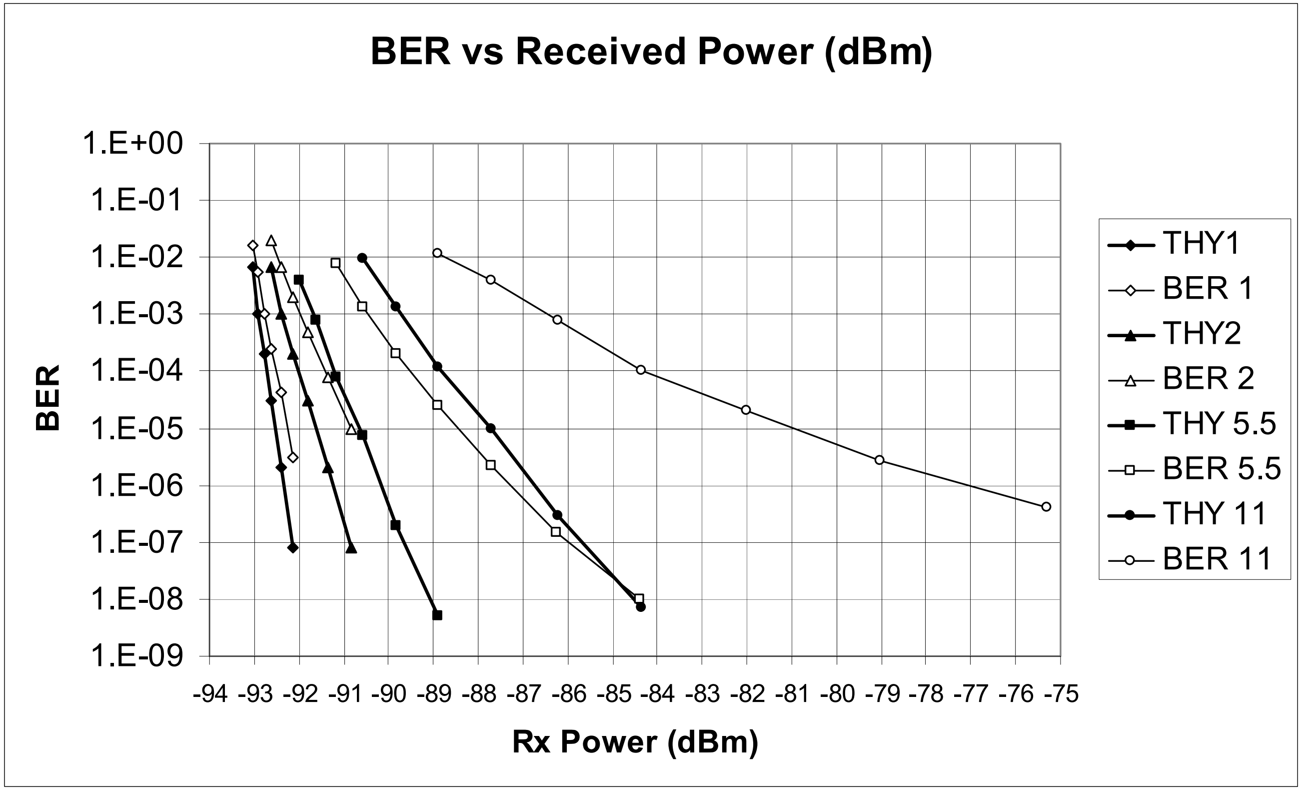
BER vs. SNR Performance Curves
Predicted Performance of UNII-Link

- Convert PRISM II BER vs. E_b/N_o curves to BER vs. SNR



BER vs. Rx Power (dBm) Performance Curves Benefit of Adaptive Rate-Switching

- BER vs. Rx power curves – apply adaptive rate-switching
  - Define minimum performance, select modulation level that can provide BER
  - Required Rx power to maintain BER of 10^{-6} drops 15 dB going from 11 to 1 Mbps



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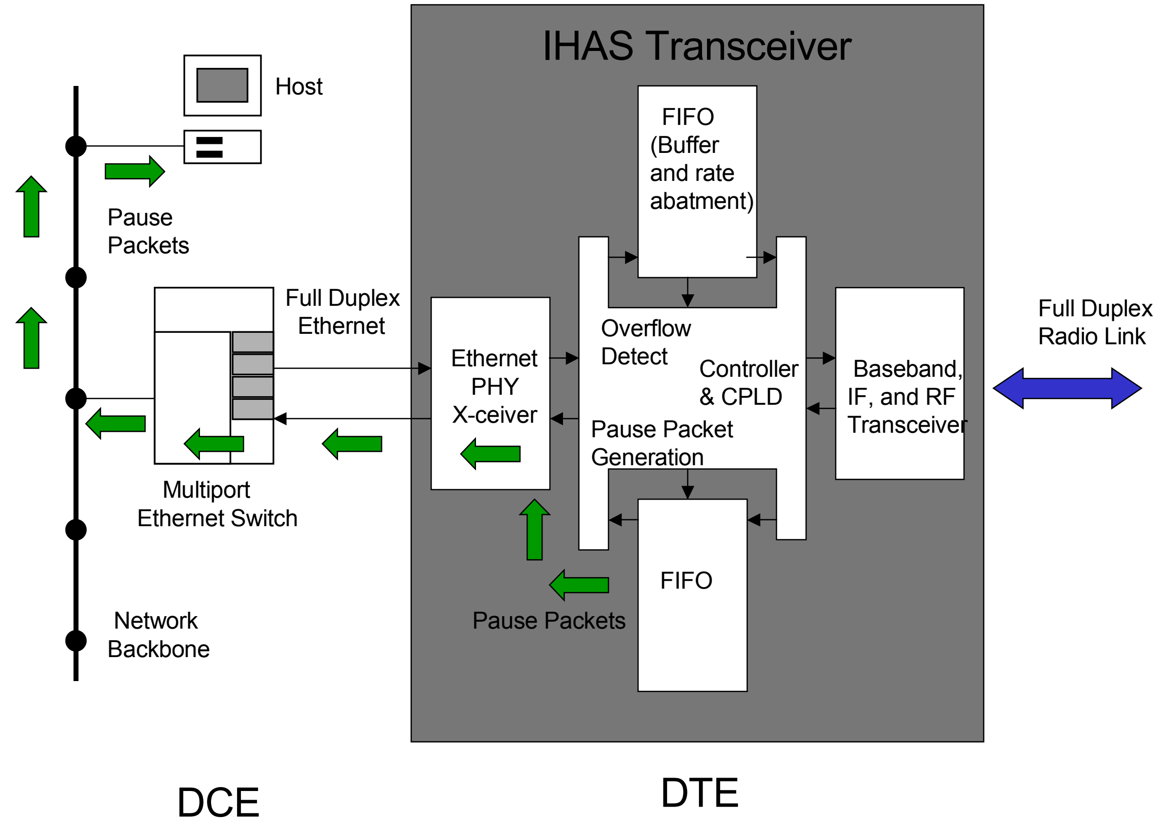
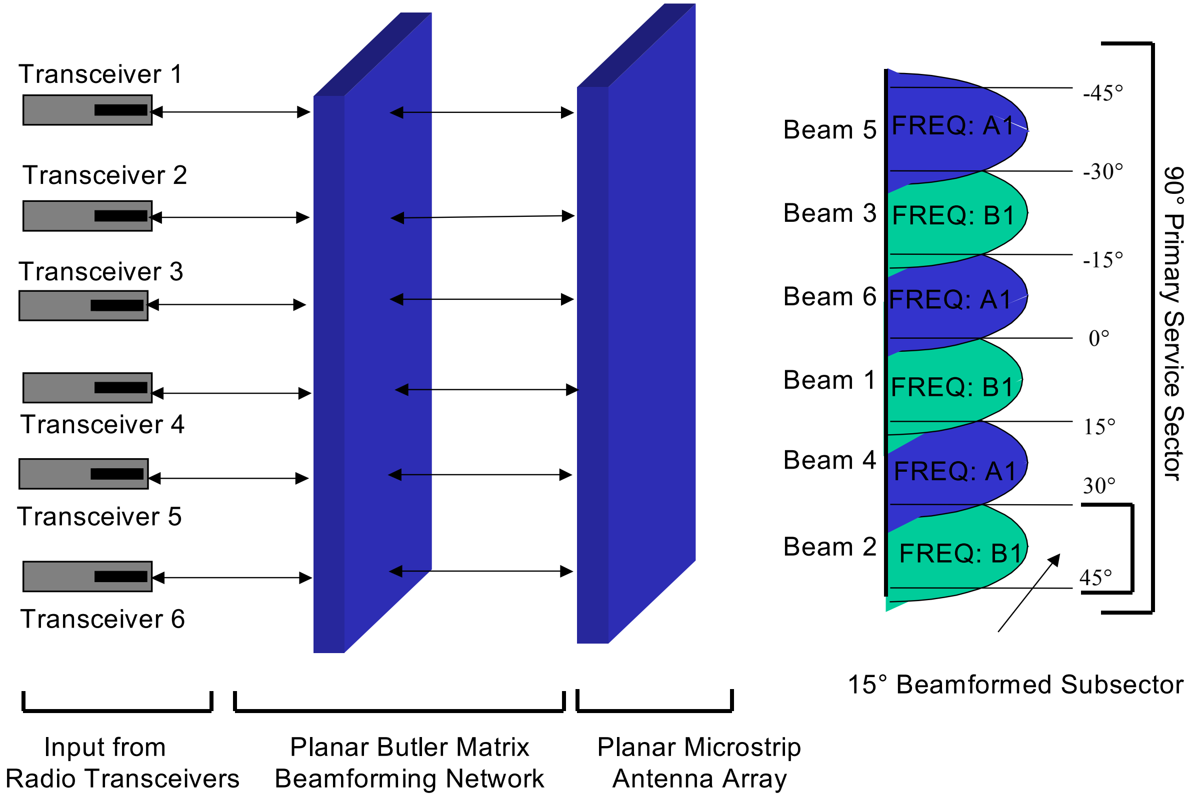
IHAS Architecture

- IHAS - Intelligent Hub Access System
  - Switched Ethernet Hub – LAN Microsegmentation
  - Pause packets quench Ethernet Source when transmit buffers reach capacity



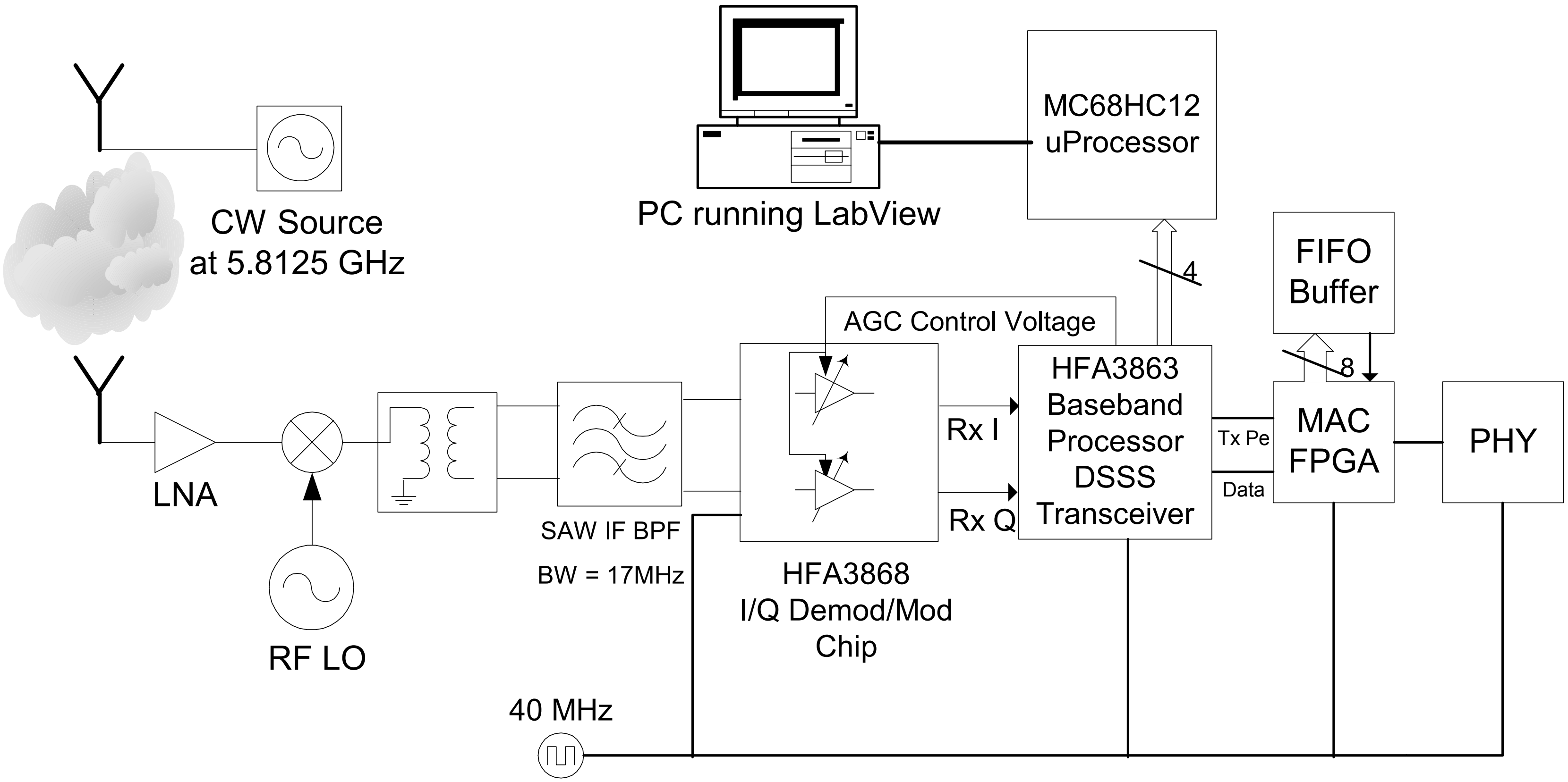
Multi-beam Antenna Assembly

- Provides angular and antenna polarization diversity
- Segments coverage area into point-to-point sub-sectors



Narrowband Channel Sounding at 5.8 GHz

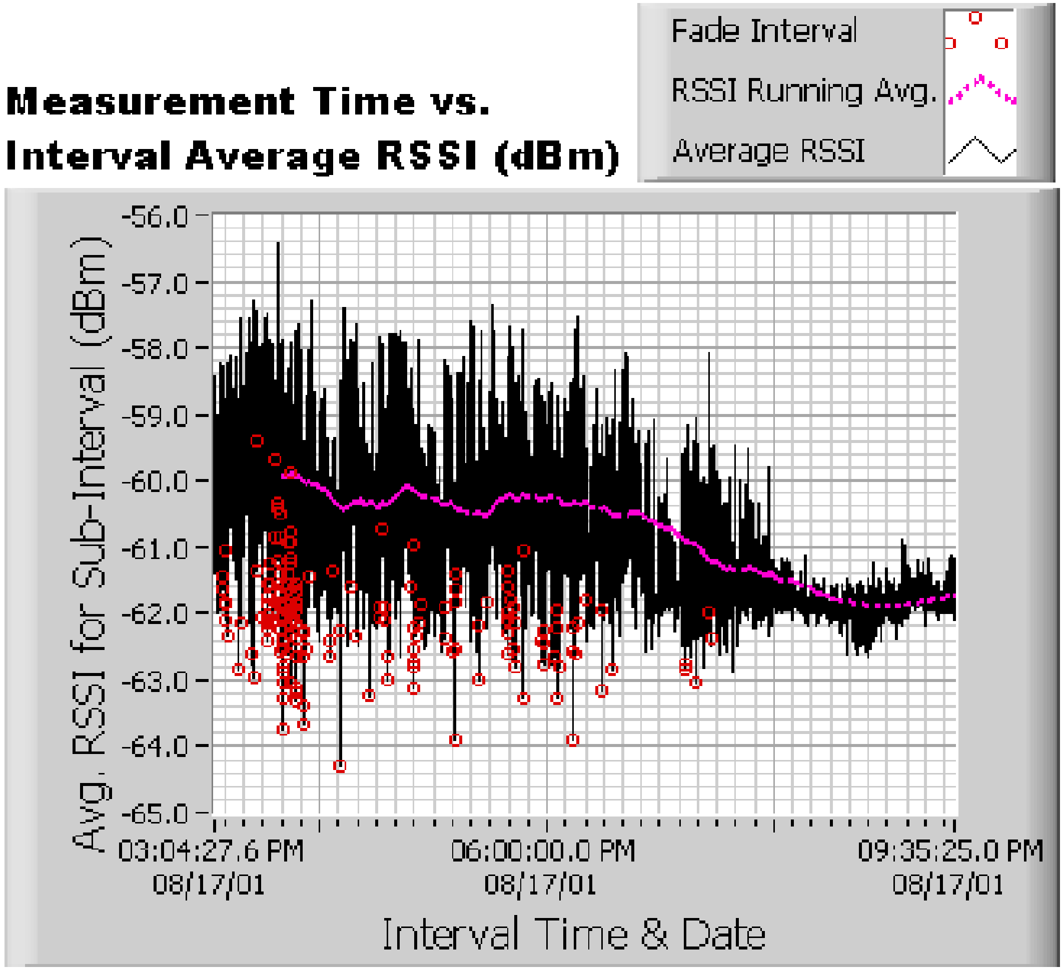
Narrowband channel sounding for Near-Line-of-Sight (NLOS) Link: Measure Received Signal Strength (RSS) of a transmitted CW signal



RSS Data Reduction Methodology (1/2)

Capture Fading Intervals:

- RSS sampling rate = 2000 S/sec
- Segment long-term measurement into 2-second intervals
- Calculate running-average of previous 2000 interval averages
- Record interval RSS samples if 15 samples are 5 dB below running-average of interval averages



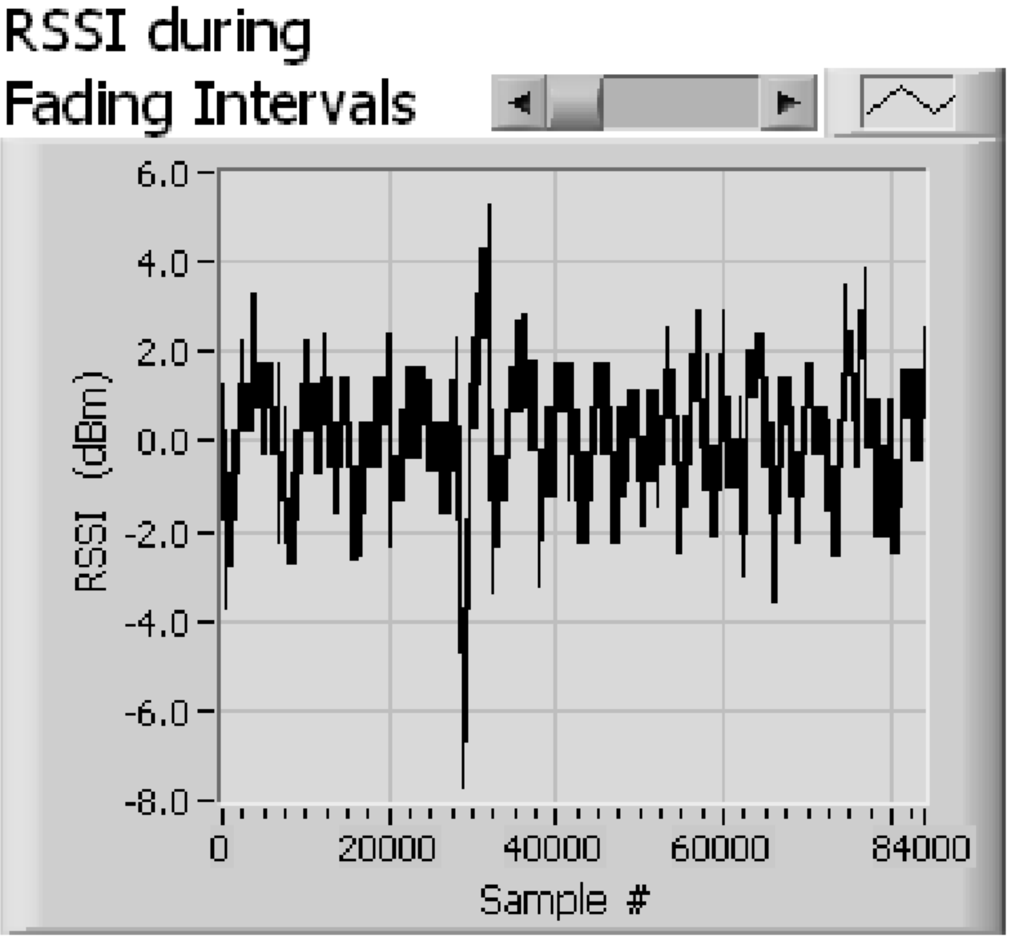
RSS Data Reduction Methodology (2/2)

Data analysis procedure:

- Normalize RSS samples to fading interval average
- Calculate histogram, CDF, level crossing rate, and average fade duration

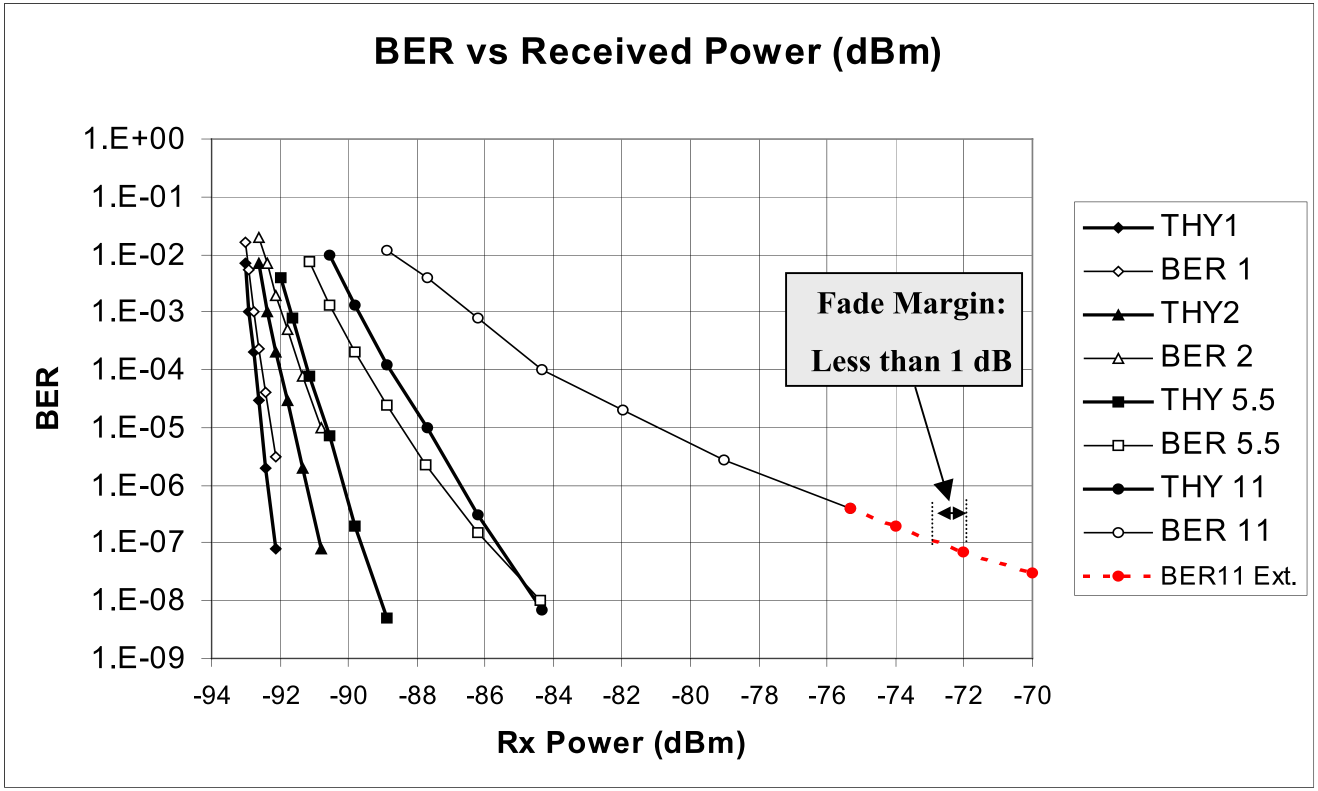
Find lowest received power:

- Minimum of temporal variations relative to interval mean: -8 dBm
- Temporal minimum occurred during 2nd lowest RSS interval mean: -64 dBm
- ➓ Lowest received power: –72 dBm

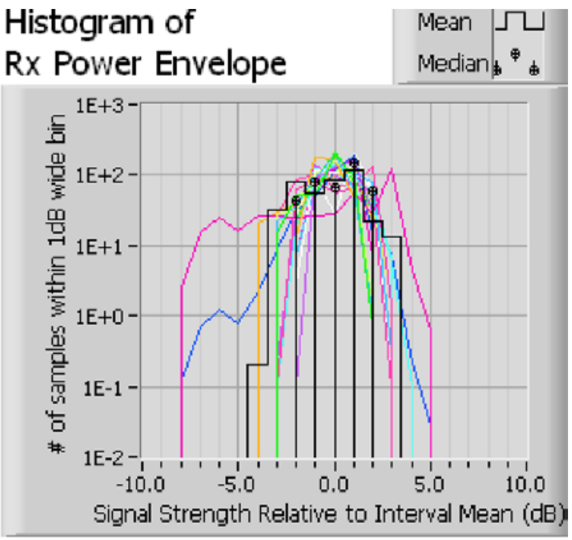


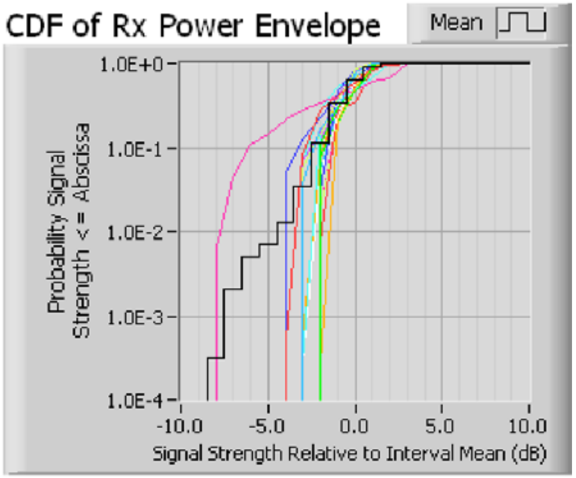
Calculating Minimum Fade Margin

- Consider the lowest received signal power: -72 dBm
  - Take measurement during worst-case channel conditions
  - Use maximum accepted BER to establish the fade margin



Experimental RSS Data Histogram and CDF





Histogram of RSS

- Outlier intervals due to mobile scattering (moving foliage in path)

CDF of RSS

- Probability of a 6 dB fade
  - Outlier interval: 10%
  - Mean: 0.7%

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Minimum Chi-Square (X^2) Analysis - Fitting Rayleigh and Rician PDFs to Experimental PMF (1/2)

- **Minimum Chi-Squared (X^2) Analysis**

$$X^2 = \sum_i \frac{N(\hat{p}(X_i) - p(X_i))^2}{p(X_i)}$$

- **Rayleigh Channel Fading Model – expressed in dB**

$$p(y) = \frac{1}{M\sigma^2} \exp\left[\frac{2y}{M} - \frac{1}{2\sigma^2}\exp\left(\frac{2y}{M}\right)\right] \qquad M = \frac{20}{\ln 10}$$

- **Rician Channel Fading Model – expressed in dB**

$$p(y) = \frac{1}{M\sigma^2} \exp\left\{\frac{2y}{M} - \frac{1}{2\sigma^2}\left[r_s^2 + \exp\left(\frac{2y}{M}\right)\right]\right\} \cdot I_0\left[\frac{r_s}{\sigma^2}\exp\left(\frac{y}{M}\right)\right]$$

  - Vary LOS component of K-Factor: $r_s = 2\sigma^2 10^{\frac{K}{10}}$

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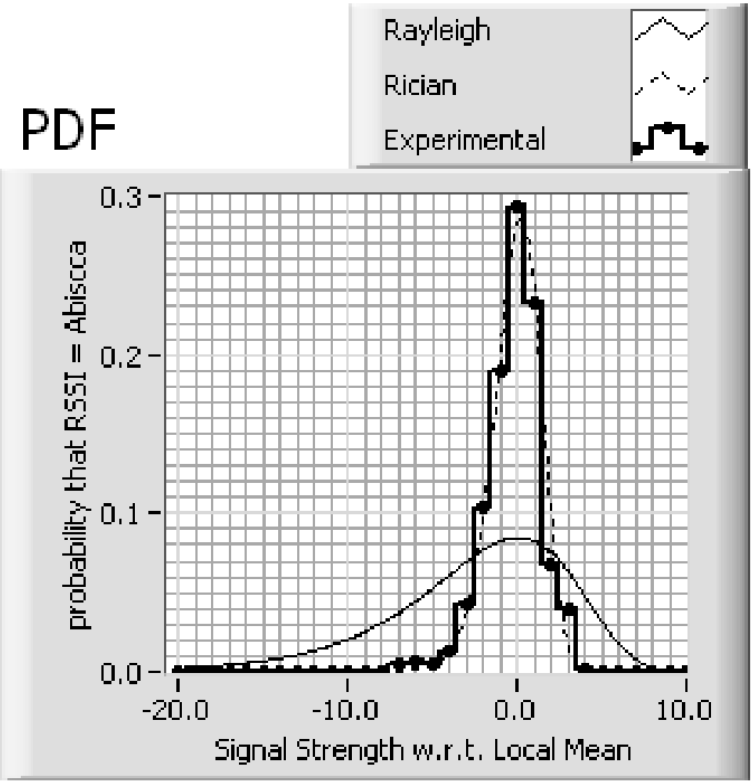
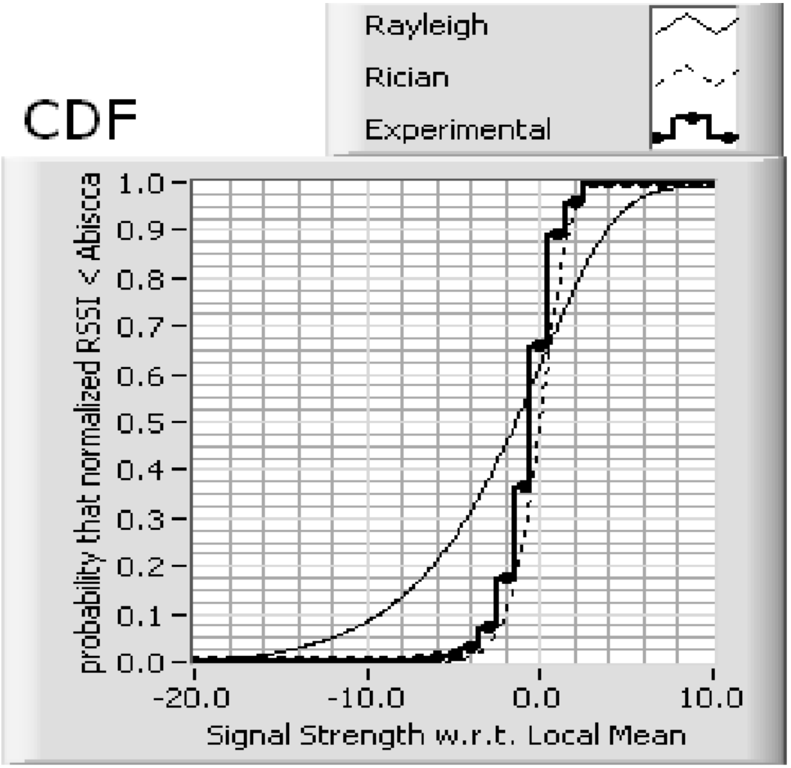
Minimum Chi-Square (X^2) Analysis - Fitting Rayleigh and Rician PDFs to Experimental PMF (2/2)





PDF Type	σ^2	K-Factor (dB)	X^2 Goodness-of-fit test result
Rayleigh	0.51	-	7.1%
Rician	0.027	12.6	99.99%

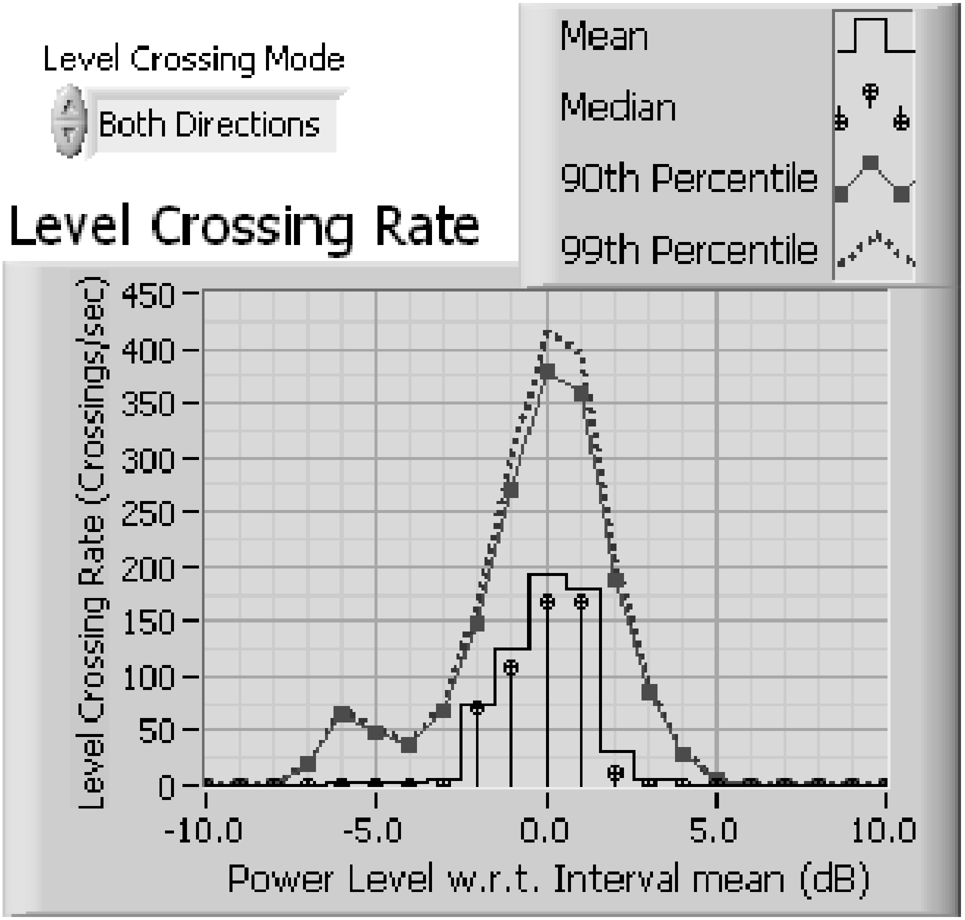
Level Crossing Rate (LCR)

LCR of RSS

- LCR is mostly symmetrical around 0 dBm

  (Fading Interval mean)

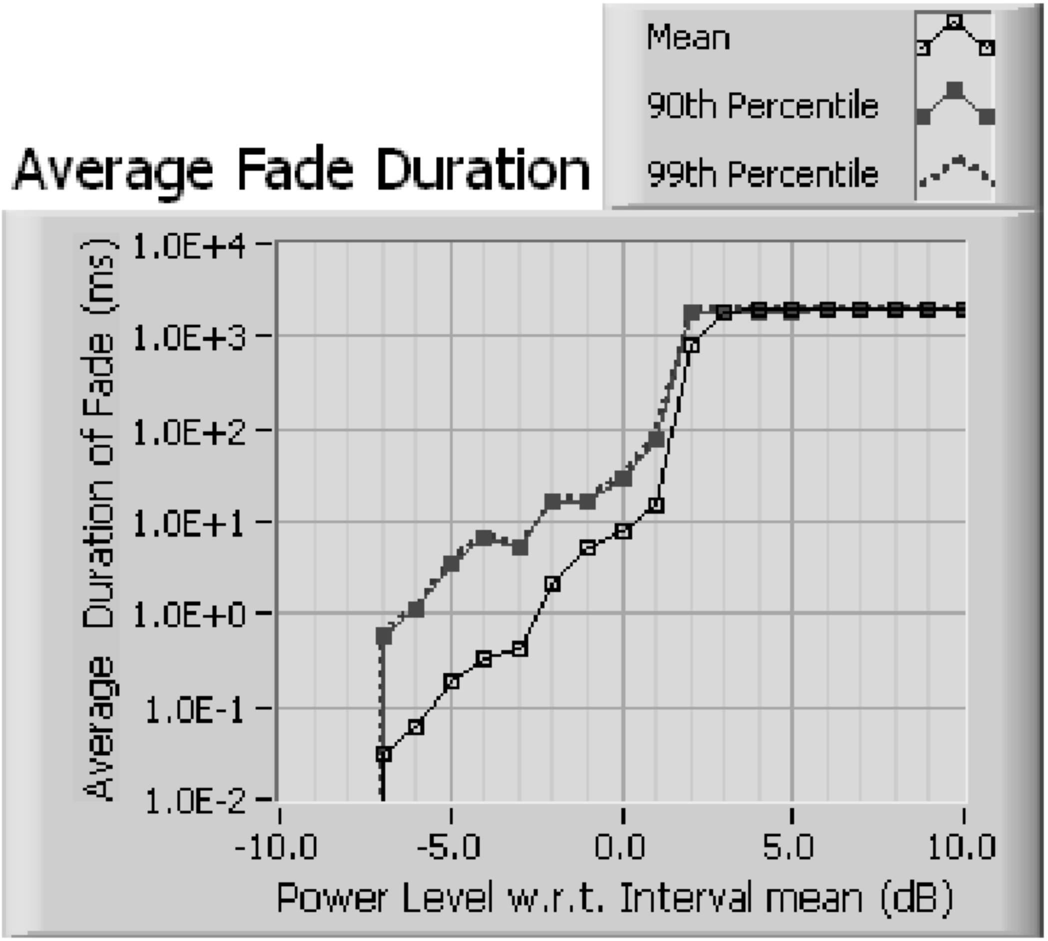
- LCR at –6 dBmn
  - 90th Percentile: $70\,\frac{\text{crossings}}{\text{second}}$
  - Mean: $< 5\,\frac{\text{crossings}}{\text{second}}$



Average Fade Duration (AFD)

AFC of RSS

- AFC at –6 dBmn
  - 90^{th} percentile: 1 ms
  - Mean: < 100 μsecs



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Conclusion

- WMAN architecture benefits from an optimized bridge
  - Stripped down MAC – remove IEEE 802.11b's inherent latency
  - Data Link Layer flow control through Pause packets
  - Adaptive rate-switching algorithm mitigates poor channel conditions due to RSS fading
  - Eliminate co-channel interference through frequency, angular, and antenna polarization diversity
- Narrowband channel sounding of NLOS link at 5.8 GHz
  - RSS measurement test hardware & software is reusable
  - Rician Channel model fit the experimental RSS data (99.99%) with K-Factor = 12.6 dB and variance = 0.027
  - A posteriori required fade margin: < 1 dB