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Purpose:

To aid in the PHY Task Group's preparation of a detailed evaluation table for performance of PHY layer air interface proposals.

Release:

The contributor acknowledges and accepts that this contribution may be made public by 802.16.

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MULTIPATH MEASUREMENTS AND MODELLING FOR FIXED BROADBAND WIRELESS SYSTEMS IN A RESIDENTIAL ENVIRONMENT

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Background

- Multipath delay spread can be a major transmission problem, which must be characterized before design of modulation, equalization and diversity can be finalized.
- Delay spread varies with environment and characteristics of transmit and receive antennas.

Objectives of the Study

- To propose a multipath model for 29 GHz broadband fixed wireless systems by analysis of measured impulse response data from two districts in Ottawa.
- The measurements and modelling were primarily for residential environments, where line of sight is not always guaranteed.

Measurements

- Impulse responses obtained by correlation from received 29.5 GHz signals, BPSK-modulated by 63-bit, 40 Mb/s PN sequences, I-Q sampled at 100 Msamples/s.
- Noise thresholding applied.
- For modelling, impulse responses normalized to unit energy, shifted so maximum is at sample #19, and rotated so max sample has zero phase.

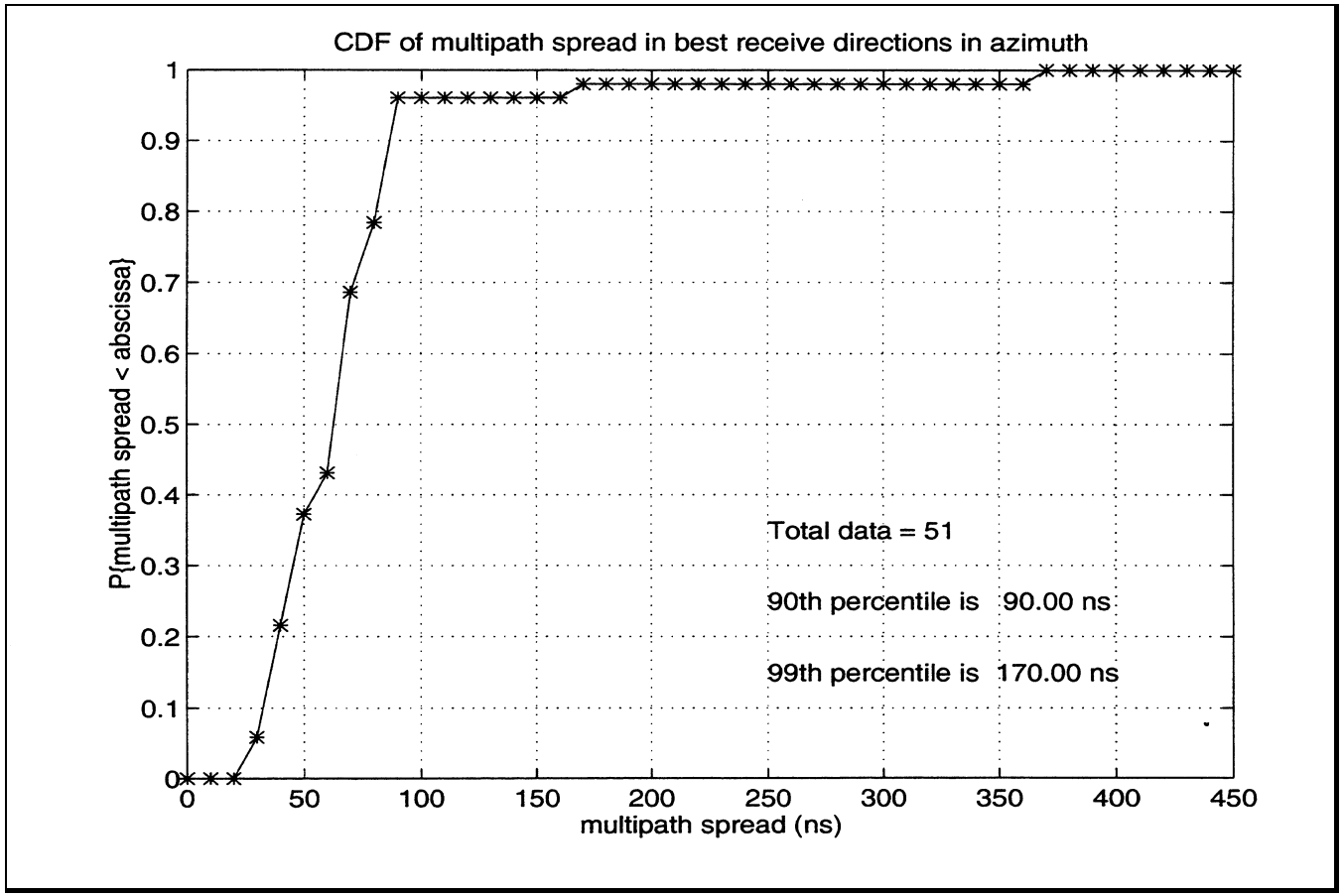
Measurements in Parkwood Hills

- Mainly residential: 1- and 2-story houses, some apartments, ~20% tree cover.
- 52 locations in 8 main sites. Ranges from 0.5 km. to 1 km. Many NLOS locations. Impulse responses measured at each of 60 bearings, 6 degrees apart at each location. RX height adjustable: 5 to 8 m.
- TX antenna mounted on roof of 40 m. apartment building: vertical 18 dBi horn; $\pm 11.5^{o}$ elevation, $\pm 8^{o}$ azimuth. Angled downwards 5^{o}.
- RX antenna: vertically polarized horn, $\pm 5^{o}$ azimuth and elevation.

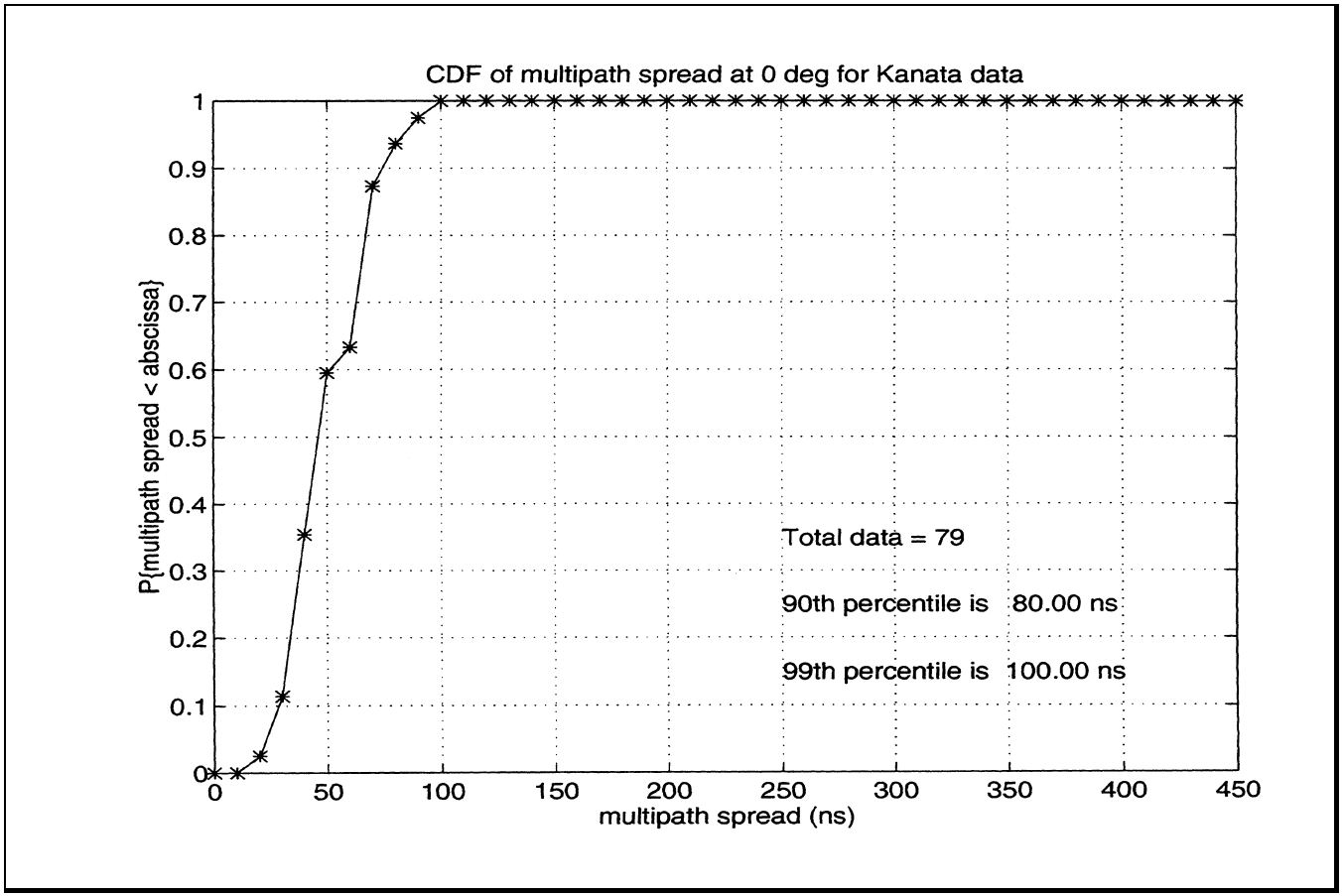
Measurements in Kanata

- Residential, light industrial. Measurement range: 1 to 3.5 km., mostly along a radial roadway leading from TX. At least ¾ of radial sites were LOS. There were also some nonradial-path sites in residential areas.
- TX antenna on 30 m. building, RX antenna at 7-10 m. height. Same TX antenna as in Parkwood Hills,but not angled down.
- RX antenna vertically polarized cassegrain reflector ±1º azimuth and elevation. Only one bearing angle at each location.
- 79 usable measurements.

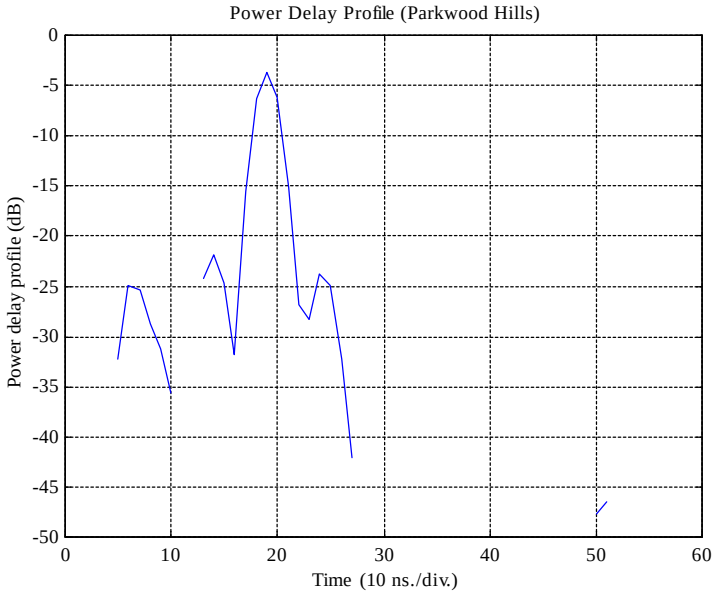
Multipath Spread Distribution Measured in Parkwood Hills

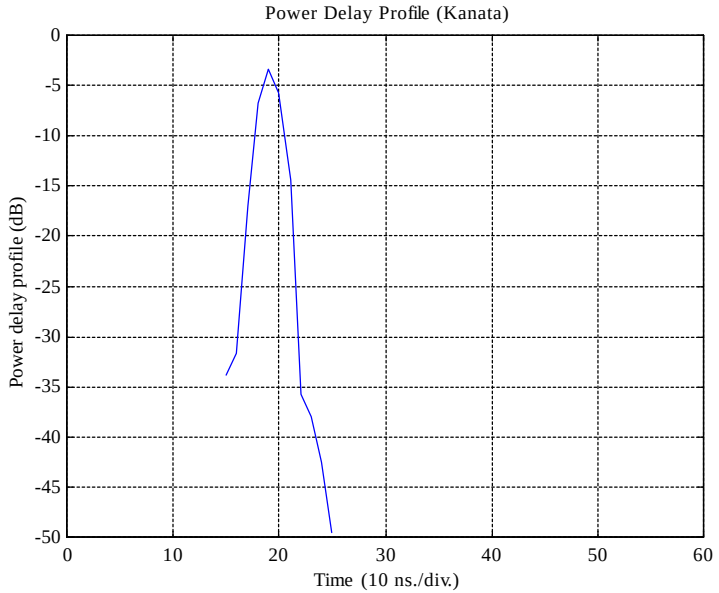


Multipath Spread Distribution Measured in Kanata

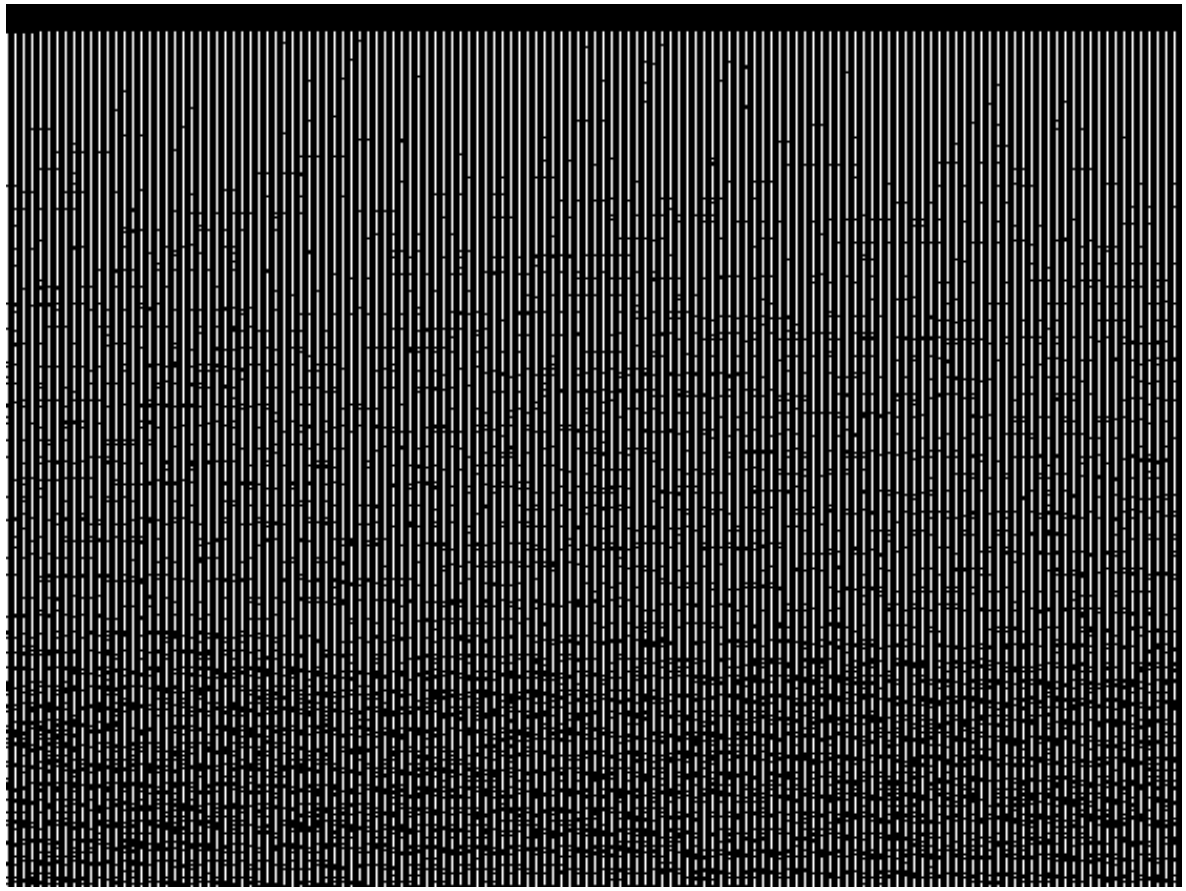


Average Power Delay Profiles for Parkwood Hills and Kanata

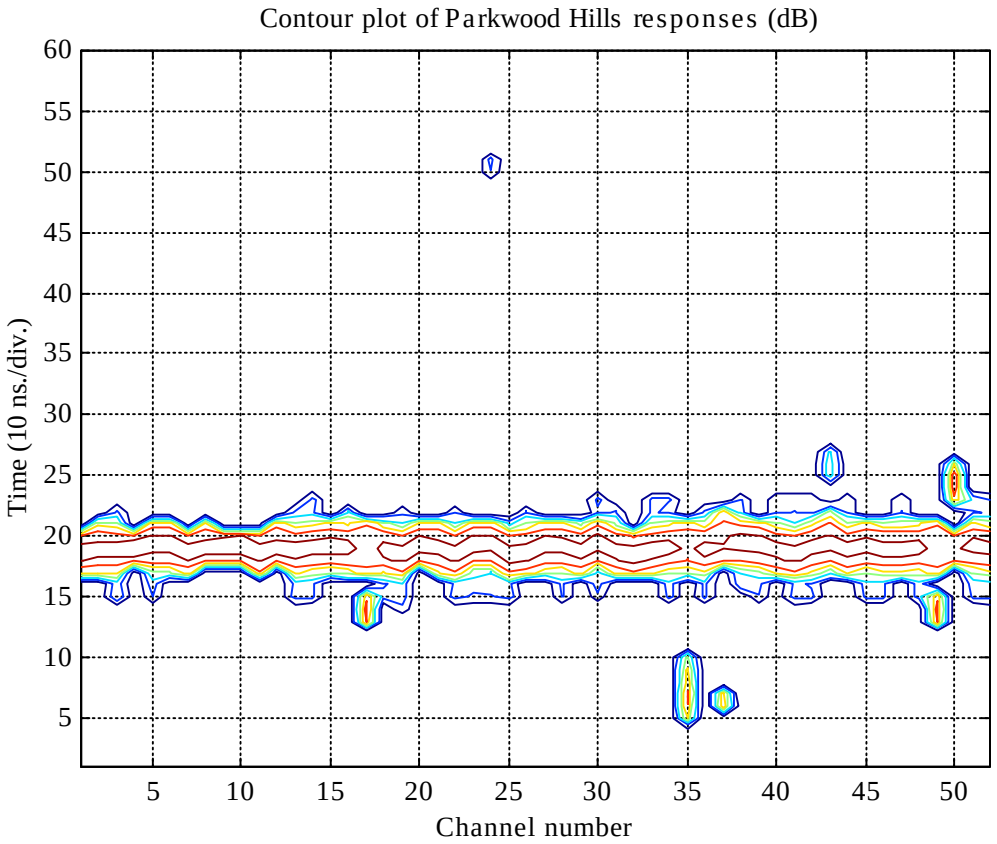




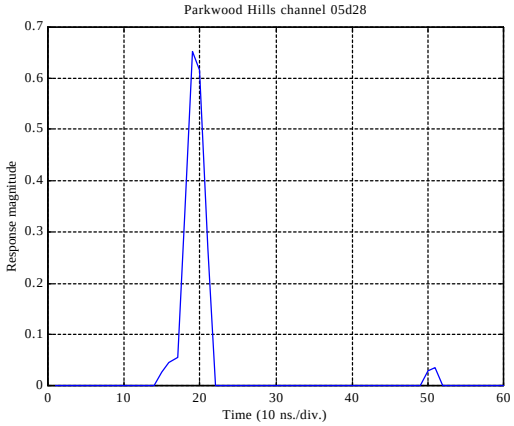
Parkwood Hills Impulse Response Magnitudes

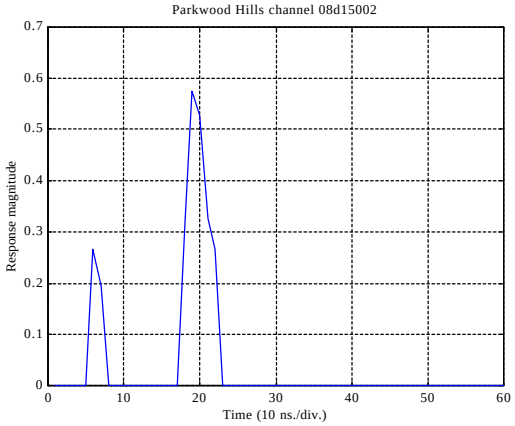


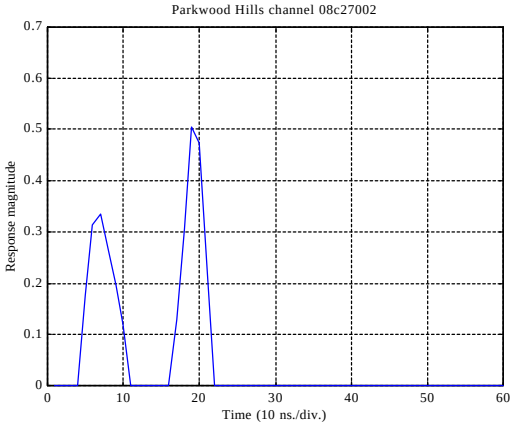
Parkwood Hills Impulse Responses – Contour Plot

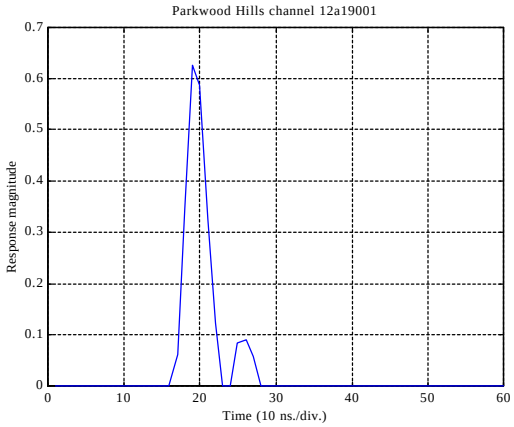


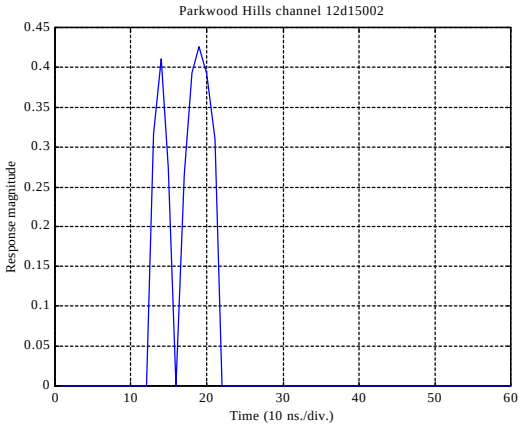
Parkwood Hills – Worst Cases

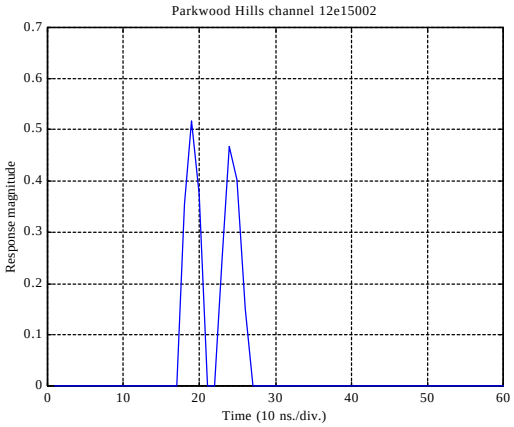




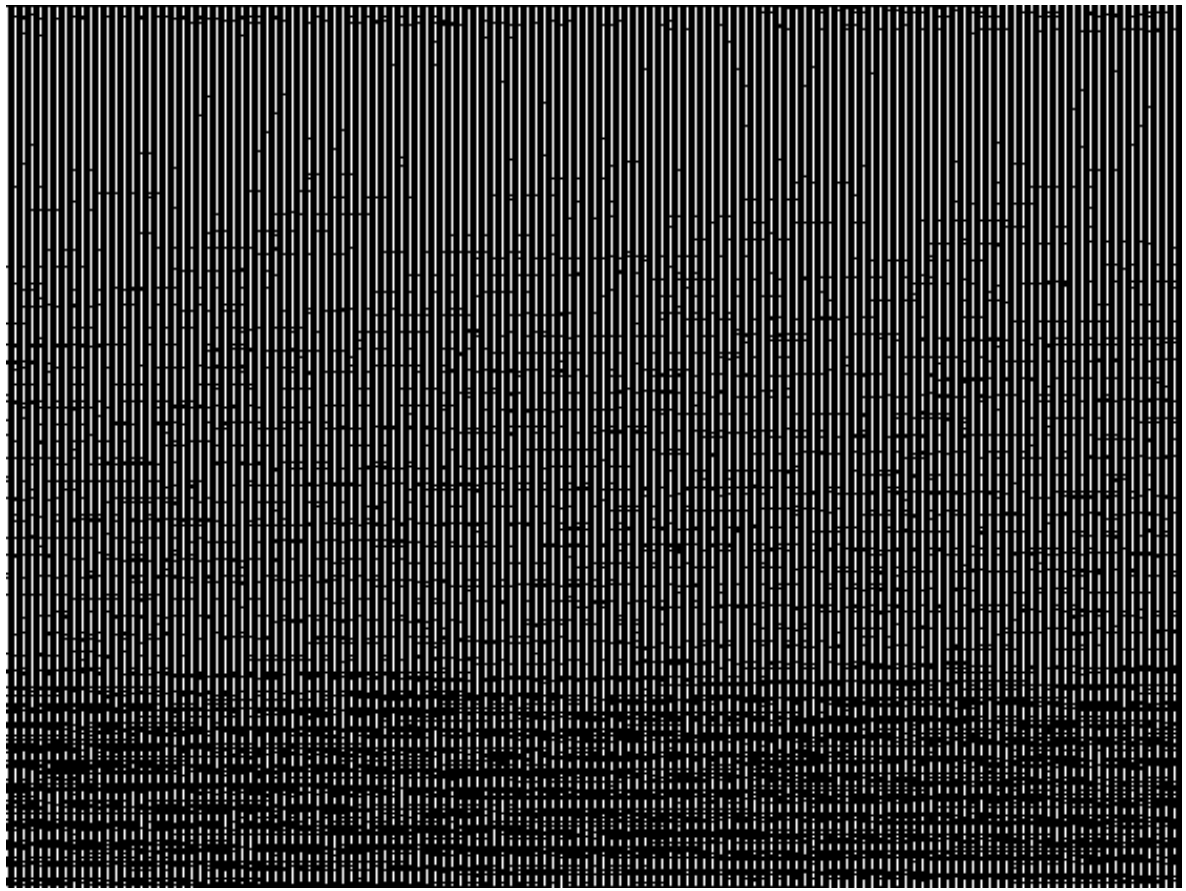




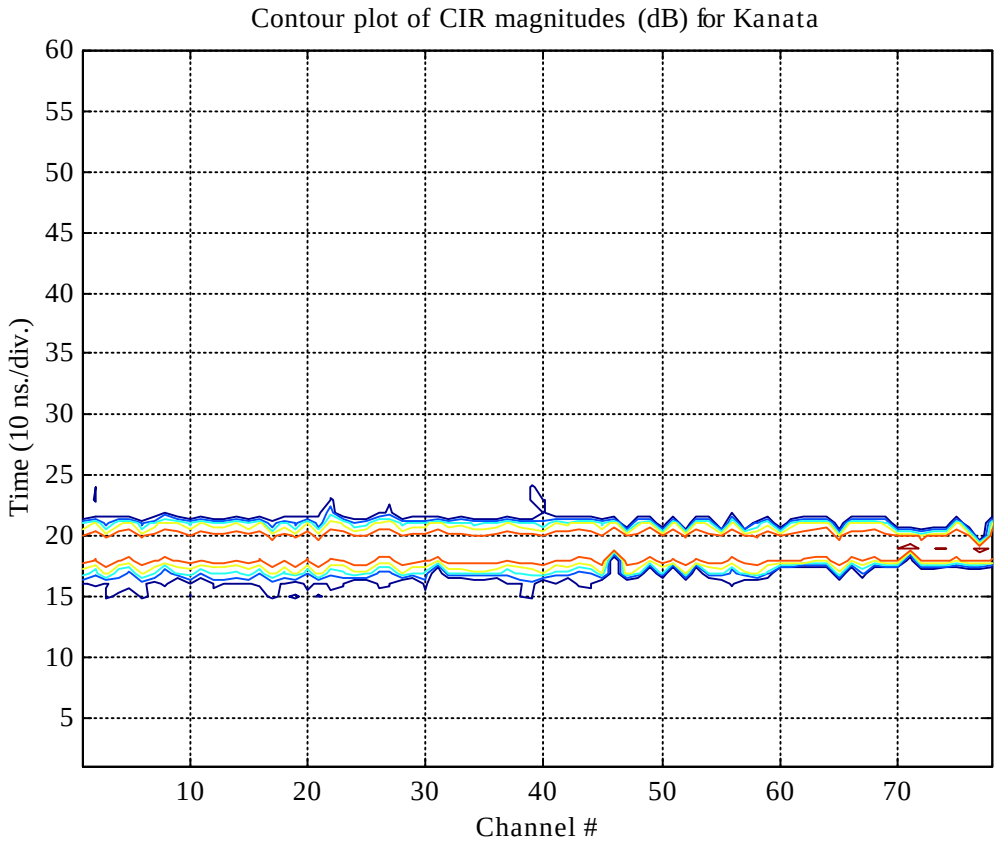




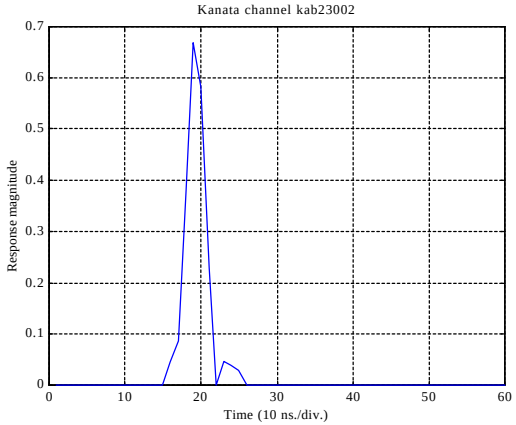
Kanata Impulse Response Magnitudes

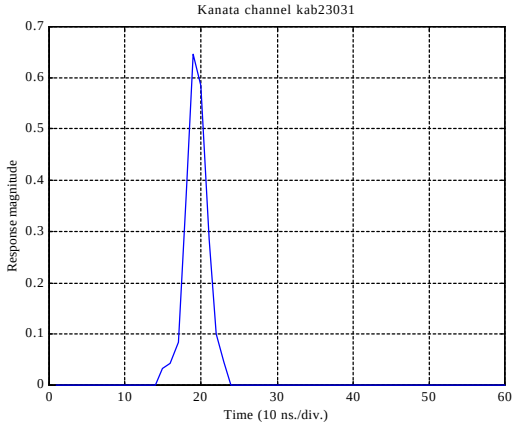


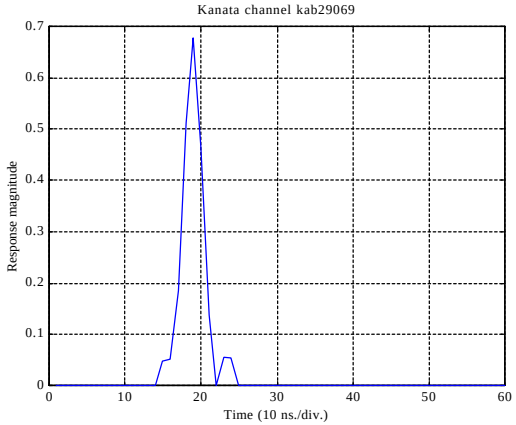
Kanata Impulse Responses – Contour Plot

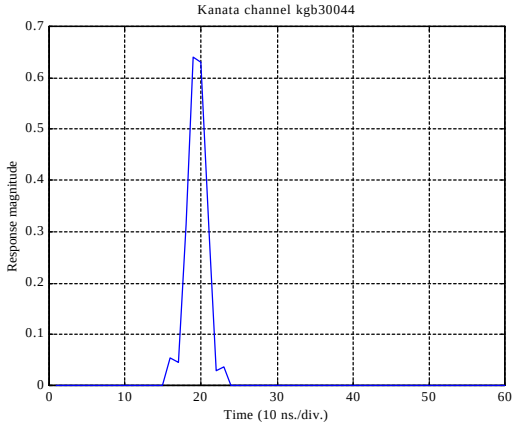


Kanata – Worst Cases

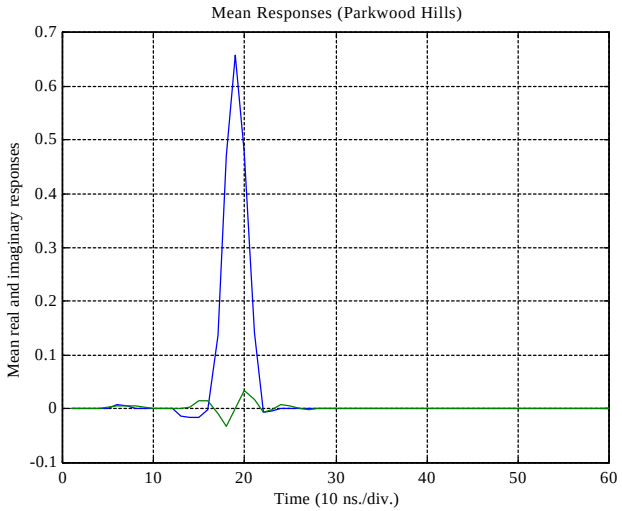


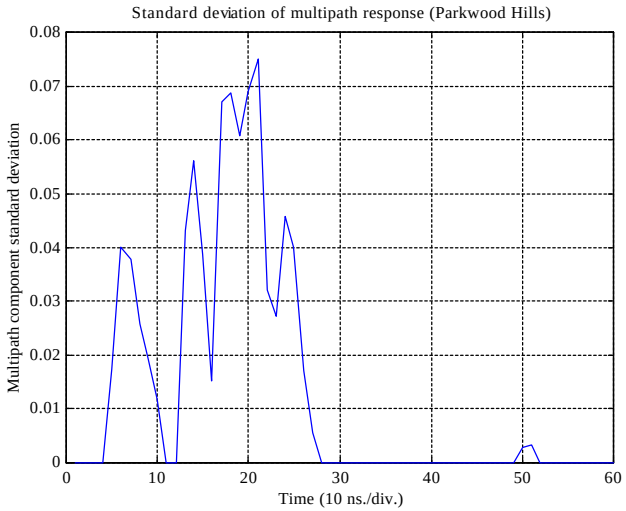


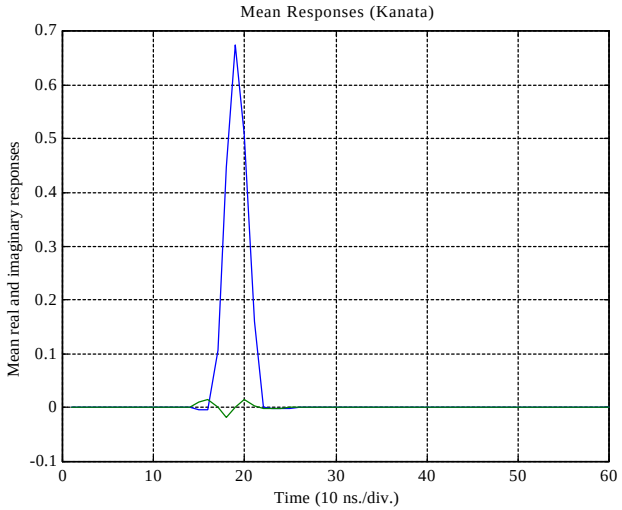


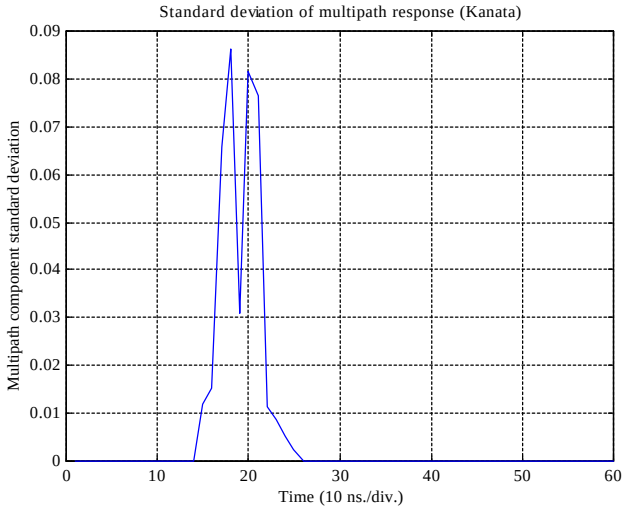


Average (Real and Imaginary Parts) and Standard Deviation of Responses

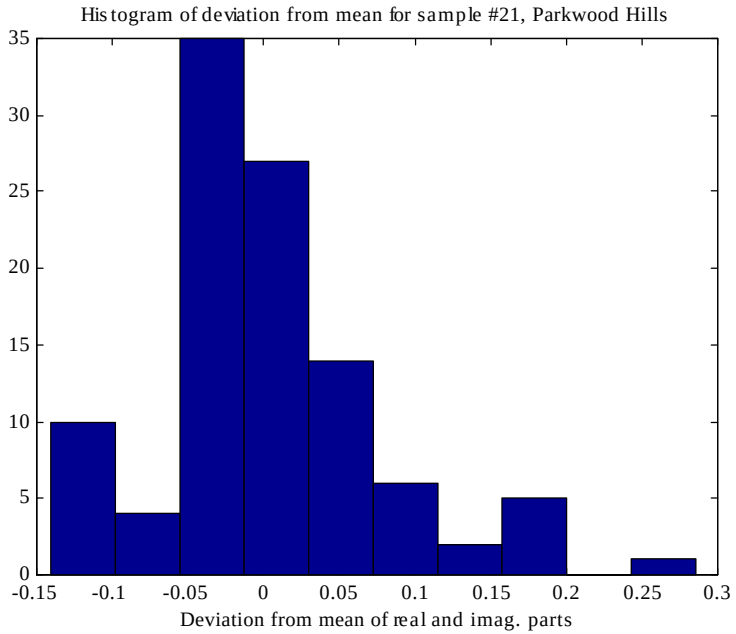


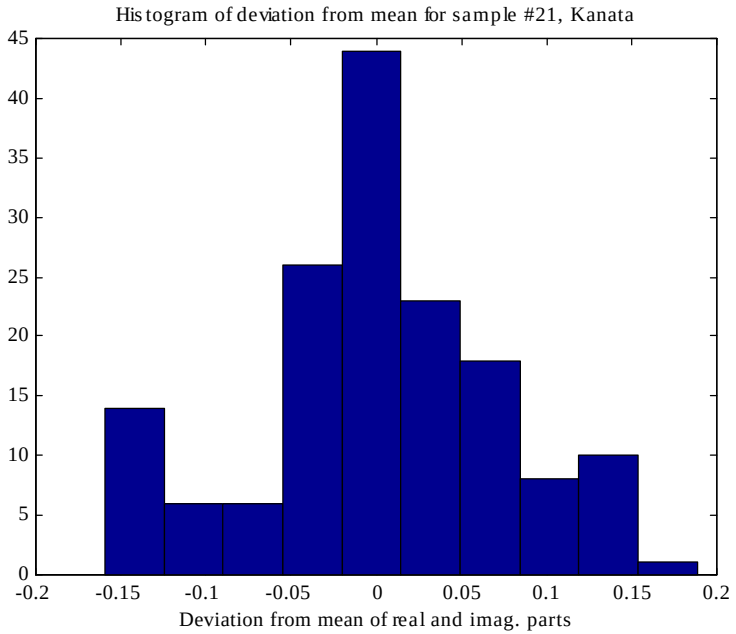




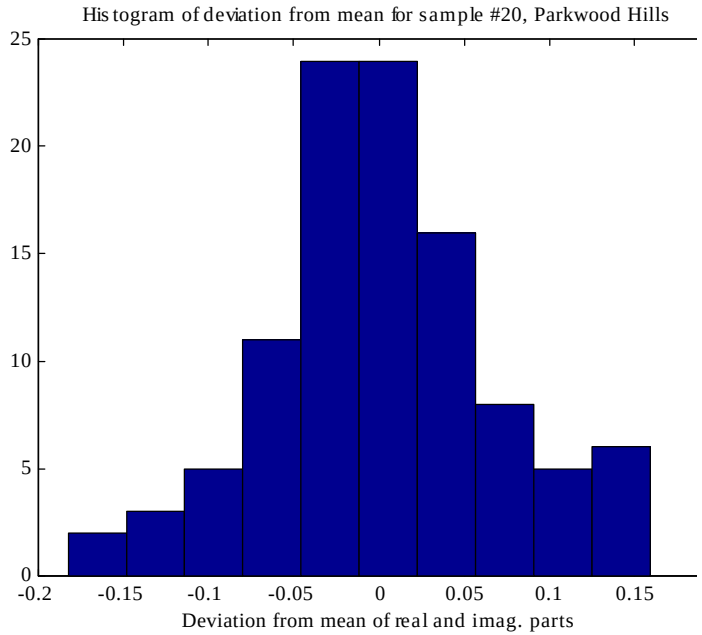


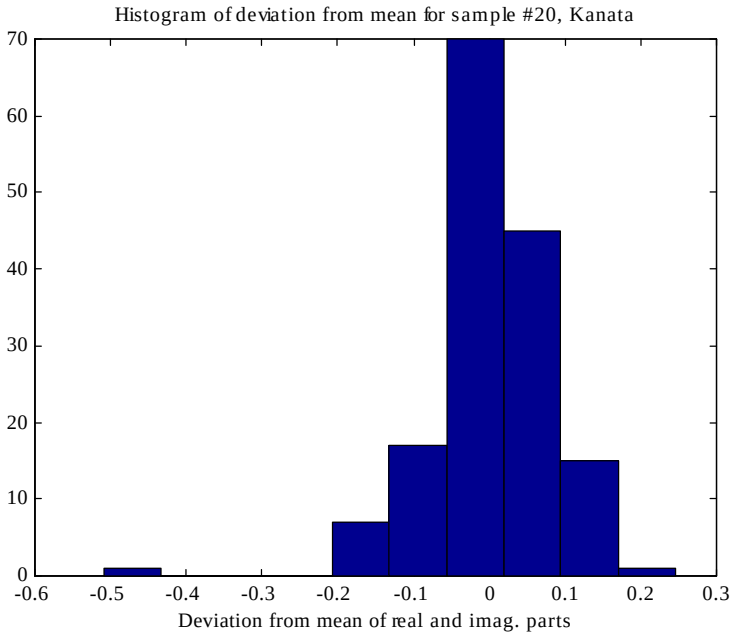
Histogram of Deviation from Mean for Samples at +20 ns.





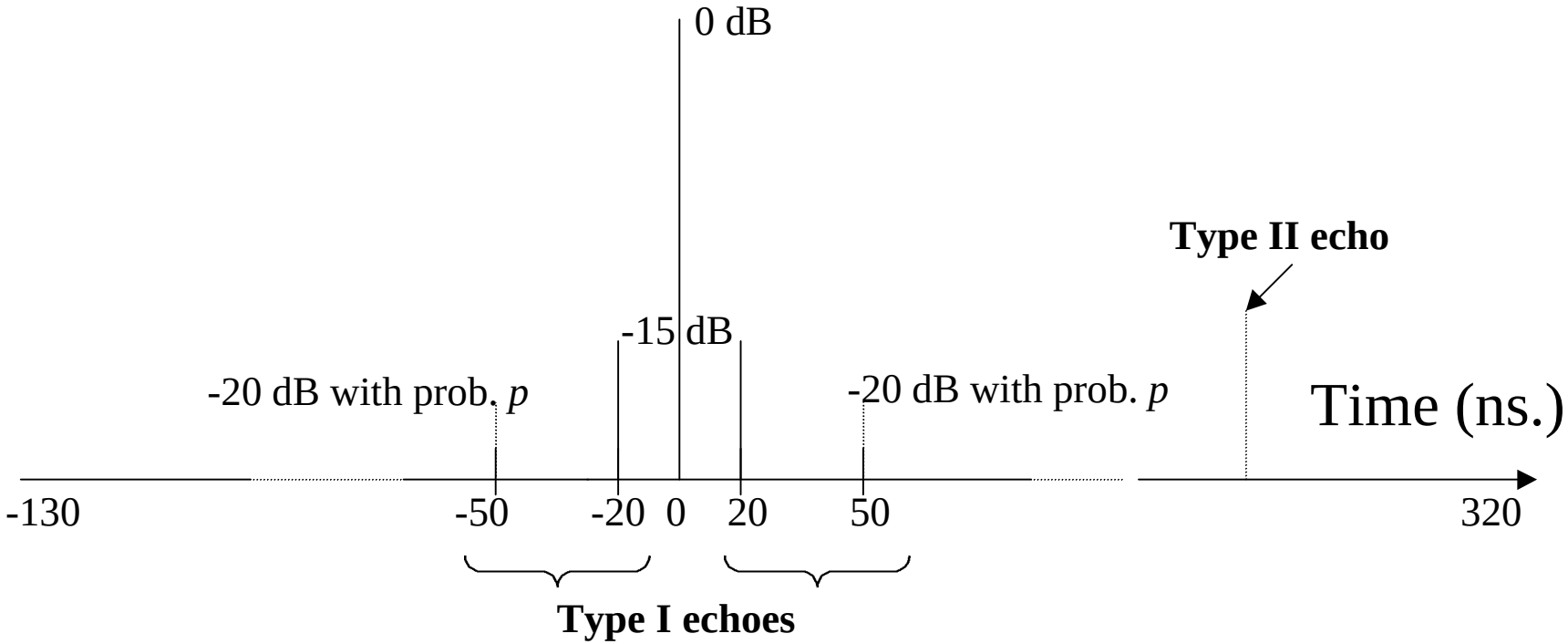
Histogram of Deviation from Mean for Samples at +10 ns.

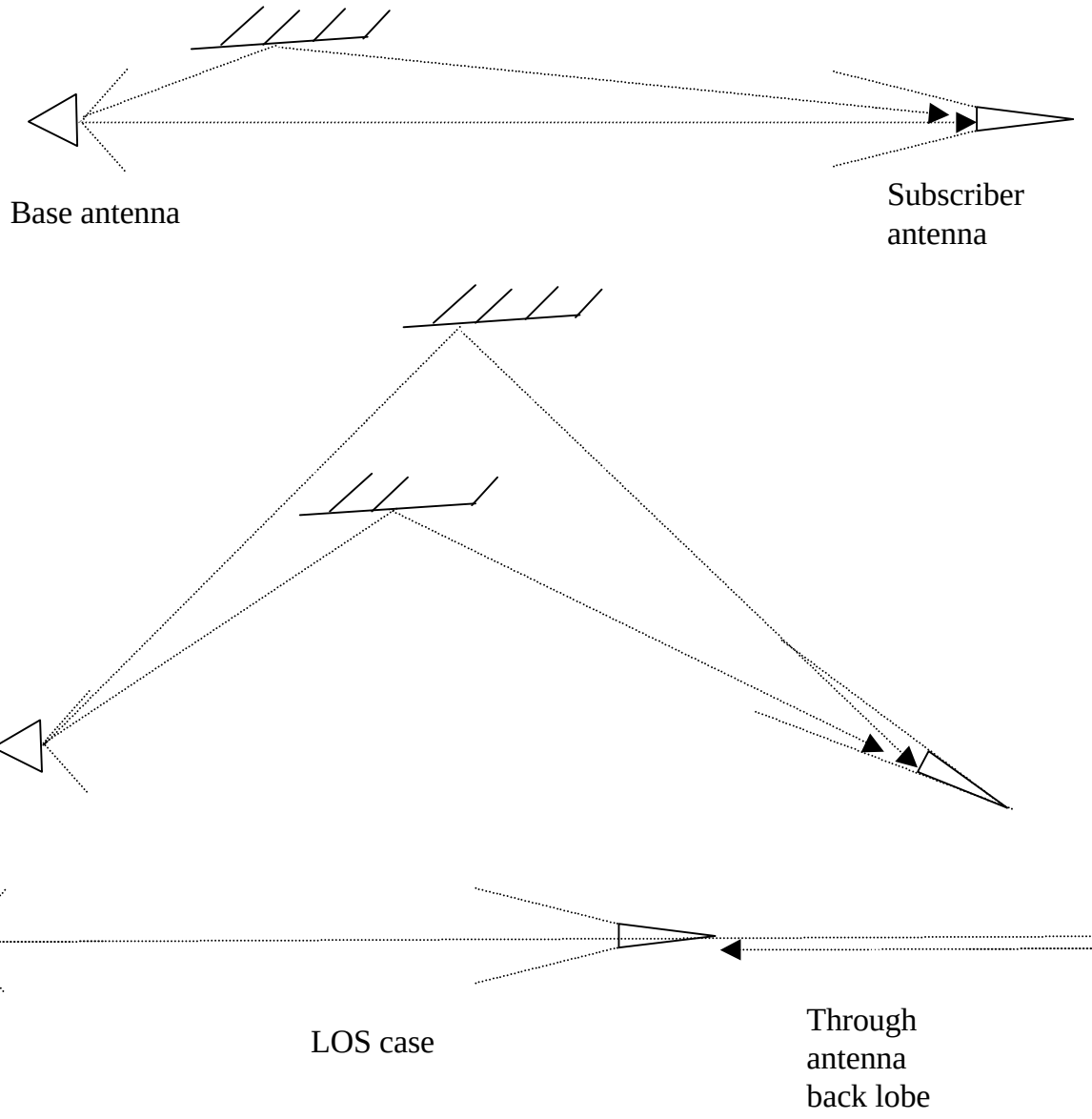




A Multipath Response Model

- Based on deviations of measured responses from their means.
- Echoes are zero-mean complex gaussian.




Base antenna
Subscriber antenna
LOS case
Through antenna back lobe

Multipath Response Model (cont.)

- Unit response at zero delay.

Type I echoes:

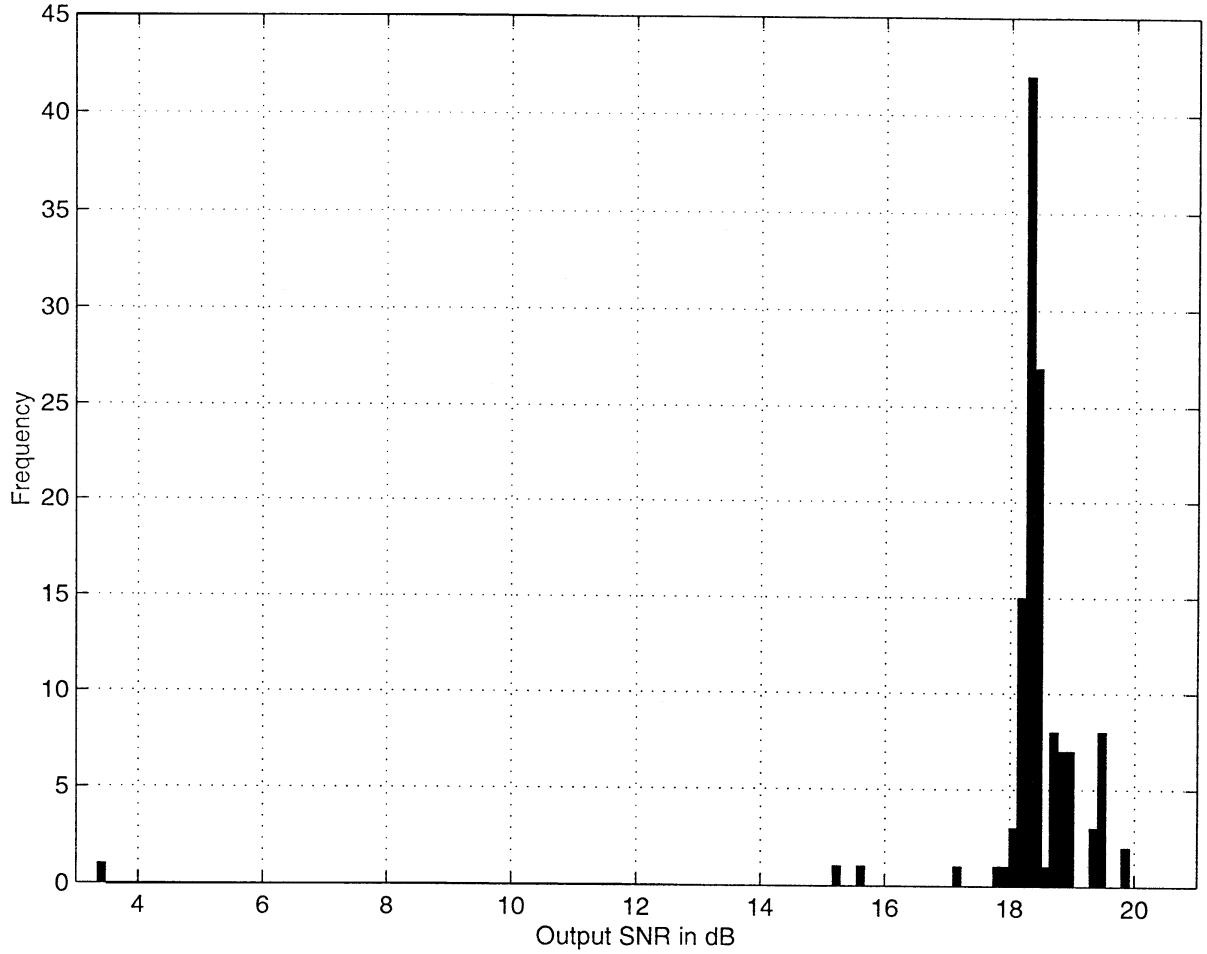
- -15 dB variance at ±20 ns. (Fairly consistent with Papazian results).
- -20 dB variance at ±50 ns. with probability *p* [*p*=0.15 for ±1° beamwidth; *p*=1 for > ±5° beamwidth].

Type II echoes:

- Present for larger beamwidths; e.g. > ±5° and where subscriber antenna bearing is not optimized for minimum multipath.
- Exists with probability 0.1: in range (0,-25 dB) at relative delay in the range (-130 ns., 320 ns.)

- Normalize overall response to unit energy.

Histogram of achieved output SNR (dB) for the channels of Parkwood Hills and Kanata with a FS-DFE of (8,1) at 50 Msps.



Conclusions re Equalization

- Highly directional antennas contribute to moderate delay spreads. In many cases, no equalizer was required for symbol rates up to 10 Msymbols/s.
- For data rates up to 50 Msymbols/s, a DFE with moderate numbers of taps is adequate; e.g. 5 forward and 1 feedback tap for symbol-spaced DFE at 50 msymbol/s.
- Fractional-spaced DFE reduces sensitivity to sampling phase at the expense of slightly increased numbers of forward taps.
- MLSE improves performance slightly.