Timing acquisition in the limit of large bandwidth

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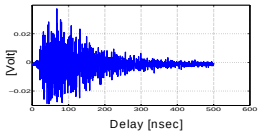
The Channel

- Multipath channels
- Path timing critical (versus amplitude information)
  - Certain modulations: PPM
  - Location/Ranging



Measurement Bandwidth ~1 GHz

- Model
  - Delay spread $T_d W = M$
  - **L** paths (**M** choose **L** possible profiles)
  - Independent path amplitudes
  - Block constant channel
  - AWGN

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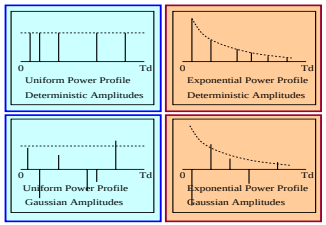
The Channel Model

- Four amplitude models
  - Deterministic or Gaussian
  - Uniform or Exponential power delay profile



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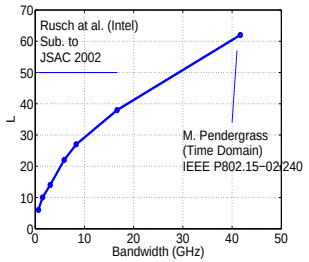
Number of Paths versus Bandwidth



- Rate of growth important
  - **L** versus **M** (bandwidth)
- Measurements
  - Strong paths counted: 60-90% of power
  - Number of paths increases with bandwidth
  - **Linear/sublinear growth**

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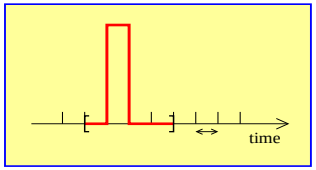
Pulse Position Modulation

Assumptions:

- Symbol time lower bounded
- Total symbol energy constrained
- Guard time allowed (no ISI)
- Flashy signaling (power concentration allowed)



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Main Result

Theorem: PPM systems with an average power constraint, operating over multi-path channels (of either of the four types) with

$L \xrightarrow[W\to\infty]{} \infty$ and $L/\sqrt{W} \to 0$,

cannot acquire any of the channel paths in the limit of large bandwidth

Proof method: exploit order statistics and equivalent structures of detectors

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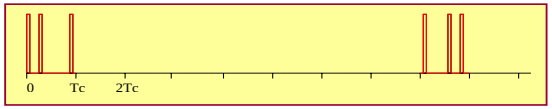
Intuition of Result

- Demonstrate simplest case: uniform PDP, deterministic path amplitudes.
- **Key observation**: PPM must transmit often enough

bits per T_c ~ $\log_2 WT_c$



Fraction of time θ used for transmission $\geq \frac{1}{\log W}$

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Idea of Proof

- As bandwidth increases, transmit at least fraction $\theta_{\min}$ of time
- Power per symbol increases ~ $\log W$
- Power spread over L multipaths
- Number of $N(0,1)$ noise positions per symbol ~ W

In limit, at least L noise positions overwhelm strongest signal position!

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Conditions for achieving capacity at limit

	PPM	DSSS
Delay Known Amp. Known	$\forall L$	$\forall L$
Delay Known Amp. Unknown	$\frac{L}{\log W} \to 0$	$\frac{L}{W} \to 0$
Channel Unknown	$L \approx const$	$\frac{L \log W}{W} \to 0$

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Summary

- Power limited PPM cannot handle multipath channels as bandwidth increases
  - **Uncertainty increases with bandwidth at a higher rate than the number of paths**
- Path delay uncertainty detrimental to communication because of low spectral efficiency
- Low spectral efficiency limits burstiness of system
- Results for idealized systems – implications for practical systems

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