Jitter Equalization for Binary Baseband Communication

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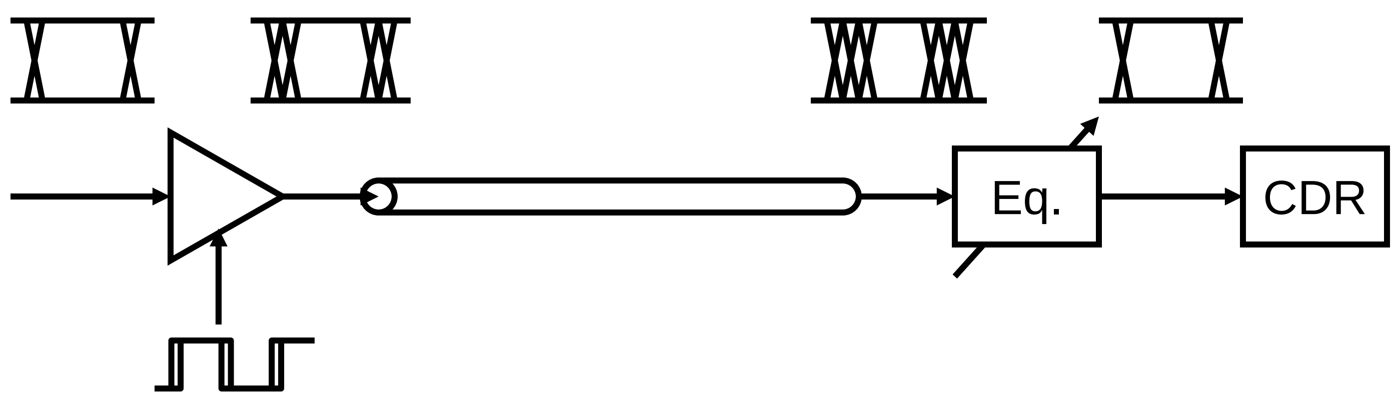
Outline

- Problem definition
- Review of LMS algorithm
- Proposed jitter equalization
- Simulations

Problem definition

- Sources of jitter:
  - Transmitter, Receiver
  - **Channel ⇒ Intersymbol interference**

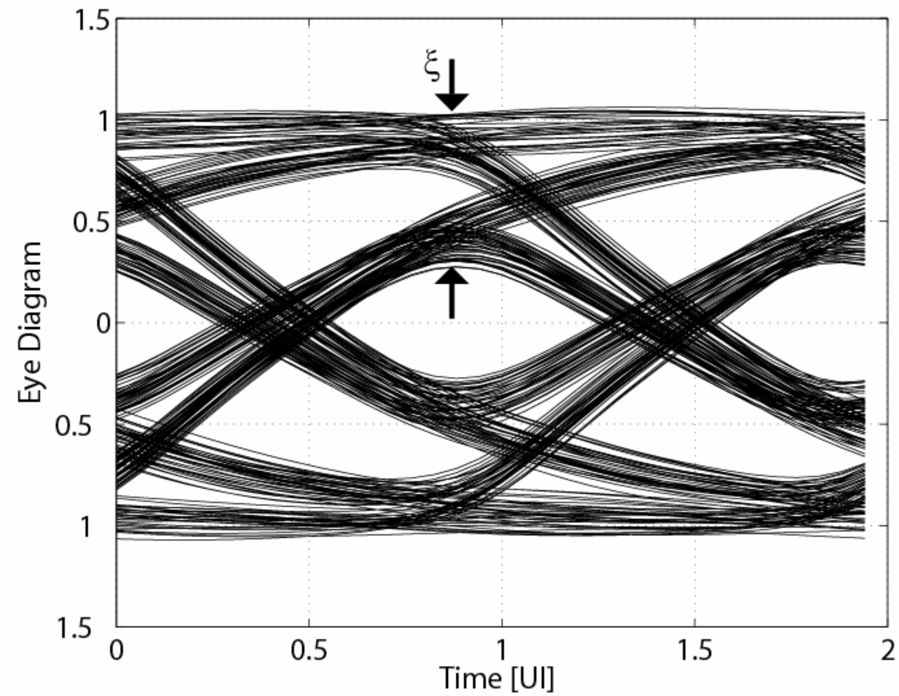


- Goal: To adapt the equalizer parameters to minimize jitter at the equalizer output

LMS algorithm

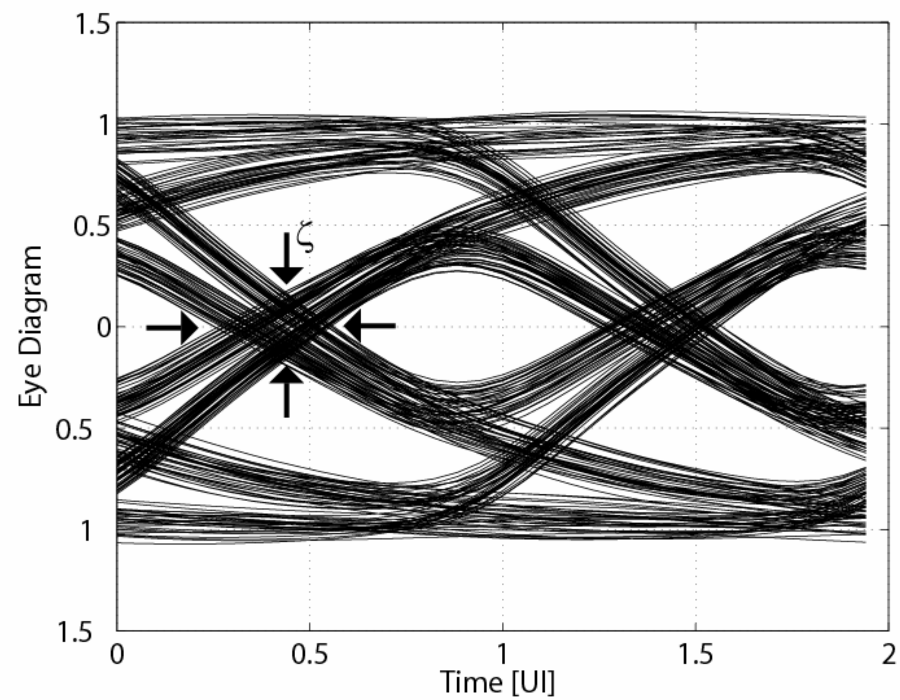
- Maximizes vertical eye opening

➢ Minimizes
$\xi = E[e^2]$
@ centre of eye



Jitter Equalization

- Instead, we want to maximize the ***horizontal*** eye opening
  - ➢ Minimize ISI at the zero crossings
  - ➢ Minimize $\zeta = E[e^2]$ @ zero crossings



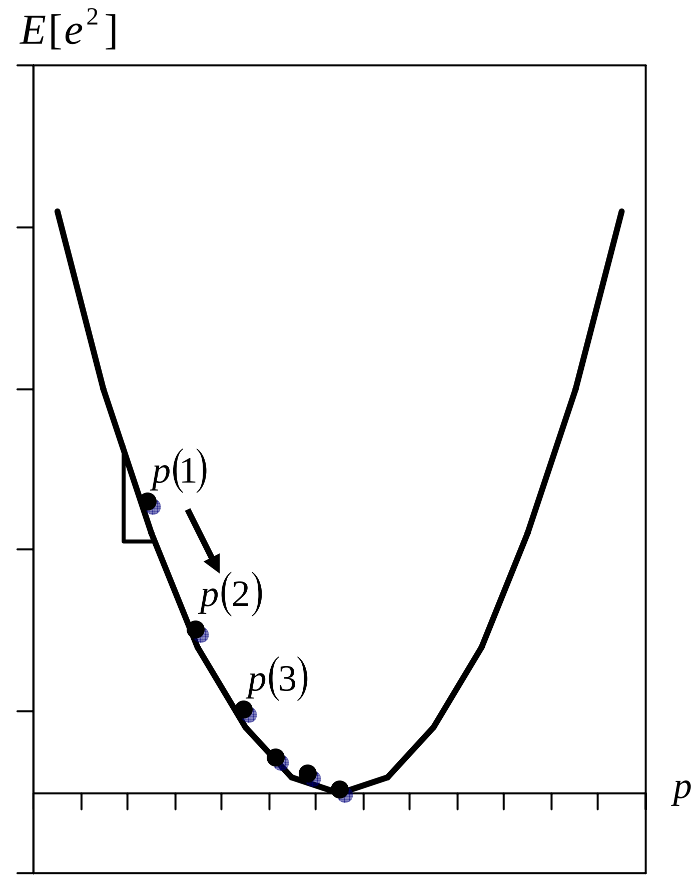
LMS algorithm - Review

Single parameter case gradient descent adaptation:

$$\frac{\partial E\left[e^2\right]}{\partial p} < 0 \qquad \therefore \; \Delta p > 0$$

$$\Rightarrow \quad p(k+1) = p(k) + \Delta p$$

$$= p(k) - \mu \frac{\partial E\left[e^2(k)\right]}{\partial p}$$



LMS Algorithm - Review

- How can we calculate $\frac{\partial E[e^2]}{\partial p}$?
  - Assume that $E[e^2(k)] \approx e^2(k)$

$$\therefore \frac{\partial E[e^2]}{\partial p} \approx \frac{\partial (e^2)}{\partial p} = \frac{\partial (e^2)}{\partial e} \cdot \frac{\partial e}{\partial p} = 2e \cdot \frac{\partial (d-y)}{\partial p} = -2e \cdot \frac{\partial y}{\partial p} \equiv -2e \cdot u(k-i)$$

  - Substitute this back into general gradient descent method:

$$p_i(k+1) = p_i(k) + 2\mu e(k) u(k-i)$$

Jitter equalization

- Everything is the same, except $e(k)$ is now sampled at zero crossings

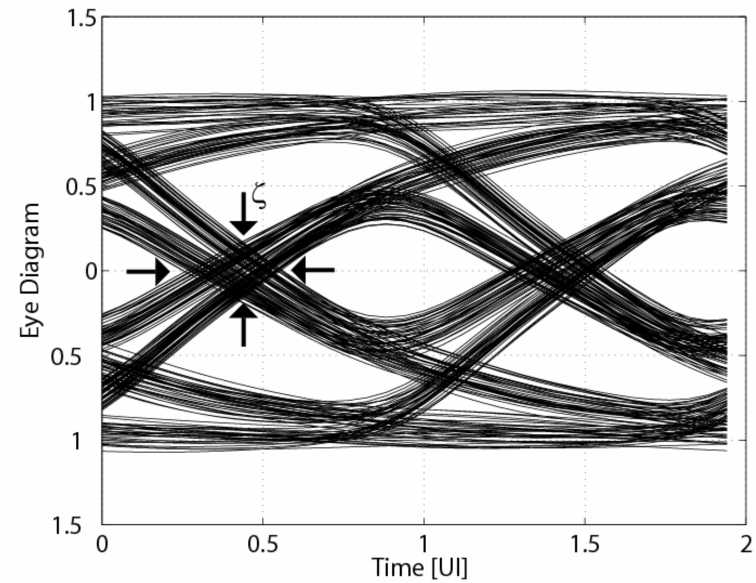
$$p_i(k+1) = p_i(k) + 2\mu e(k) u(k-i)$$

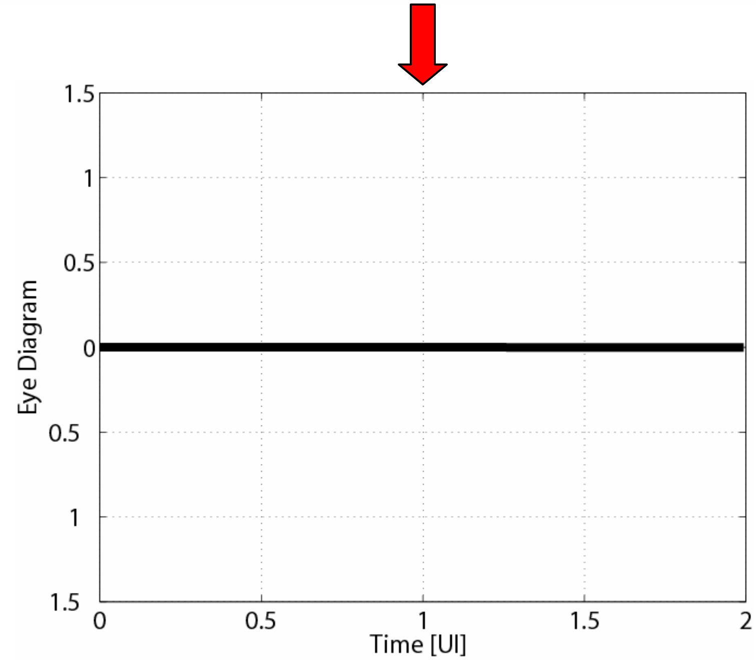
- **Note:** $e(k)$ is often already sampled at zero crossings for timing recovery

Jitter equalization

- **Problem:** ζ can be made zero by setting all p_i's equal to zero

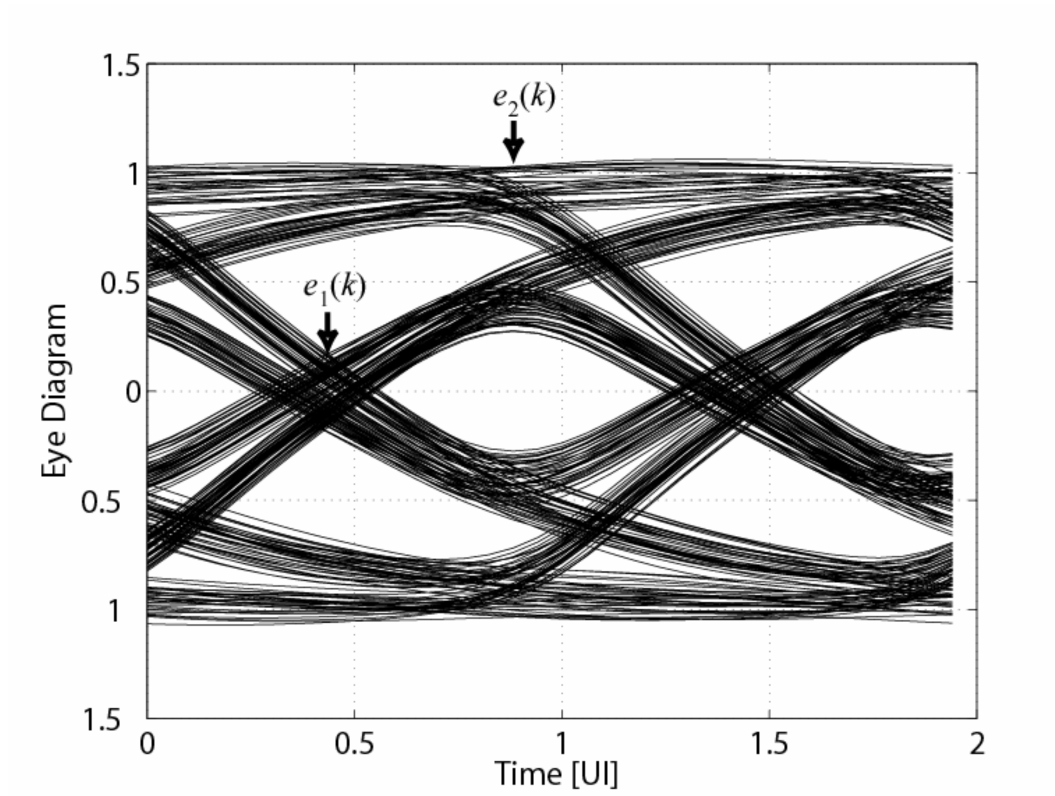
➢ Adaptation based on jitter criterion converges to this trivial operating point





Jitter equalization

- **Solution:** Compromise between minimizing ξ and ζ by alternating between (1) & (2)

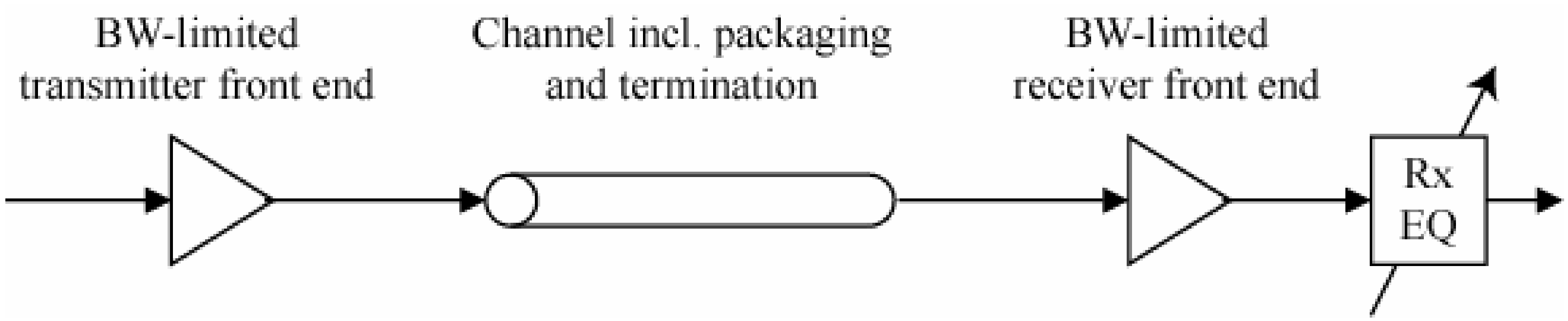


$$p_i(k+1) = p_i(k) + 2\mu_1 e_1(k) u(k-i) \quad (1)$$

$$p_i(k+1) = p_i(k) + 2\mu_2 e_2(k) u(k-i) \quad (2)$$

Simulation Model

- System model used for simulations:



Simulation Model

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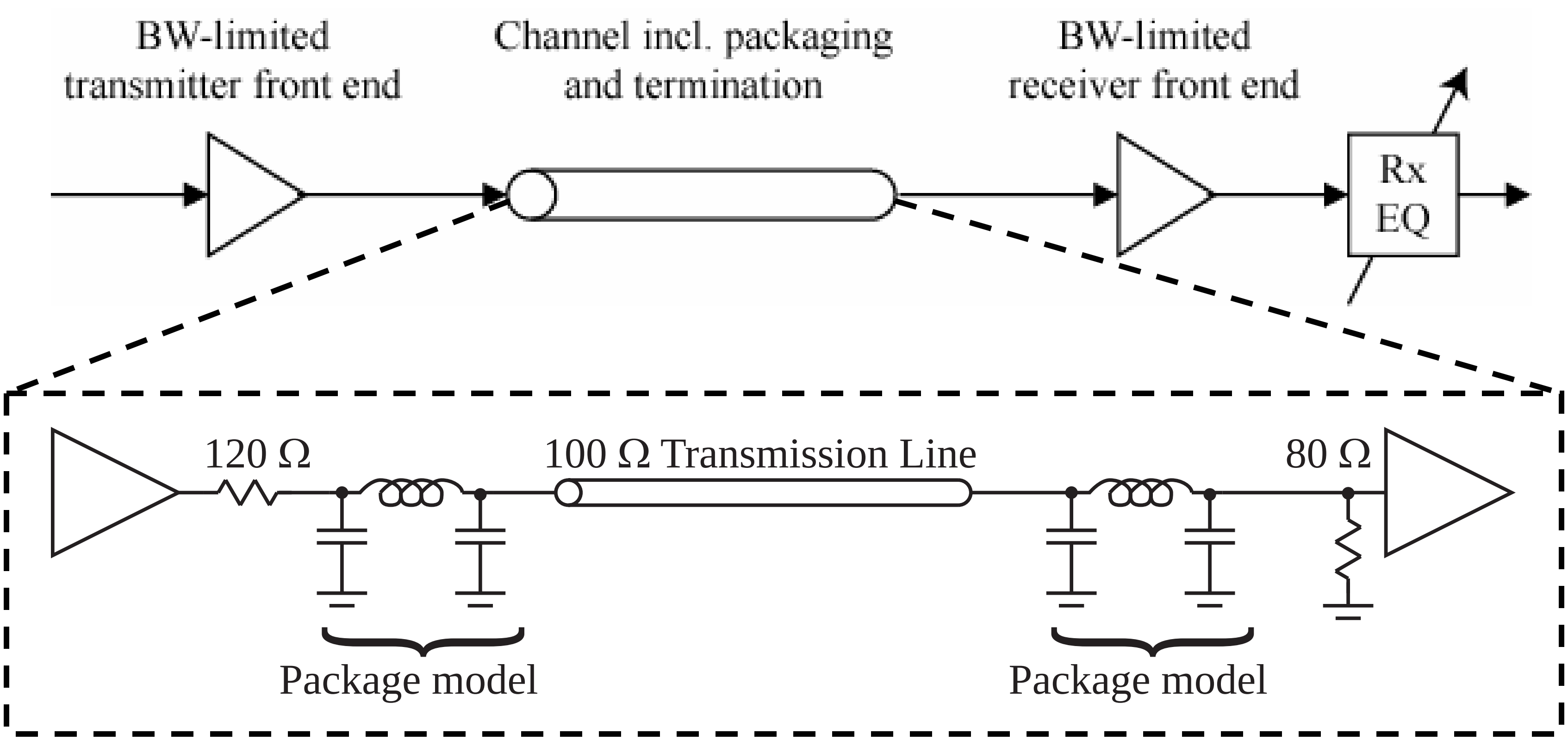
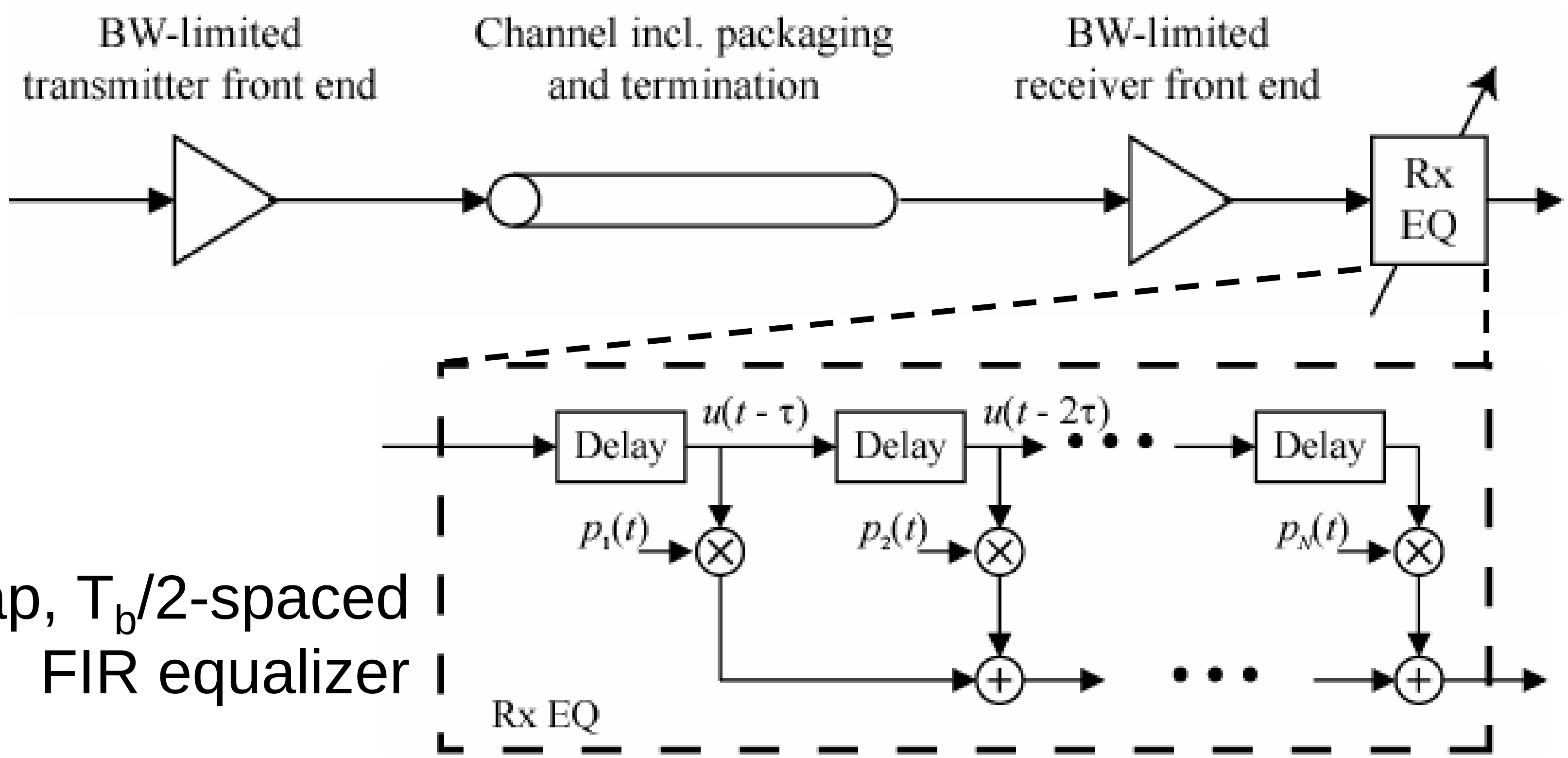


Simulation Model

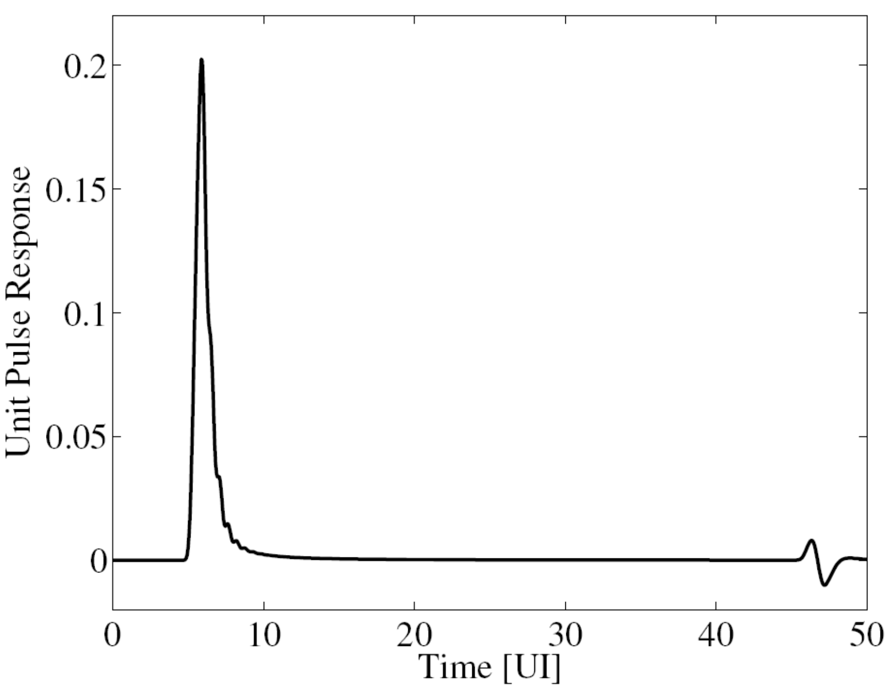
- System model used for simulations:

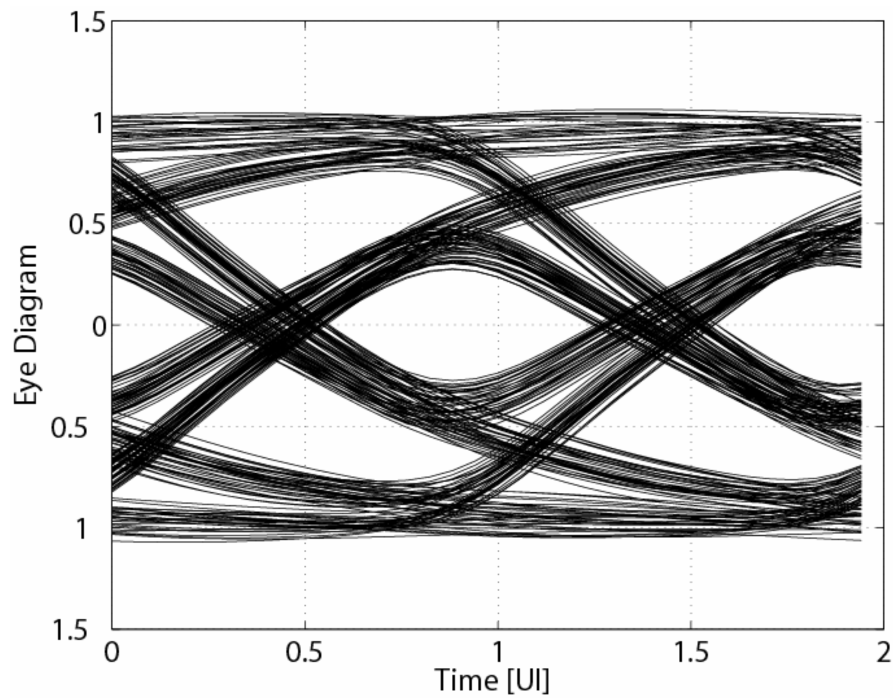


7-tap, T_b/2-spaced
FIR equalizer

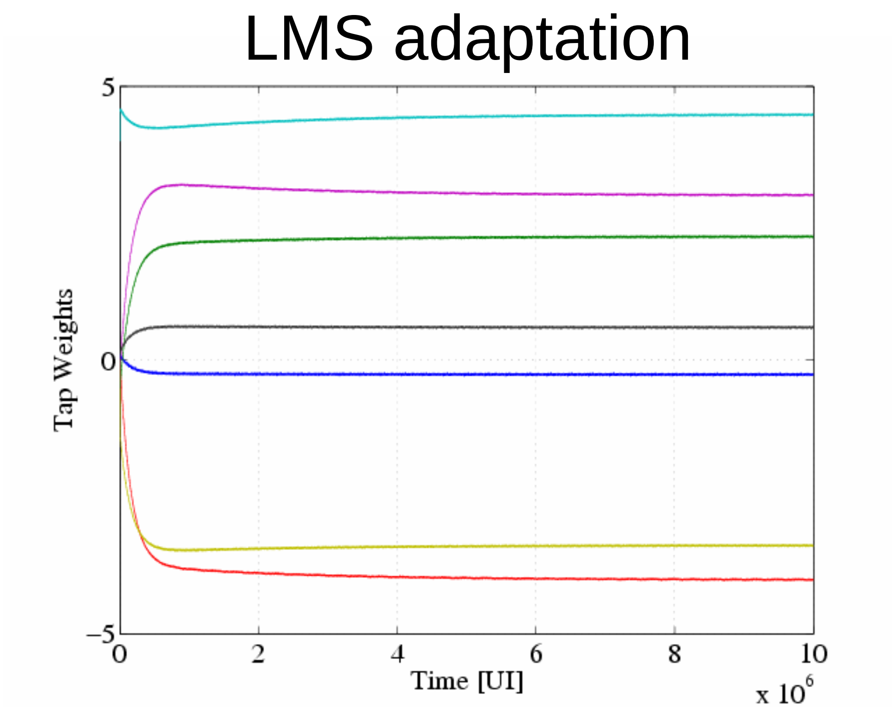
Simulation Model

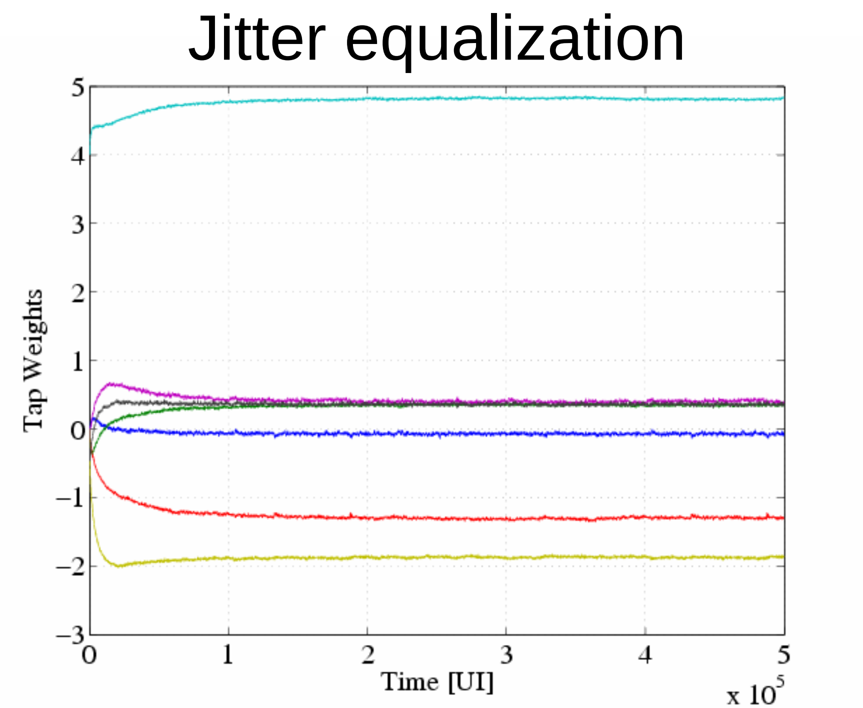
- Unequalized channel:





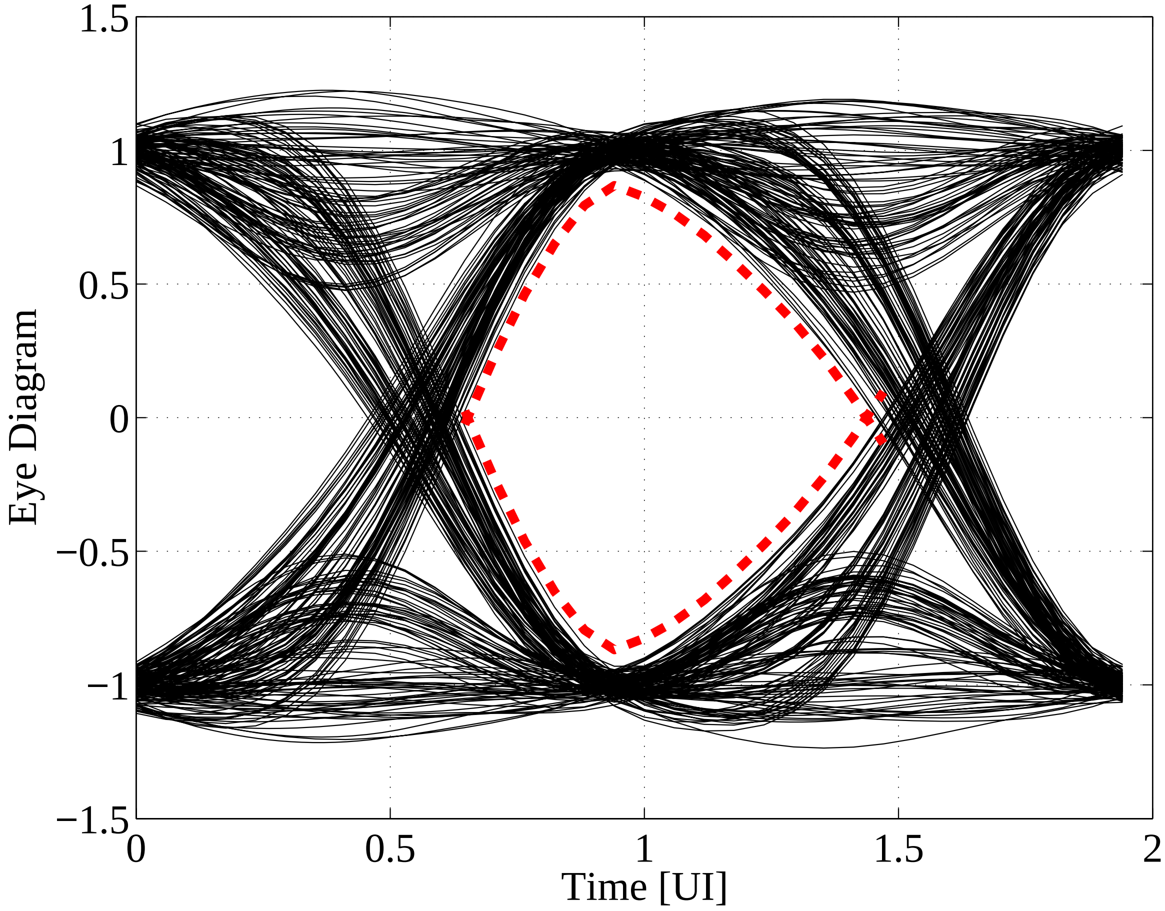
Simulations



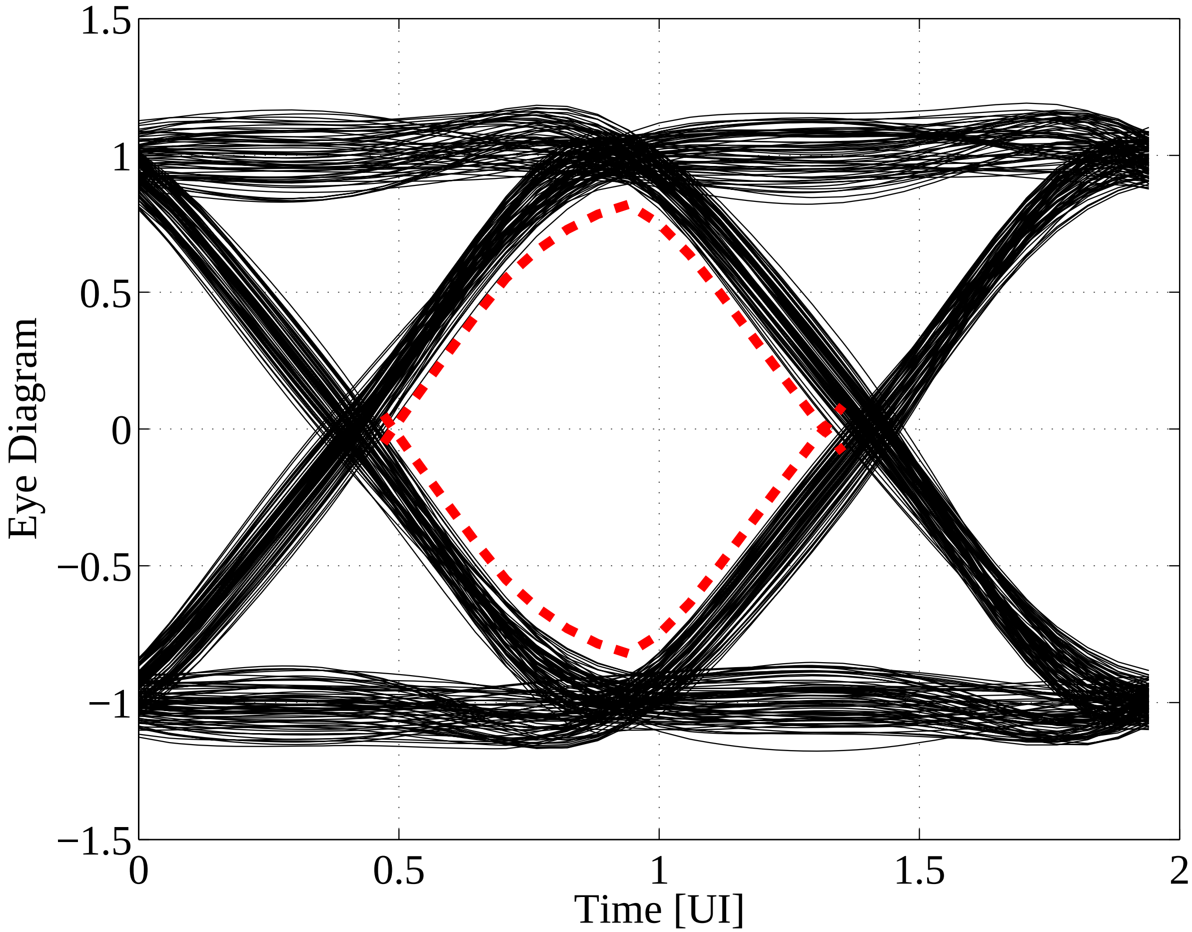


- Convergence of the tap weights over time is subject to the usual speed/accuracy tradeoffs

Traditional LMS adaptation

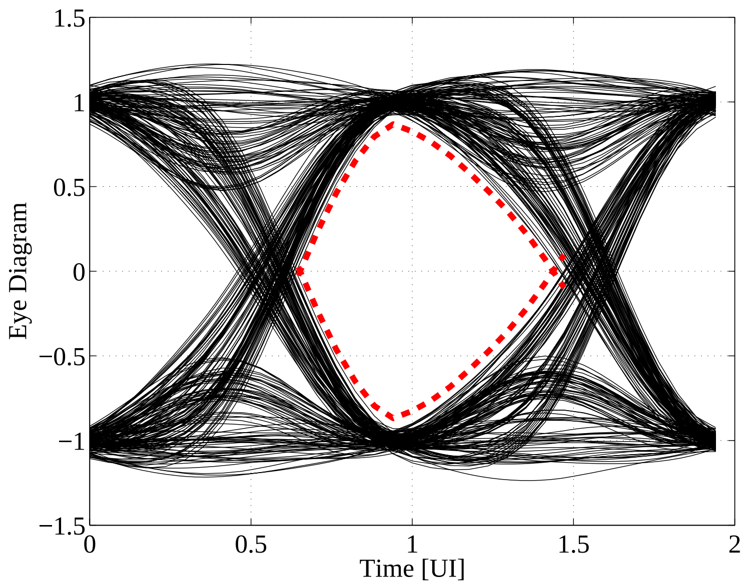


Jitter equalization

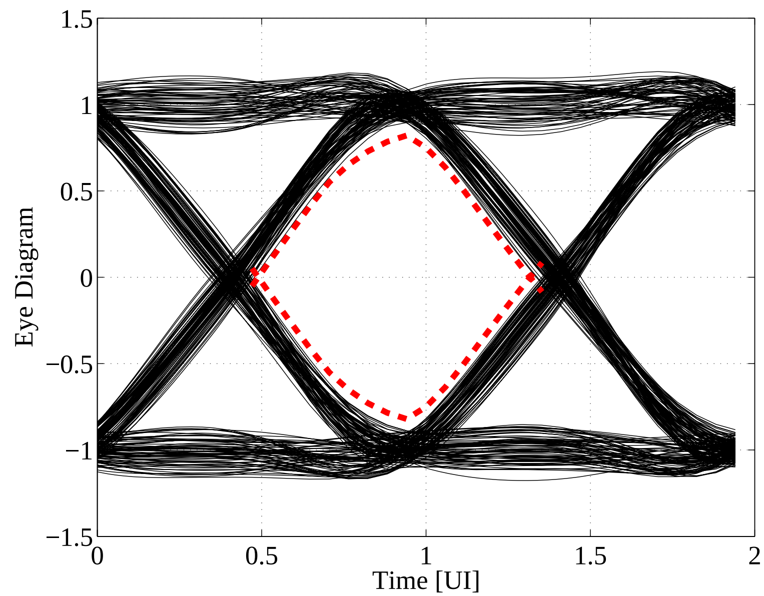


Jitter equalization

LMS adaptation



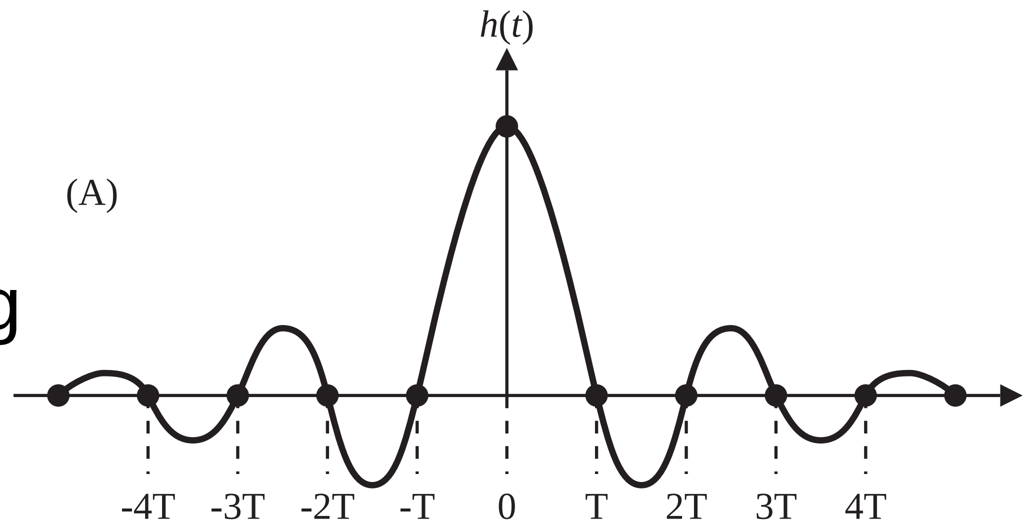
Jitter equalization



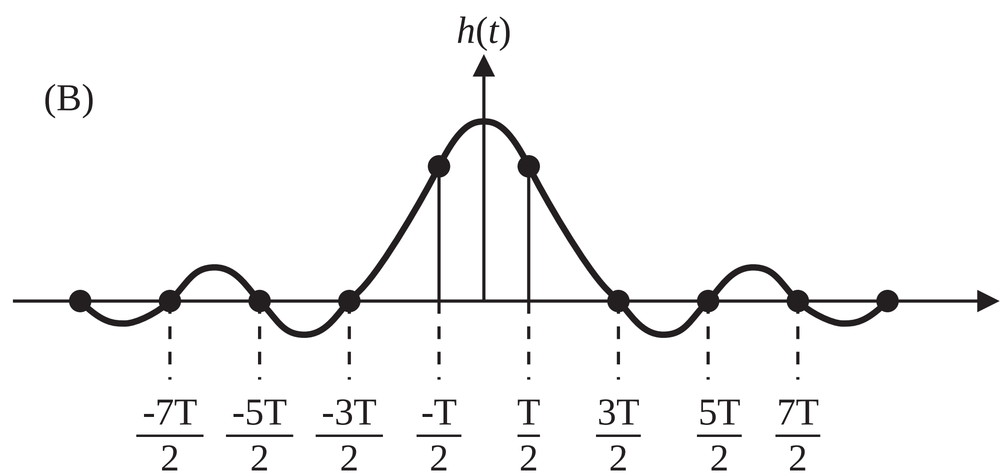
- In this case, jitter equalization provides 6% less vertical eye opening in exchange for 25% less pattern dependent jitter

Nyquist criteria

- Nyquist 1 criterion: Zero ISI at sampling time

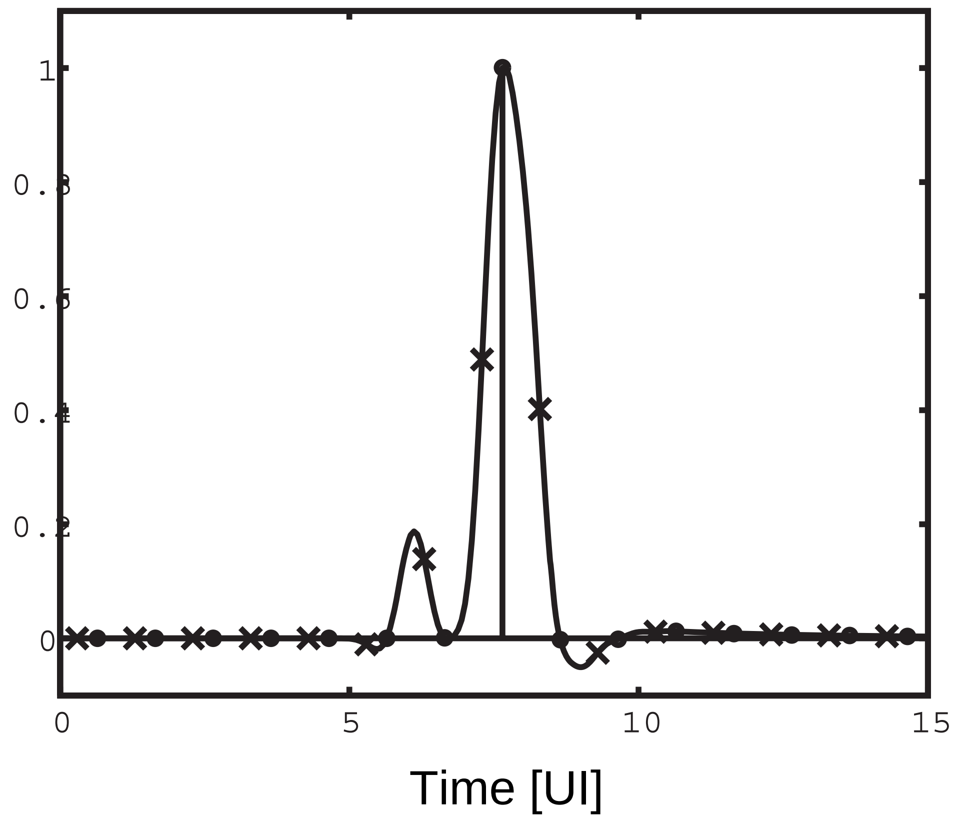


- Nyquist 2 criterion: Zero ISI at zero crossings



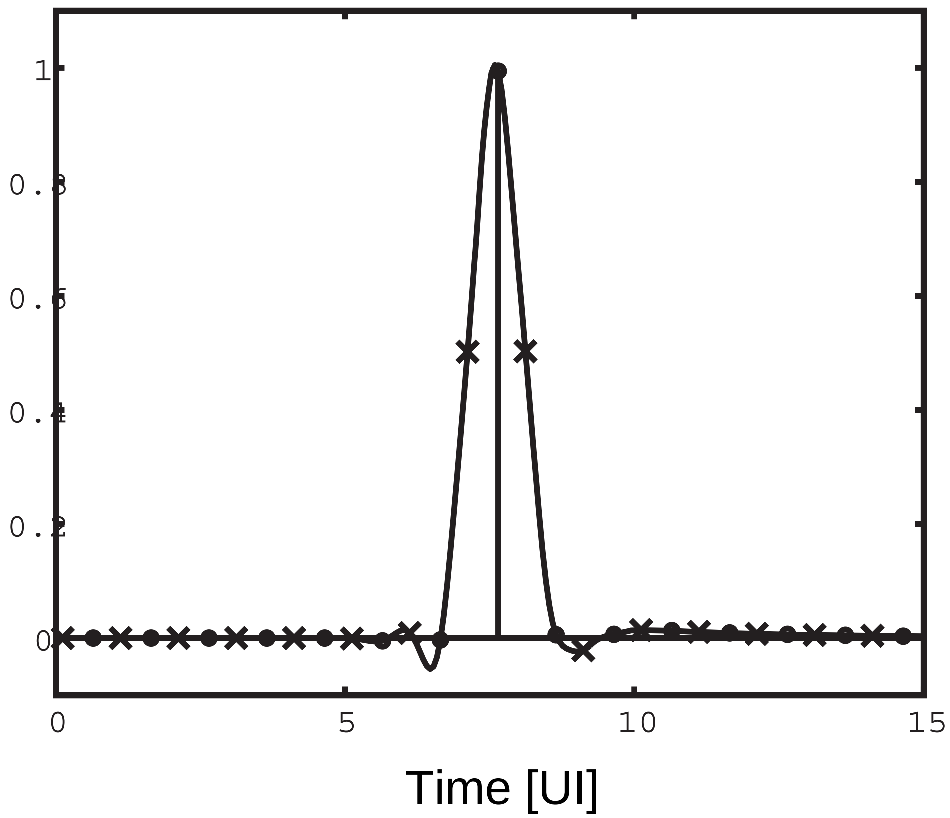
Nyquist criteria

- Equalized response using LMS adaptation resembles Nyquist 1 pulse



Nyquist criteria

- Using jitter equalization, the response resembles both Nyquist 1 & 2 pulses



Conclusions

- The traditional LMS algorithm does not minimize jitter, even with a fractionally-spaced equalizer
- Often preferable to update equalizer parameters to minimize MSE alternately at the centre of the eye and at zero-crossings
- The resulting pulse response approximates both the Nyquist 1 & 2 criteria simultaneously
- The additional error information required may already be available in the timing recovery circuit