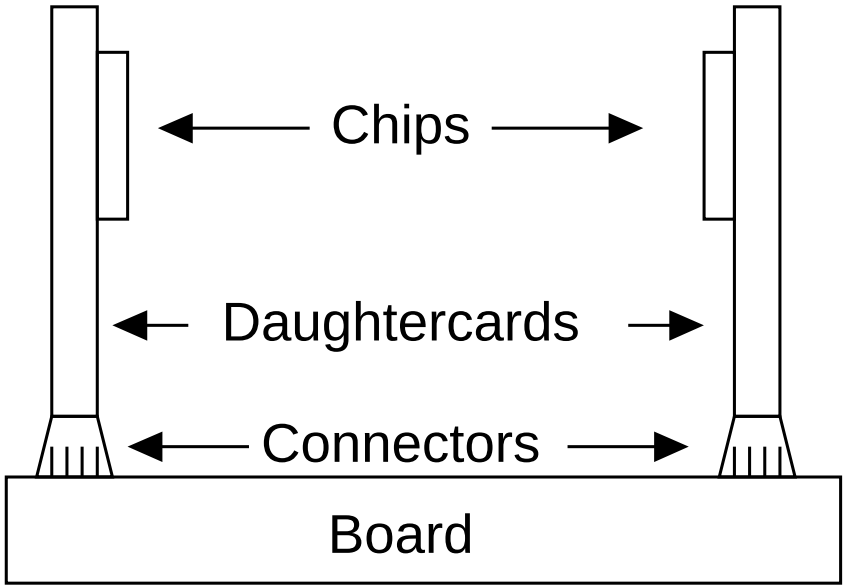
Crosstalk-Aware Transmitter Pulse-Shaping for Parallel Chip-to-Chip Links

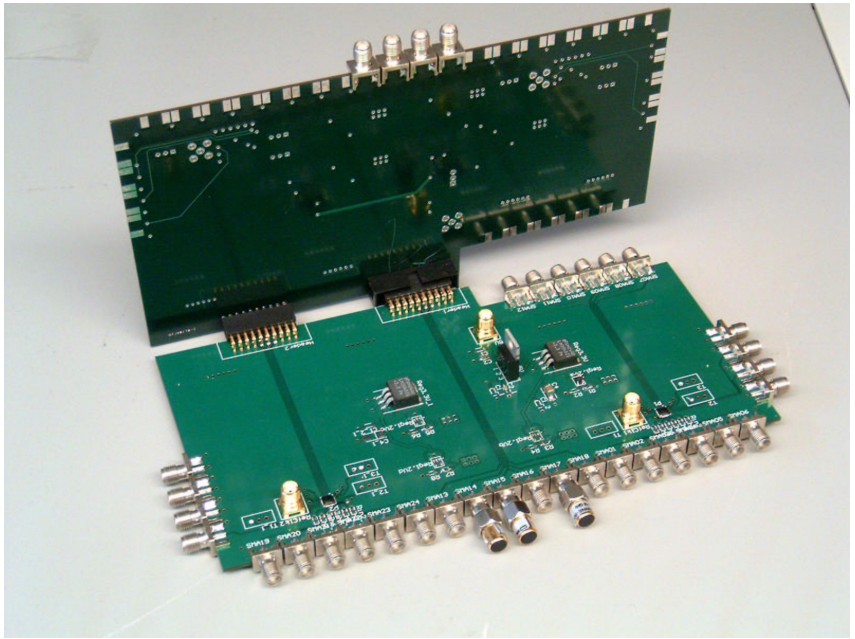
Mike Bichan, Anthony Chan Carusone

Department of Electrical and Computer Engineering
University of Toronto

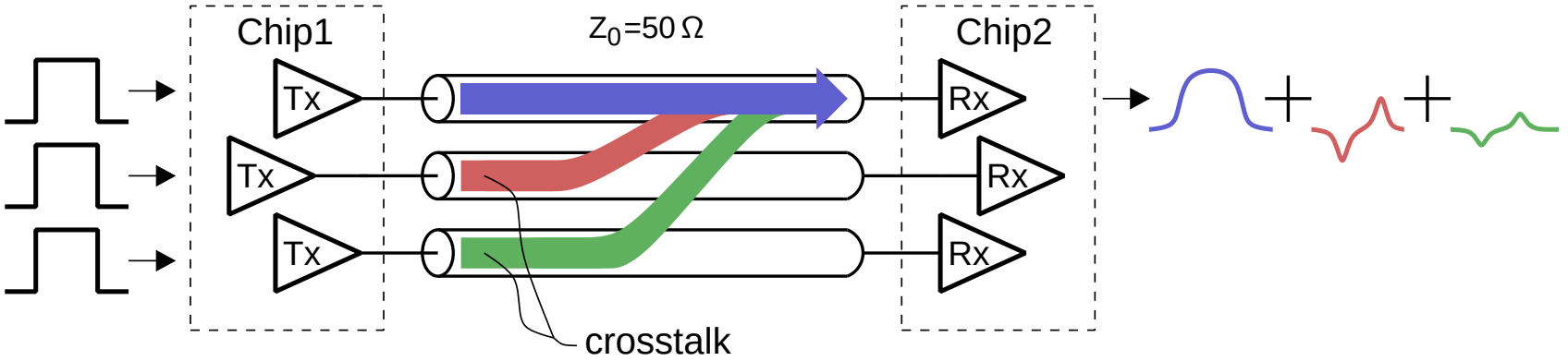
ISCAS 2007

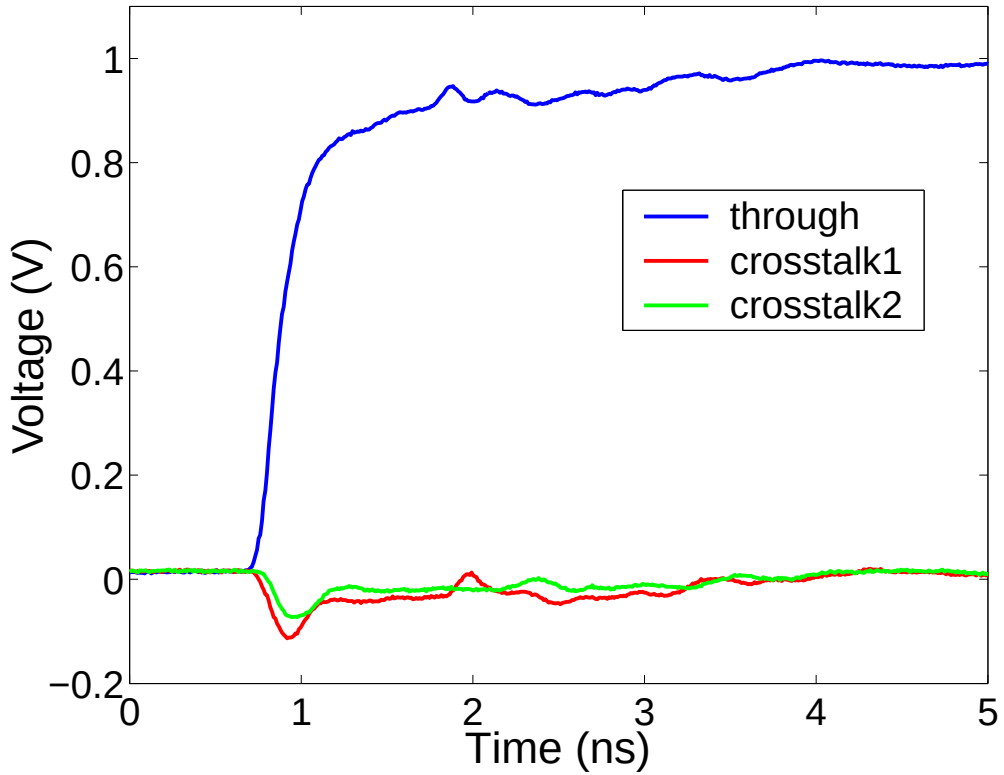
Board-to-Board Channel



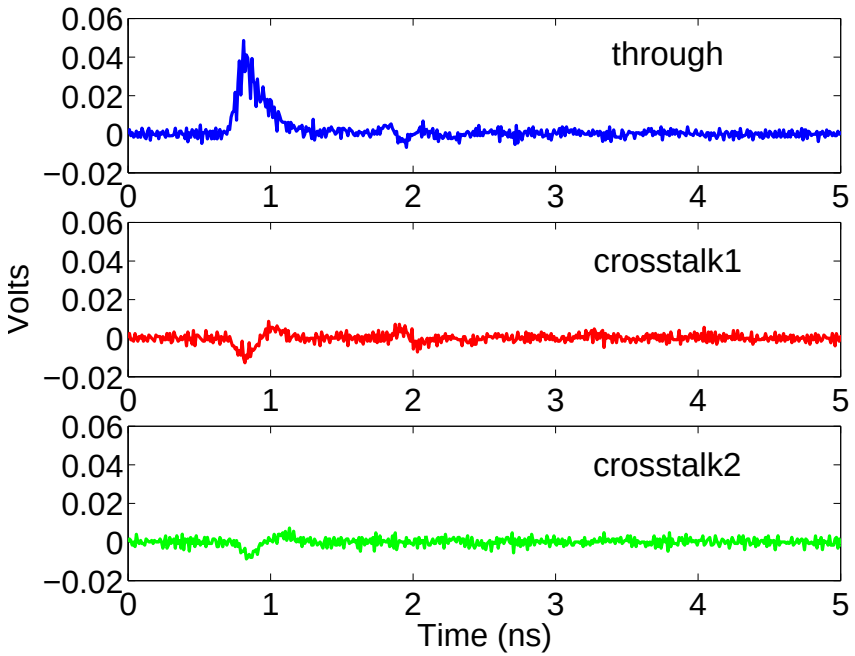


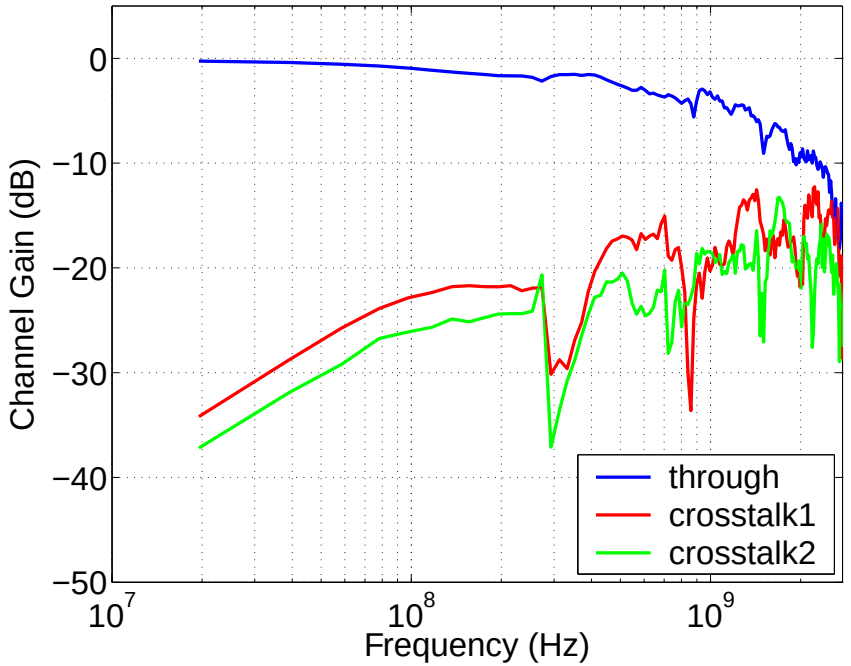
Characterize the Channel



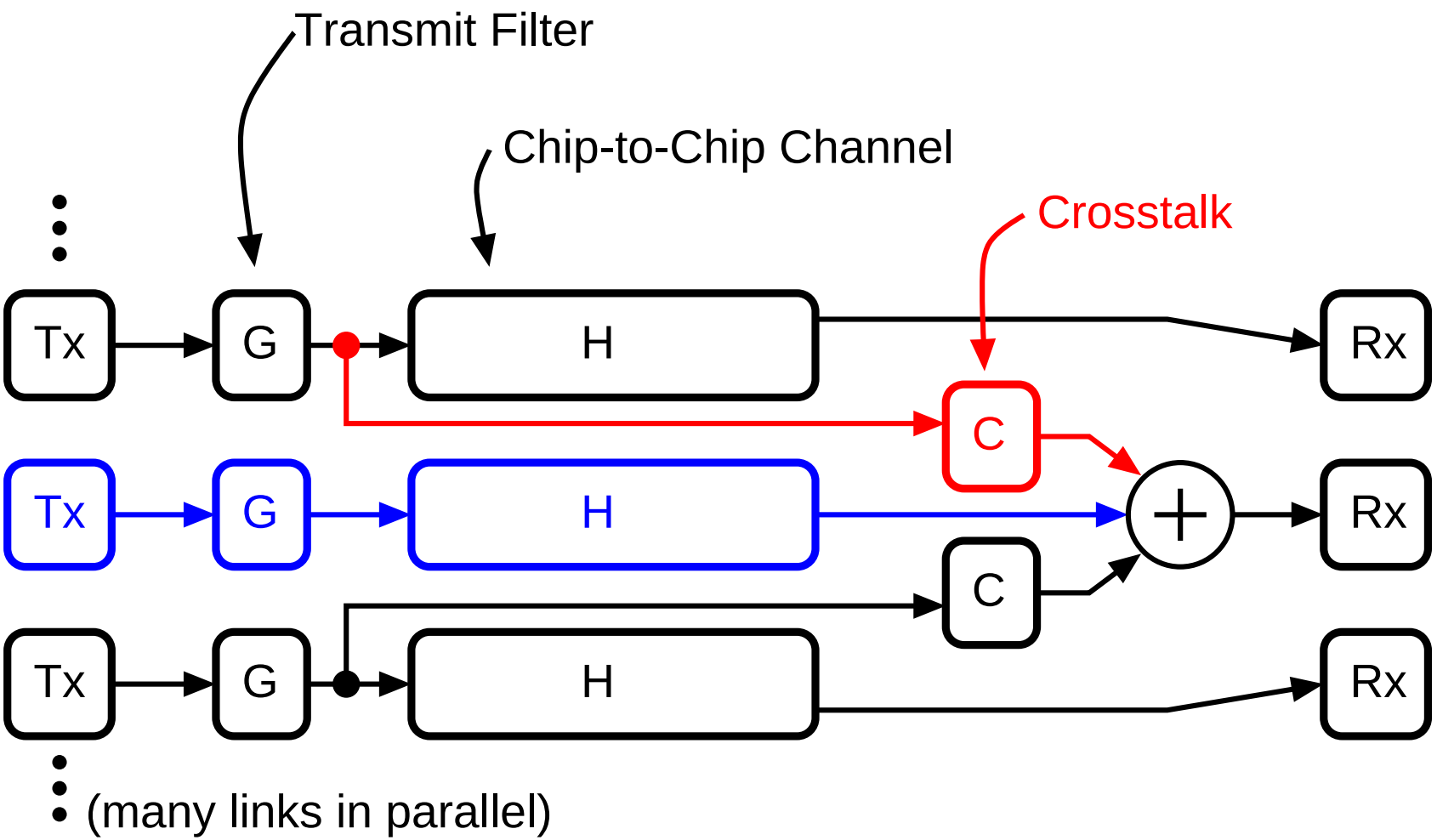


Impulse and Frequency Responses

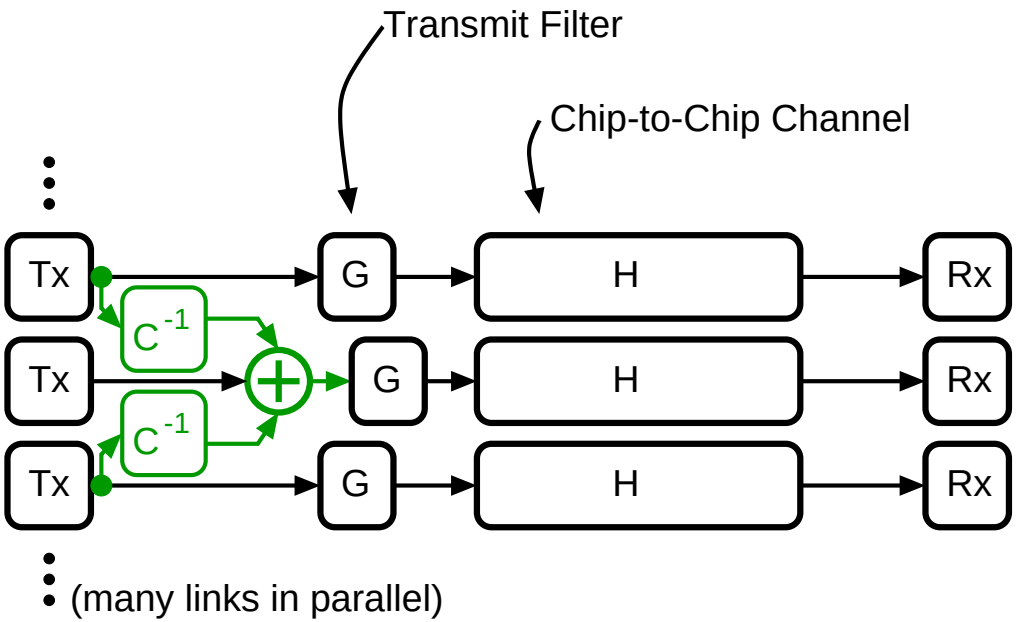




System Model

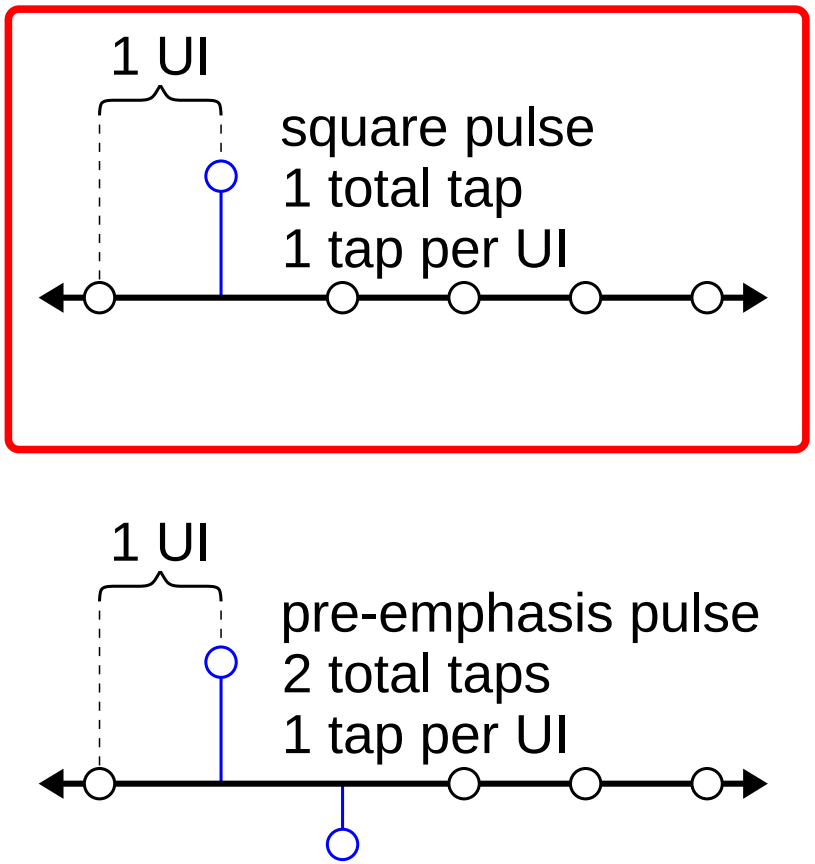


Conventional Solutions

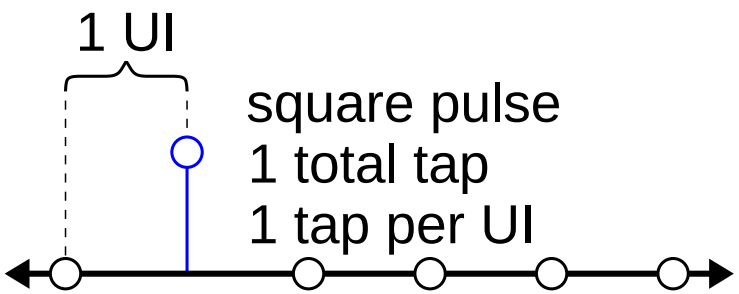


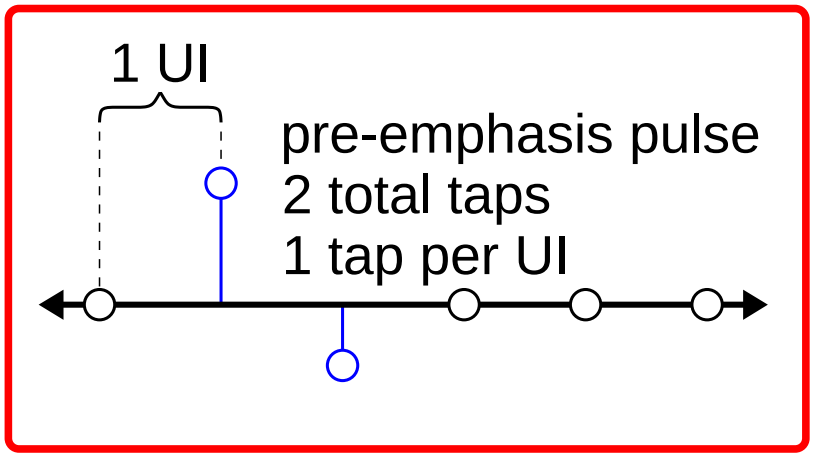
- slew-rate limiting
  - pro: simple
  - con: not good when ISI is severe
- crosstalk cancellation in addition to transmit filter G
  - pro: good performance
  - con: hardware cost

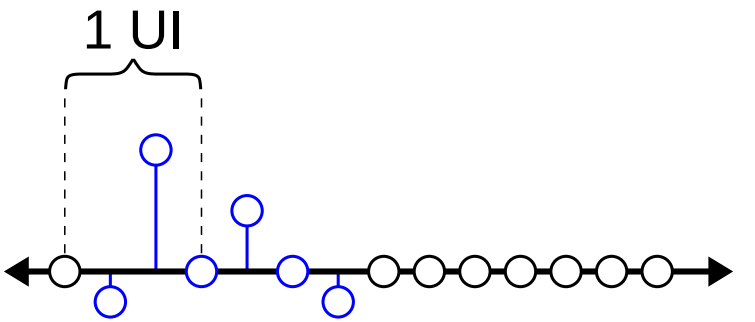
Example: Different Pulse Shapes



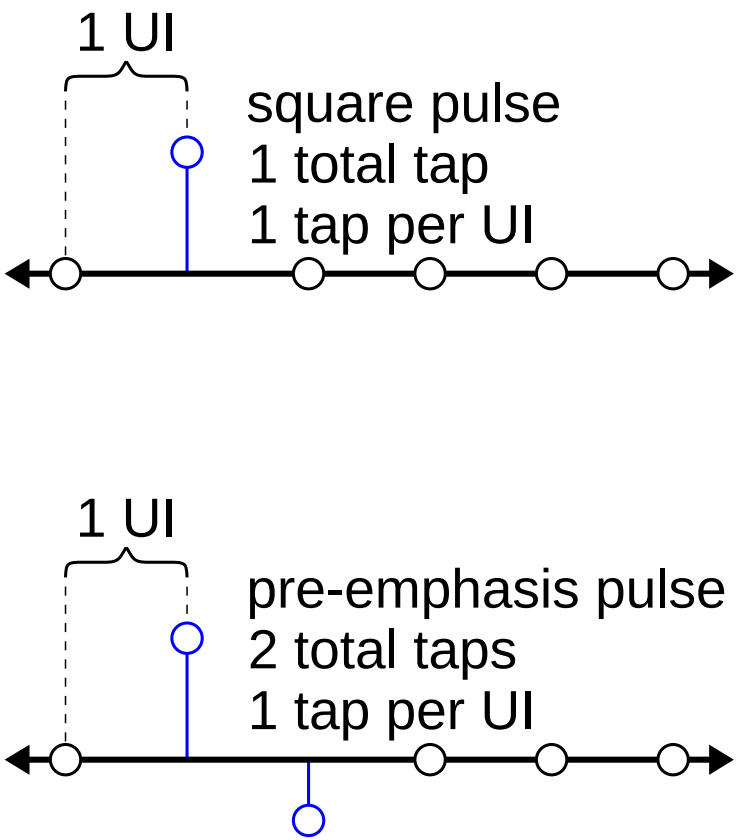
Example: Different Pulse Shapes

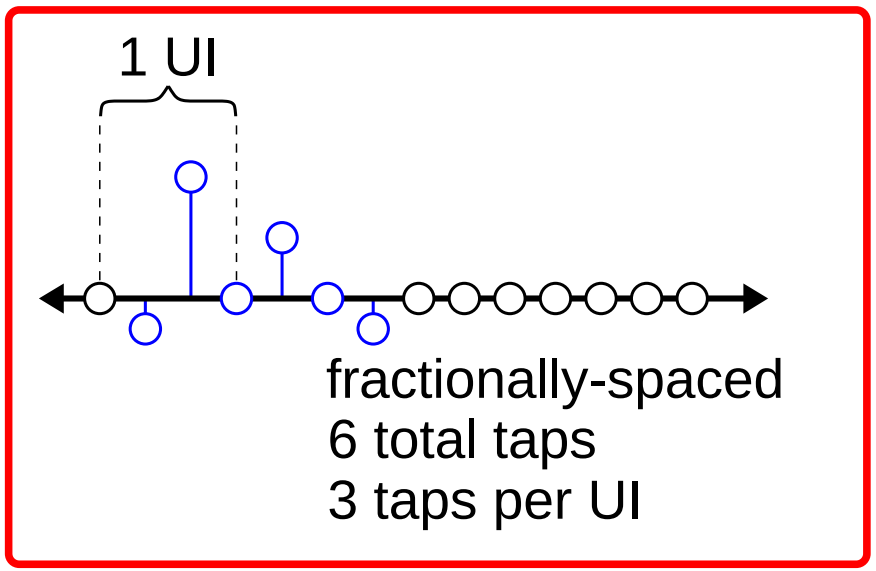






Example: Different Pulse Shapes

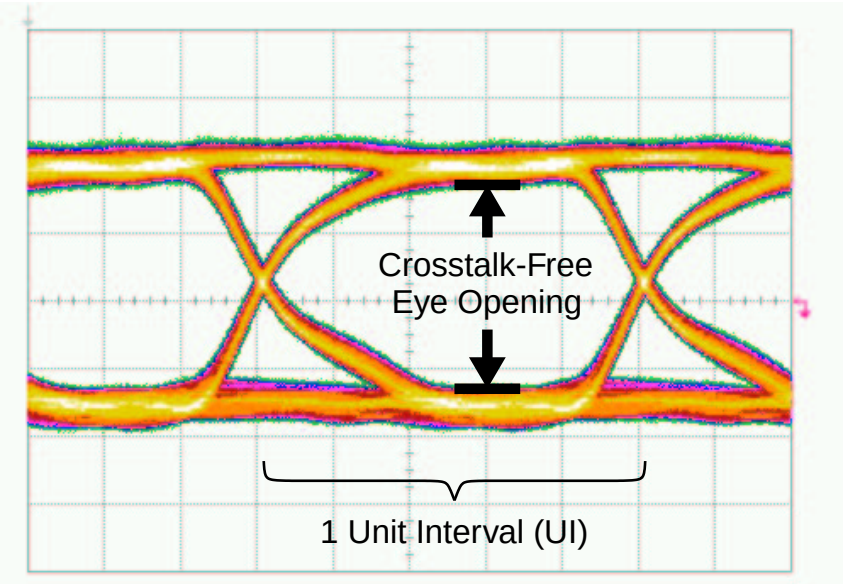


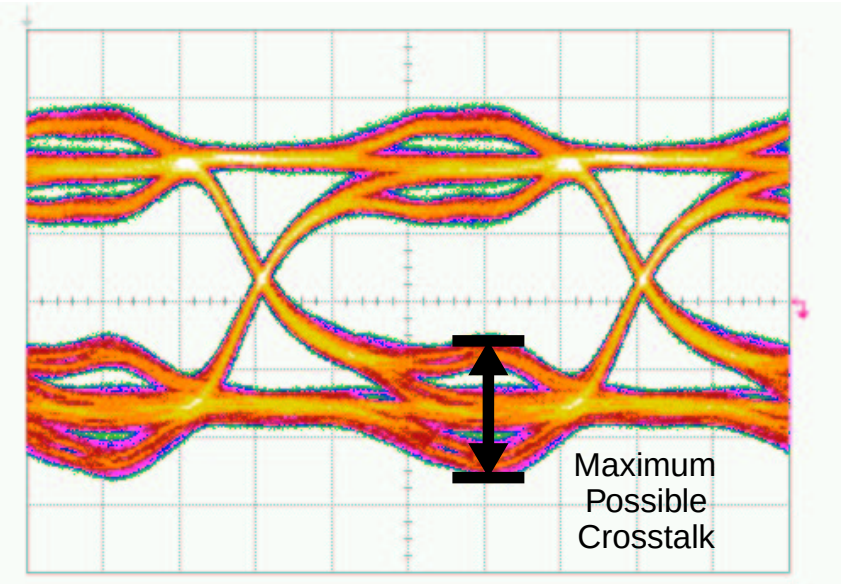


Optimize with Respect to a Figure of Merit

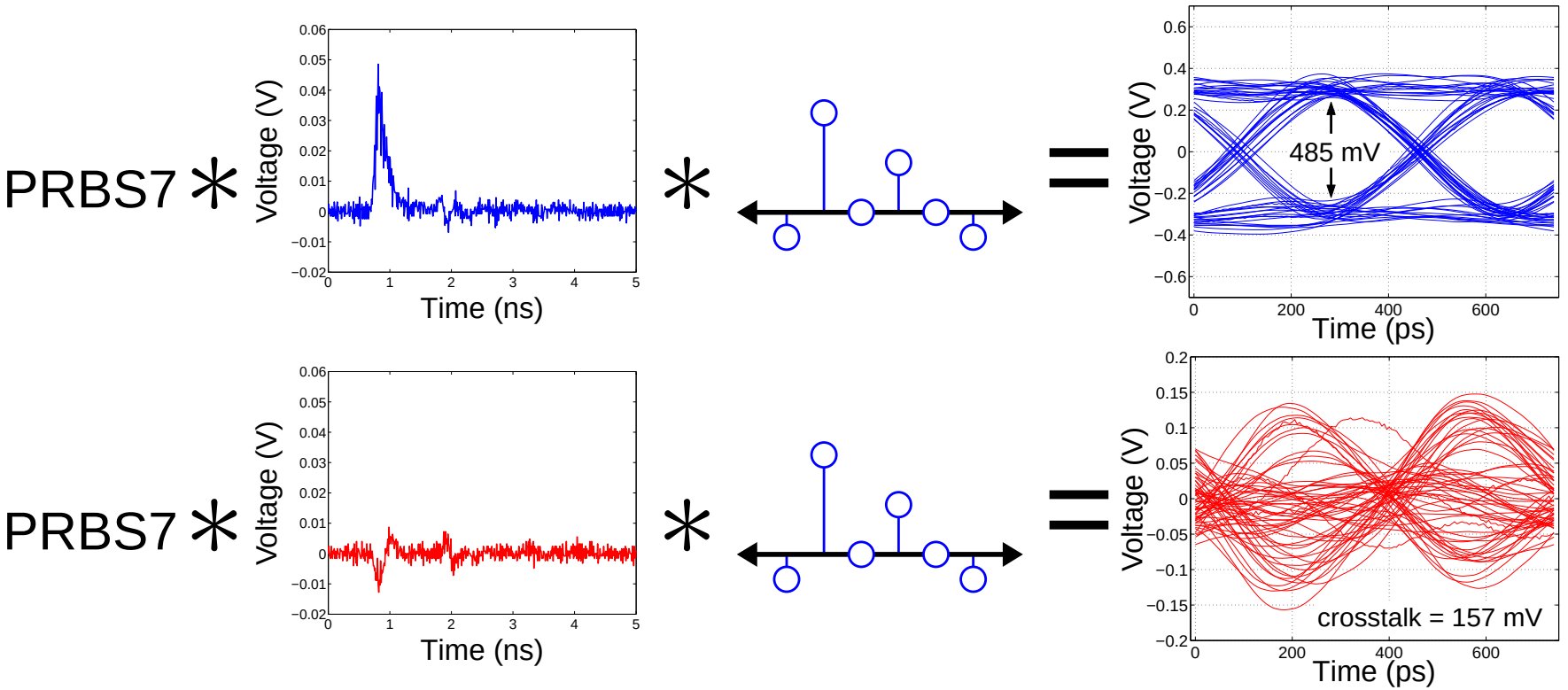
Definition

$$E2C = \frac{\text{crosstalk-free eye opening}}{\text{maximum possible crosstalk}}$$



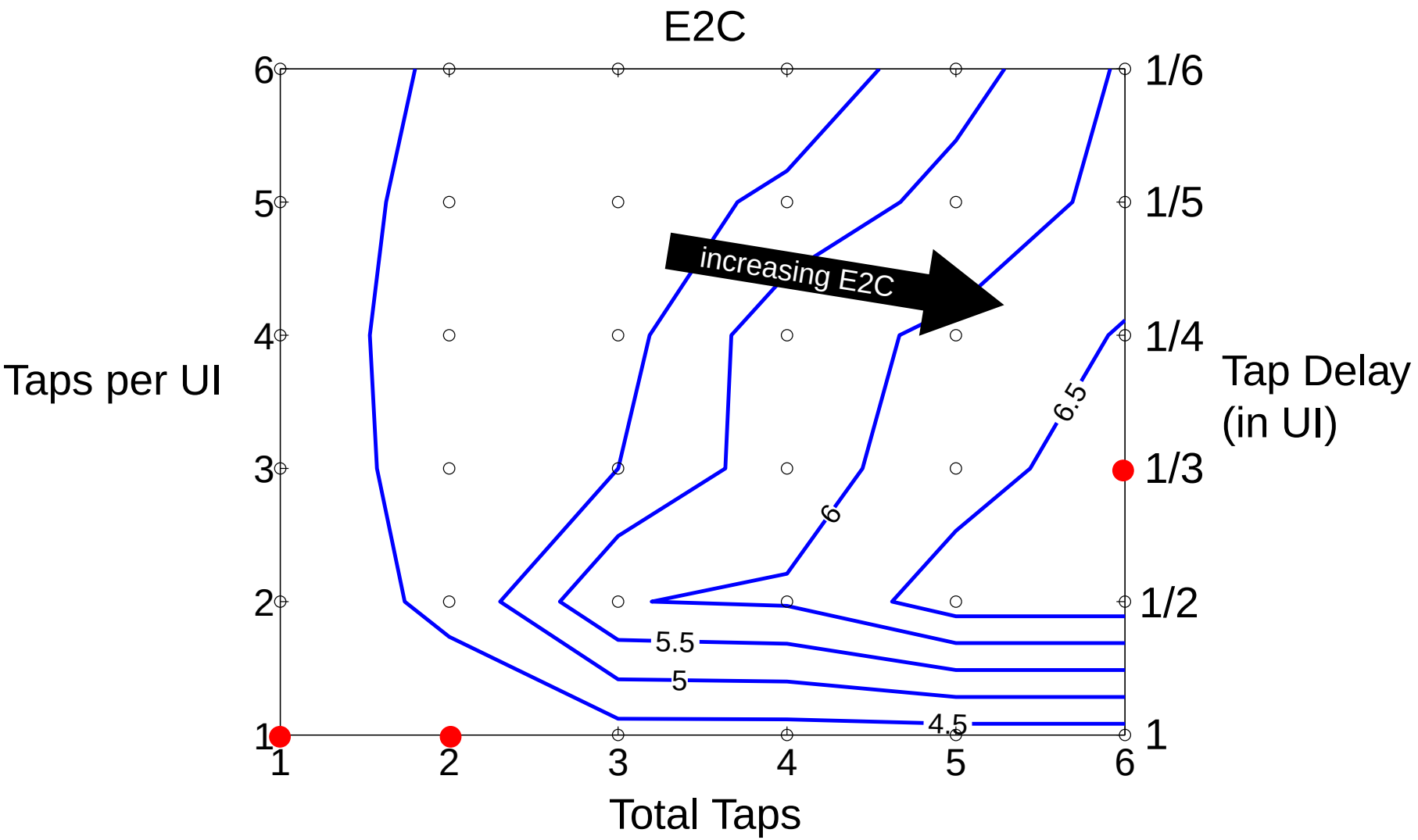


Find E2C for each Pulse Shape

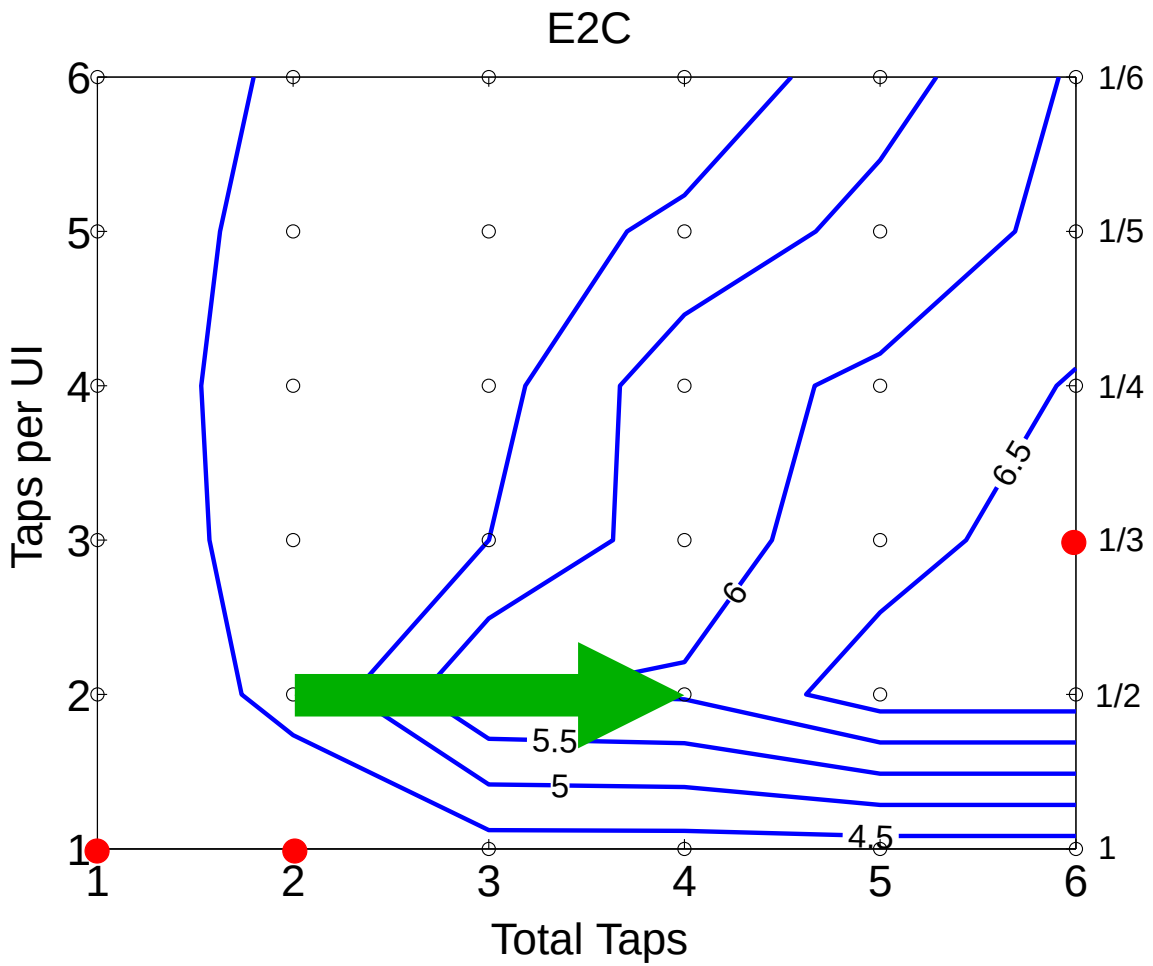


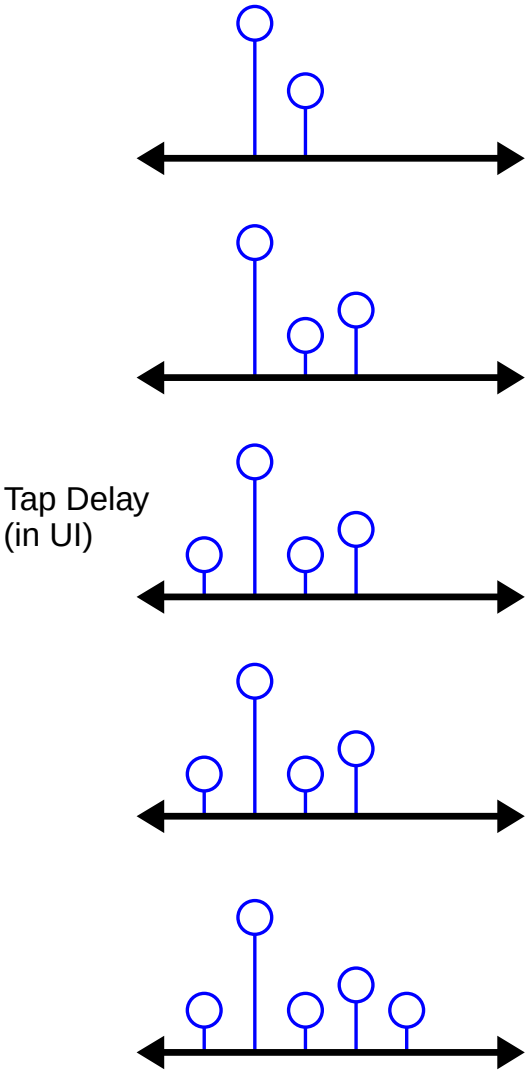
- $E2C = \frac{485\,mV}{2 \times 157\,mV} = 1.54$
- Repeat calculation for all candidate pulse shapes

Maximum E2C for Various Filter Types at 2.7 Gb/s

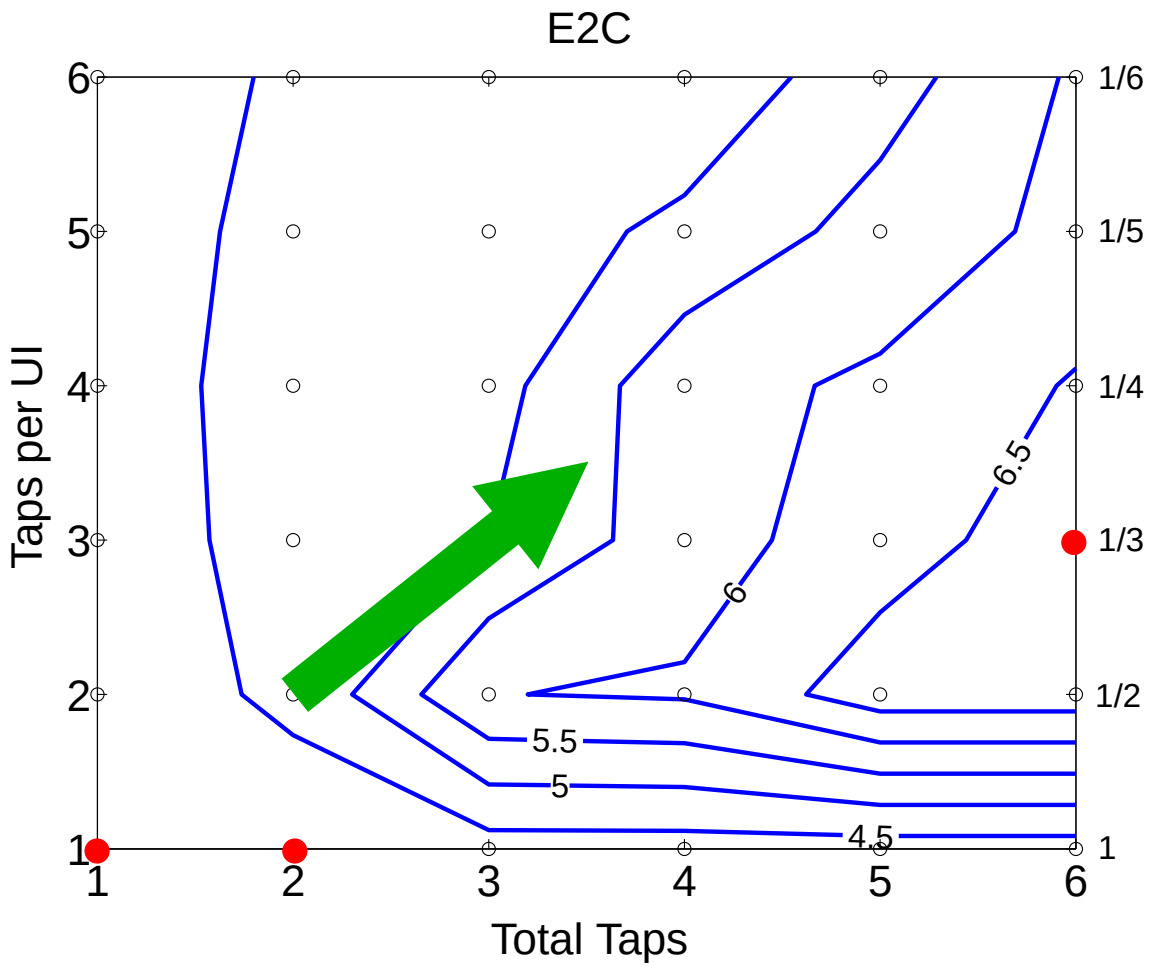


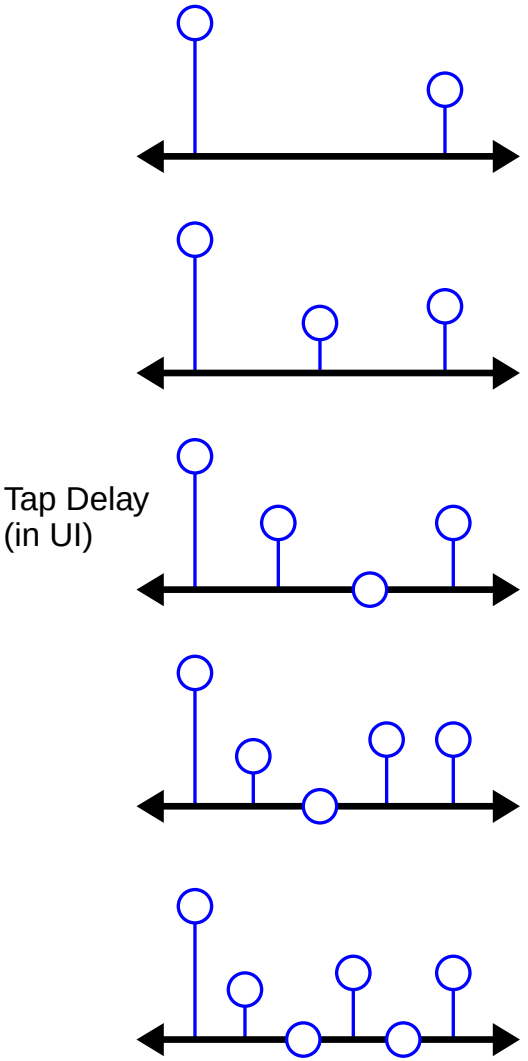
Increasing Total Taps



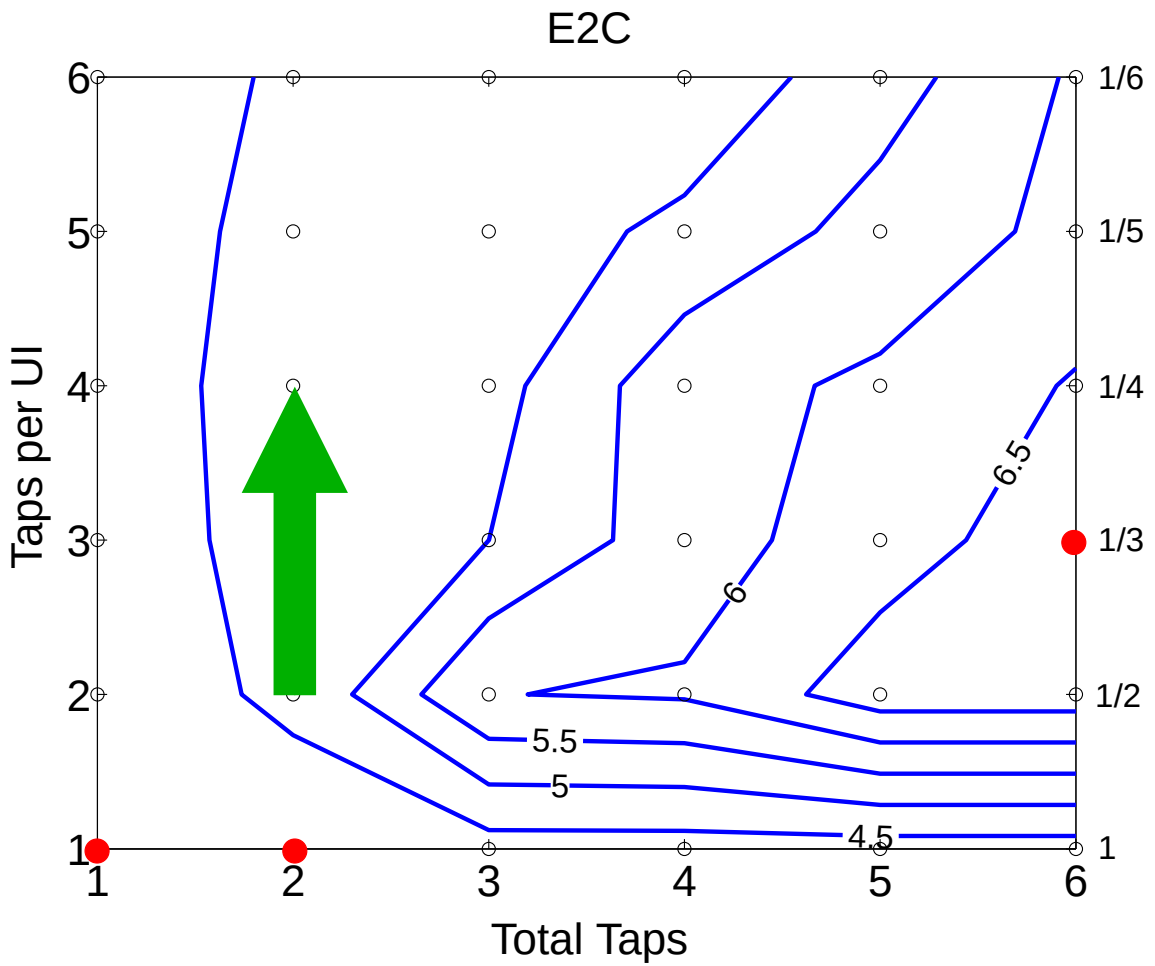


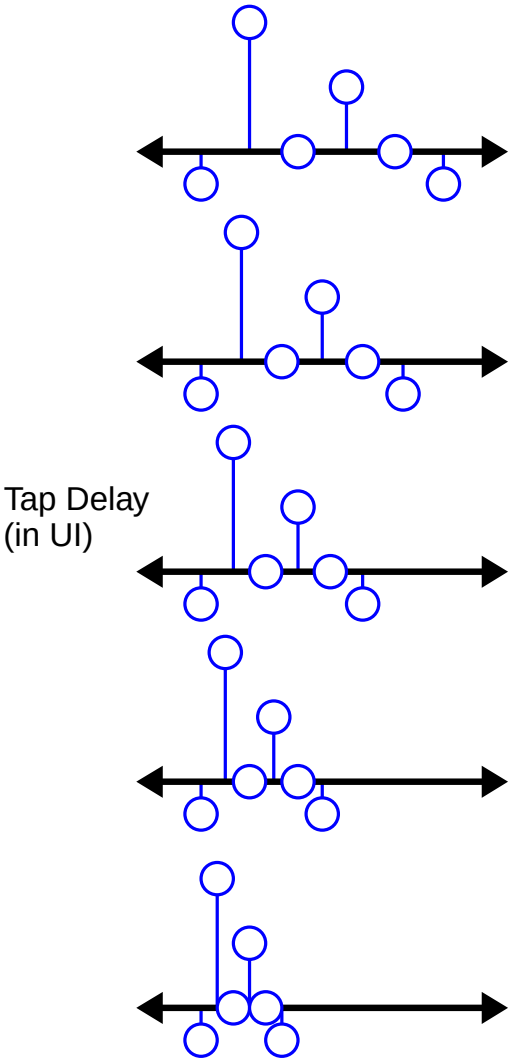
Increasing Granularity



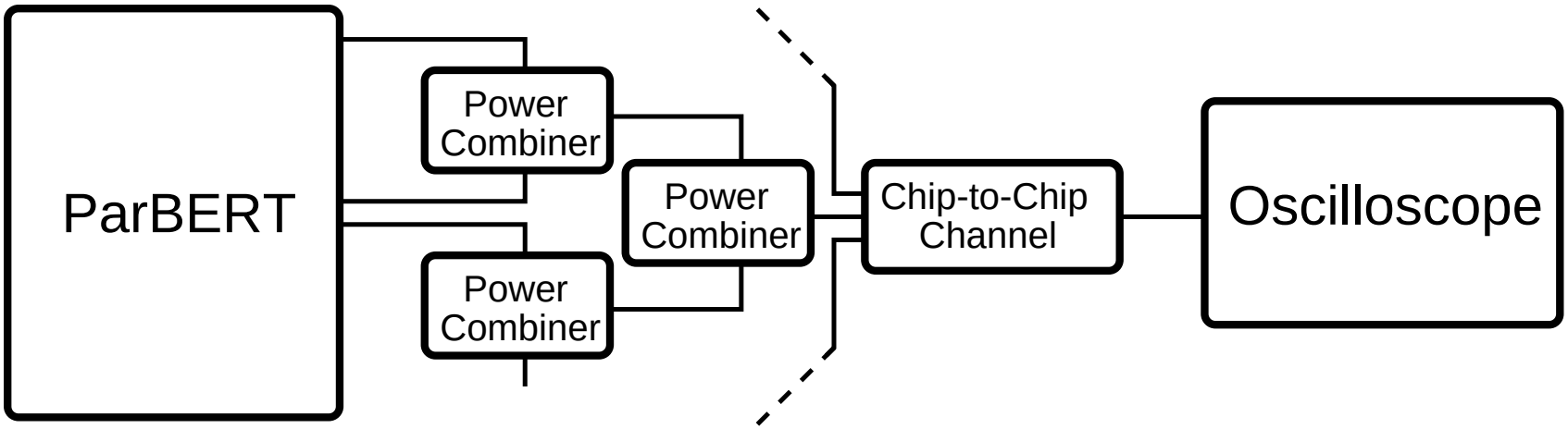


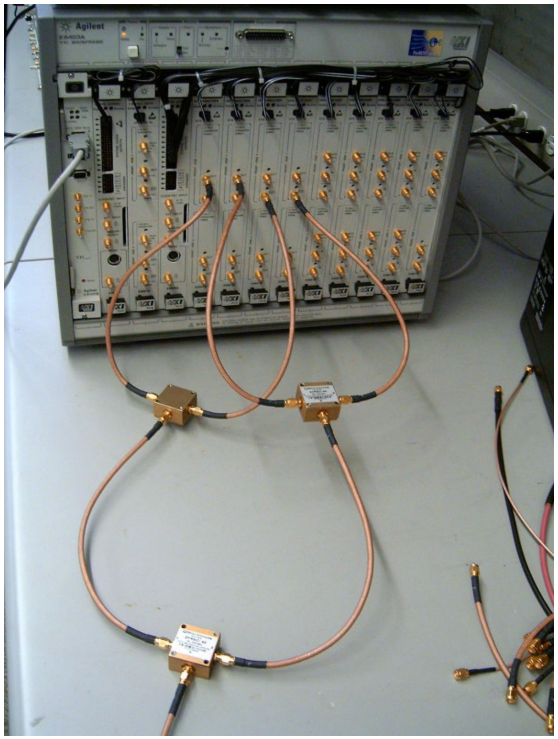
Increasing Taps per UI

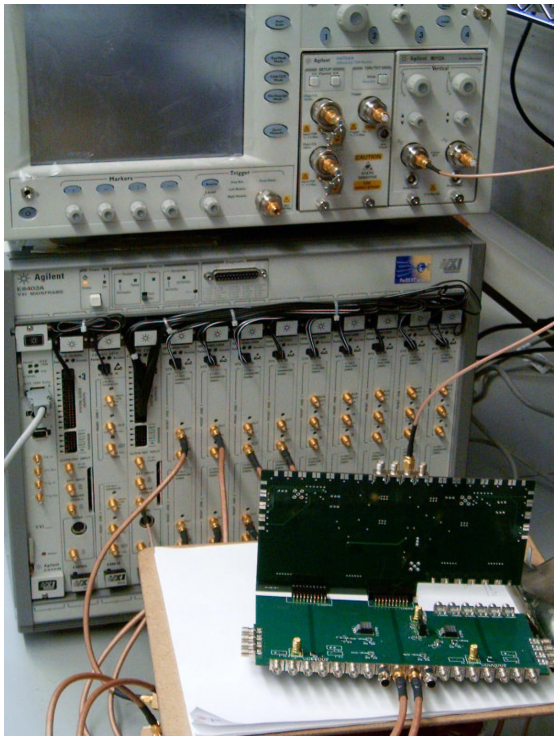




Hardware Proof-of-Concept

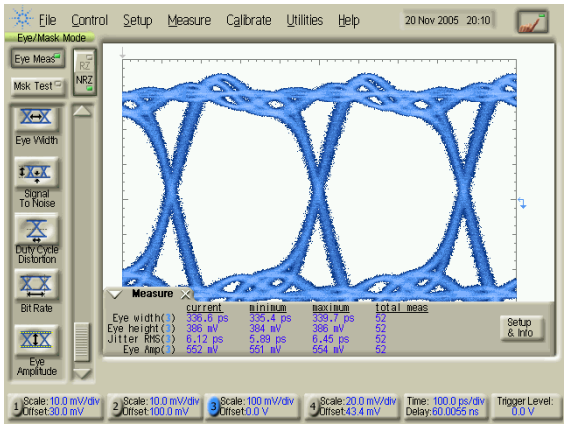




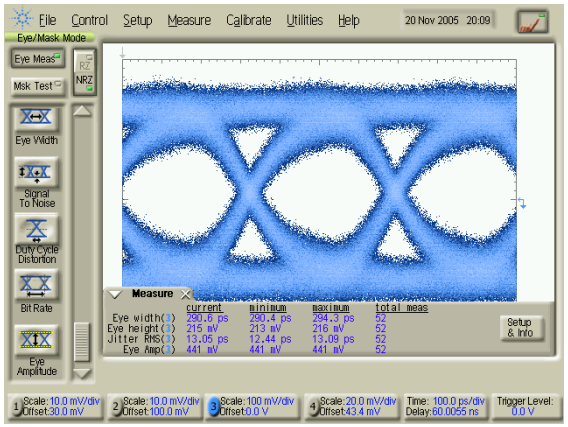


Channel Introduces ISI and Crosstalk

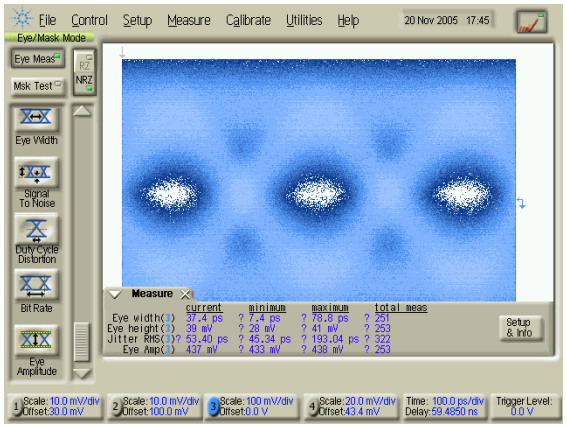
- 2.7 Gb/s
- PRBS: $2^{31}-1$



- input to channel
- square pulse

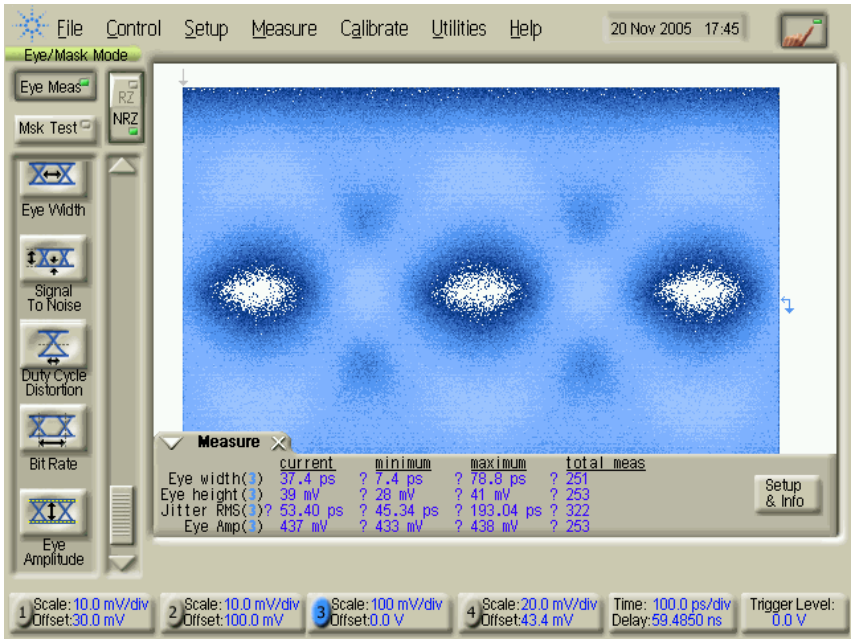


- output from channel
- no aggressors

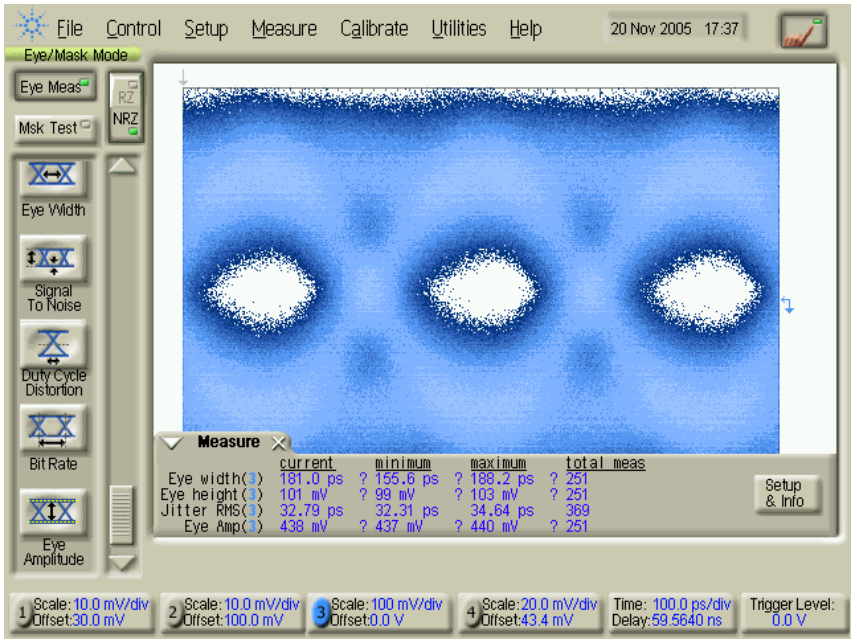


- output from channel
- two aggressors

Filter Opens the Eye

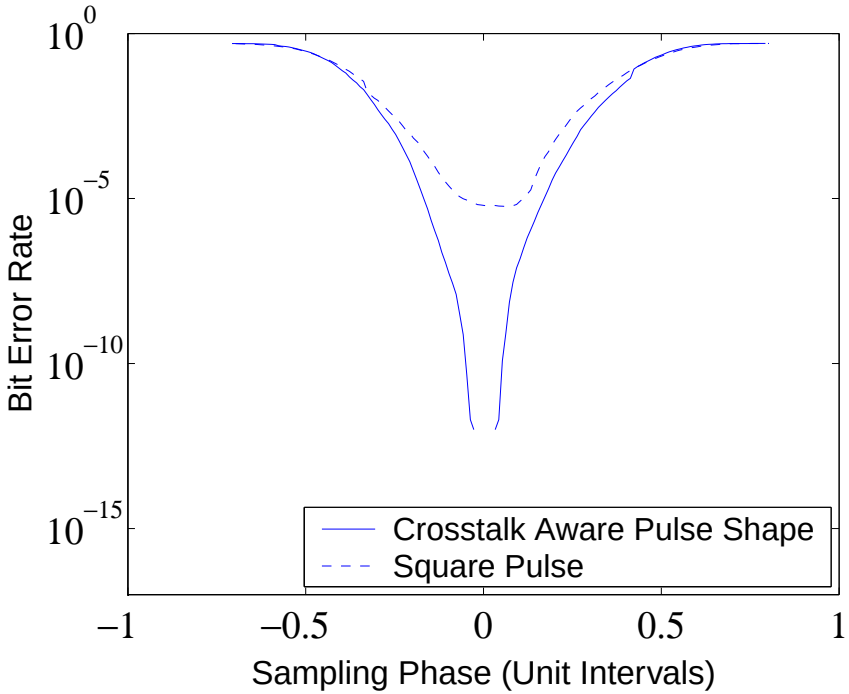


- output from channel
- two aggressors
- square pulse input
- $jitter_{RMS} = 53\,ps$

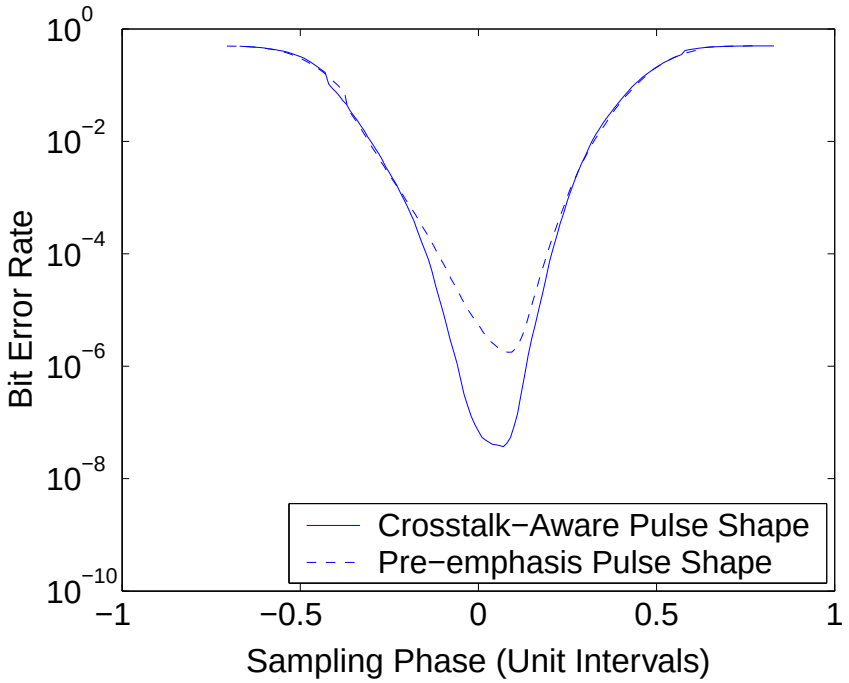


- pulse shape chosen to maximize E2C
- 3 total taps
- 2 taps per UI
- $jitter_{RMS} = 33\,ps$

Filter Improves Bit Error Rate



- square pulse: $BER = 10^{-5}$
- crosstalk-aware pulse: $BER < 10^{-12}$



- pre-emphasis pulse: $BER = 10^{-7}$
- crosstalk-aware pulse: $BER = 10^{-5}$

Conclusion

- Crosstalk is significant in board-to-board channels
- Received eye opening can be increased by taking crosstalk into account when equalizing
- Crosstalk-aware pulse shape decreased BER by 10^2 at 2.7 Gb/s