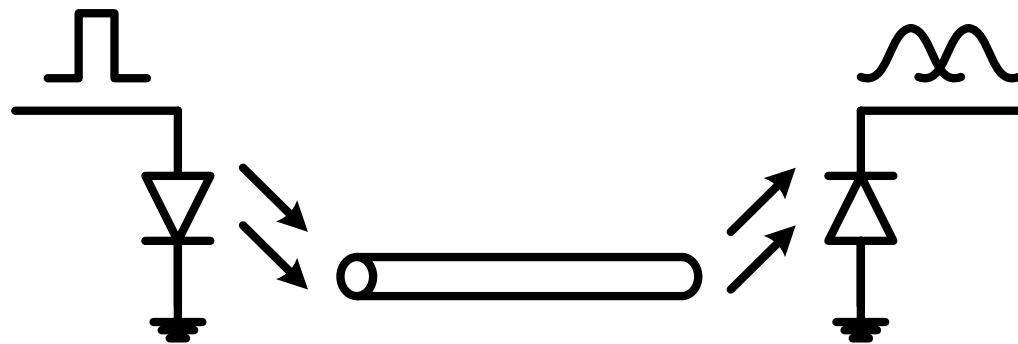


Electronic Dispersion Compensation of 40-Gb/s Multimode Fiber Links Using IIR Equalization

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Transmitting Data Over Short Multimode Fiber Links

- Data transmission speed limited by intermodal dispersion
- Intermodal dispersion causes a wide variety of channel responses
- Result: Inter-symbol Interference (ISI) at receiver

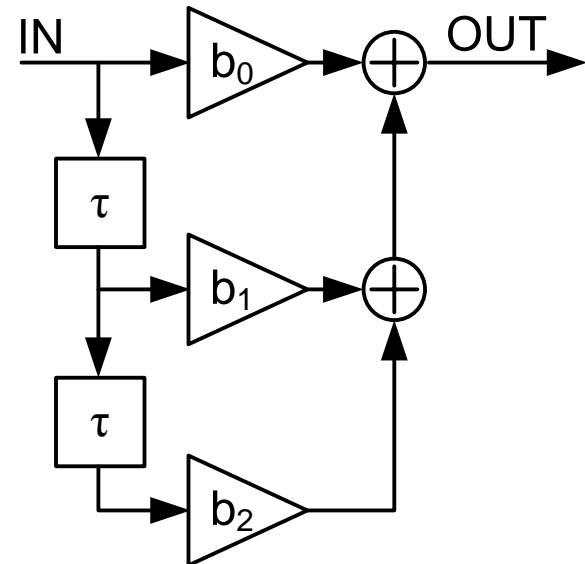


Modal Dispersion Mitigation

- Two dispersion compensation methods
 - Optical
 - Electrical
- Electrical equalization advantages
 - Low cost
 - Adaptive
 - Robust

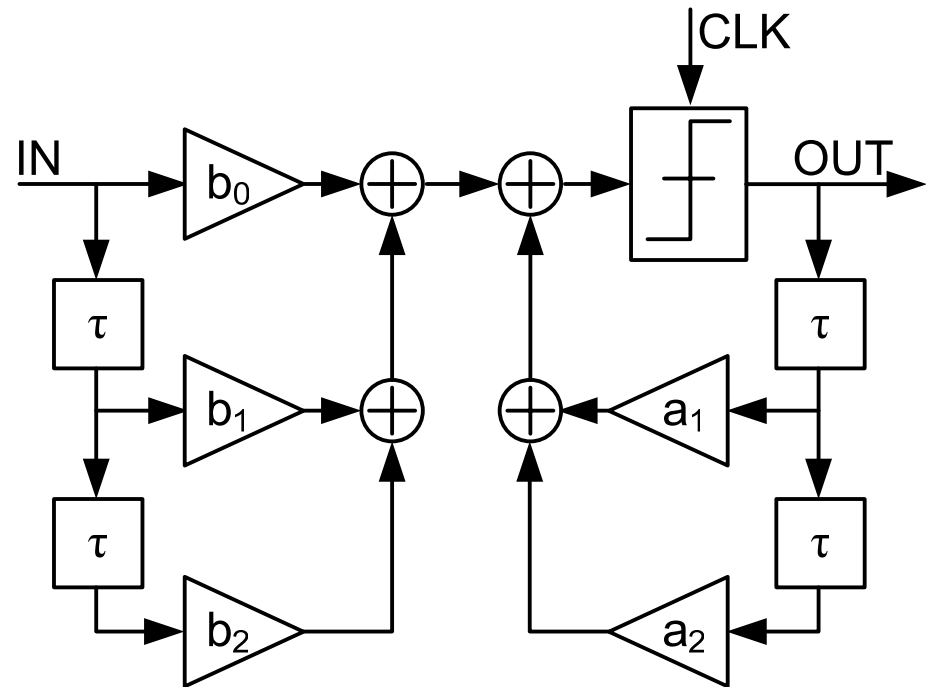
Typical Equalizer - FIR

- ✓ Clockless
- ✓ Low power
- ✓ Guaranteed stability
- ✗ Cannot compensate spectral nulls
- ✗ Restricted to manipulating zeros
- ✗ Only cancels ISI up to length of equalizer



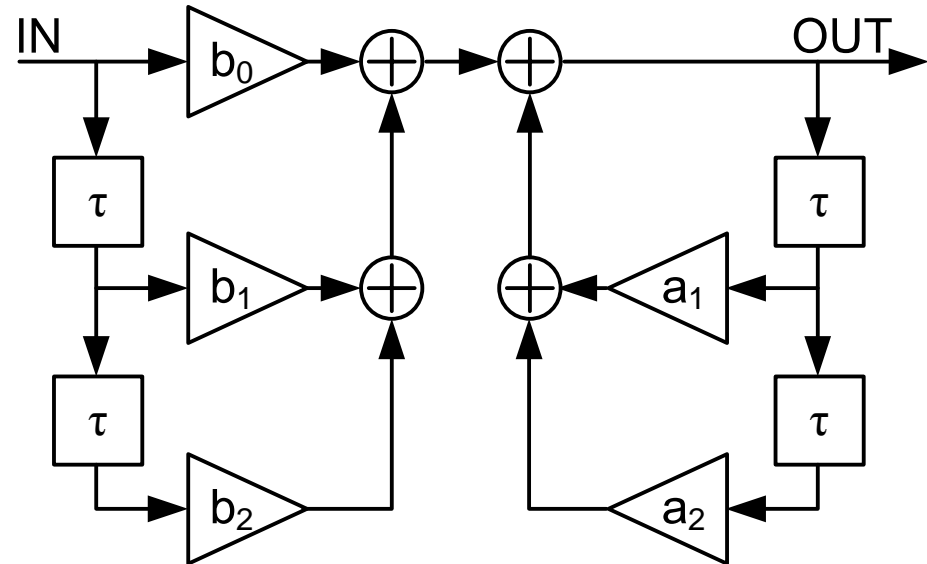
Typical Equalizer - DFE

- ✓ Compensates spectral nulls without noise enhancement
- ✗ Difficult to meet timing in feedback path at high speeds
- ✗ Difficult timing recovery



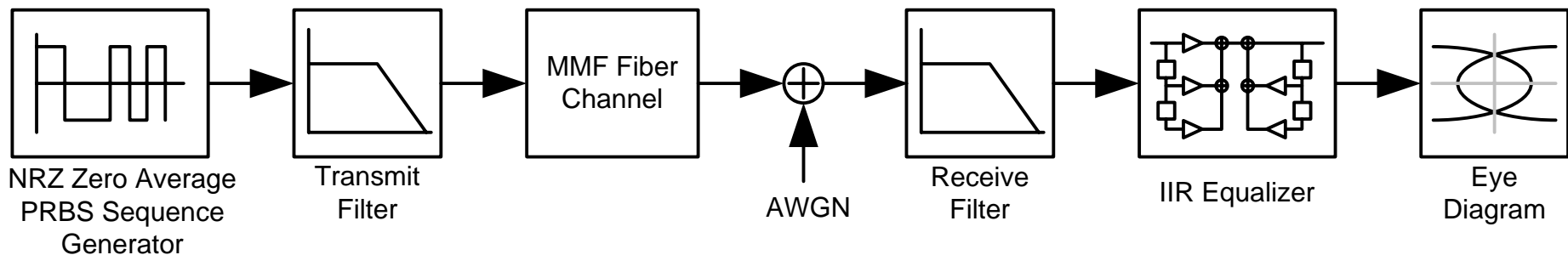
IIR Equalizer

- ✓ Clockless
- ✓ Manipulate both poles and zeros
- ✓ Cancels ISI beyond length of equalizer
- ✗ More noise enhancement than DFE
- ✗ Possibly unstable



System Simulation

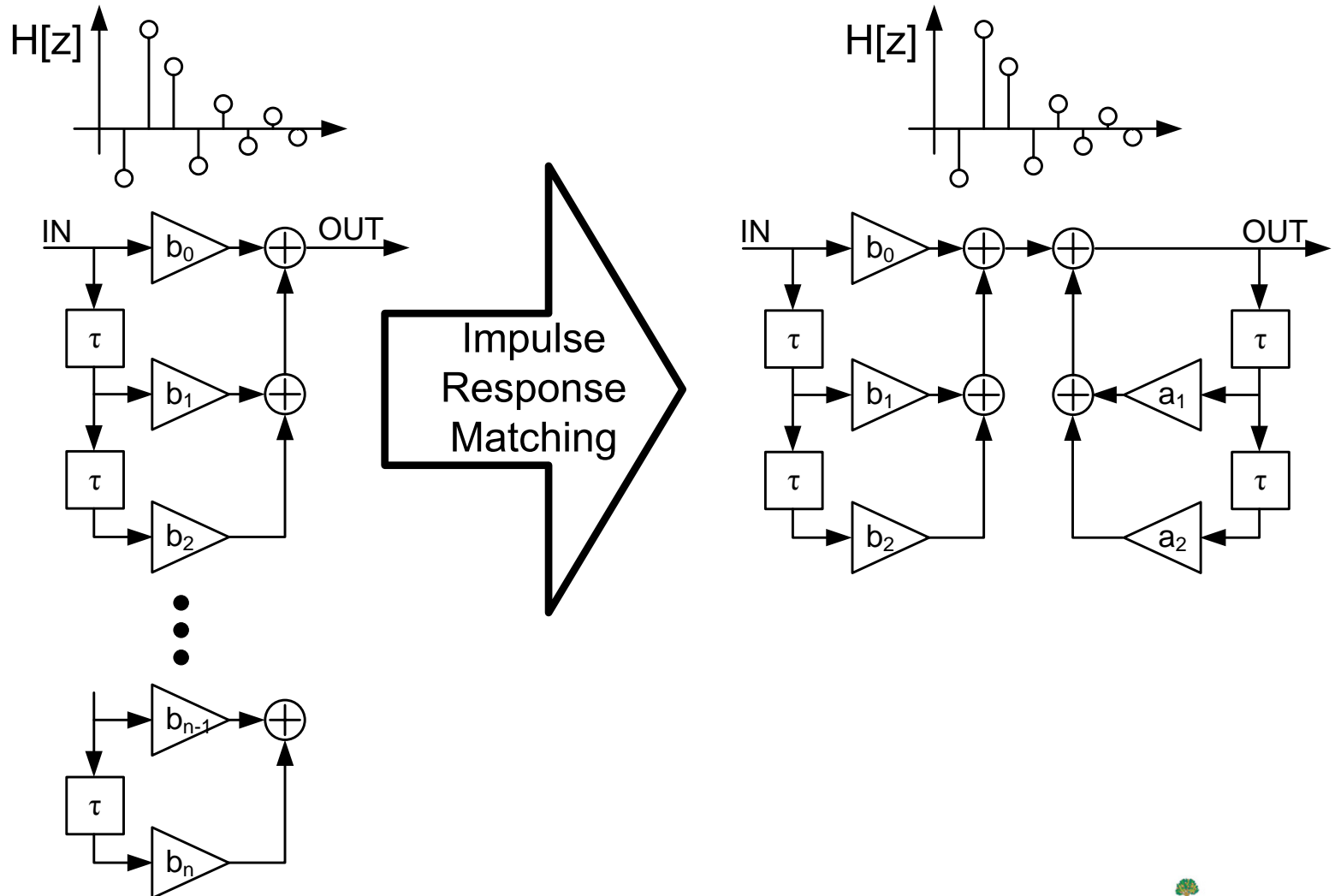
- IIR equalization of a 50 m MMF link at 40 Gb/s
- Comparing the performance of a 3-Tap FIR versus a 3-Tap FF and 2-Tap FB IIR equalizer
- Both equalizers have $T_s/2$ tap spacing



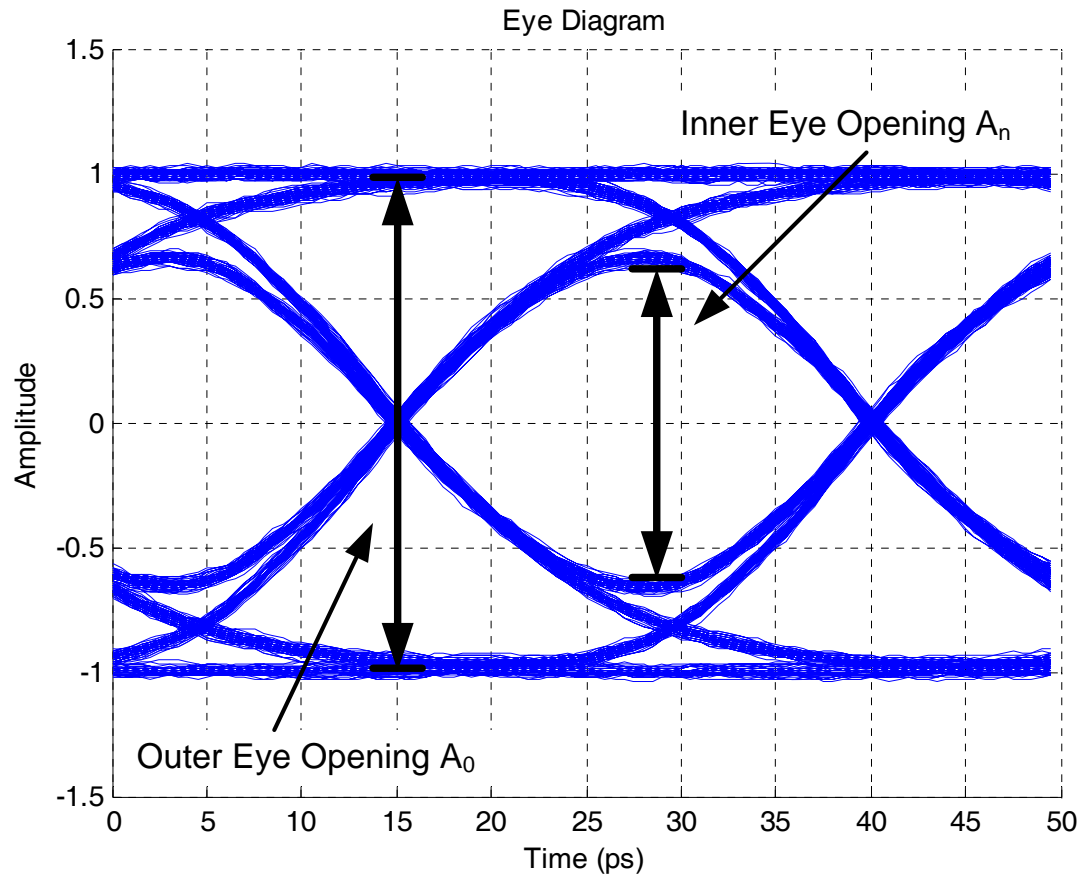
MMF Fiber Channel Model

- Statistical MMF channel model
- Based on restricted launch scheme at various radial offsets
- Model represents the performance of the worst-case 5% of installed fibers
- Model linearly scaled from original 300 m length to 50 m

IIR Coefficient Optimization

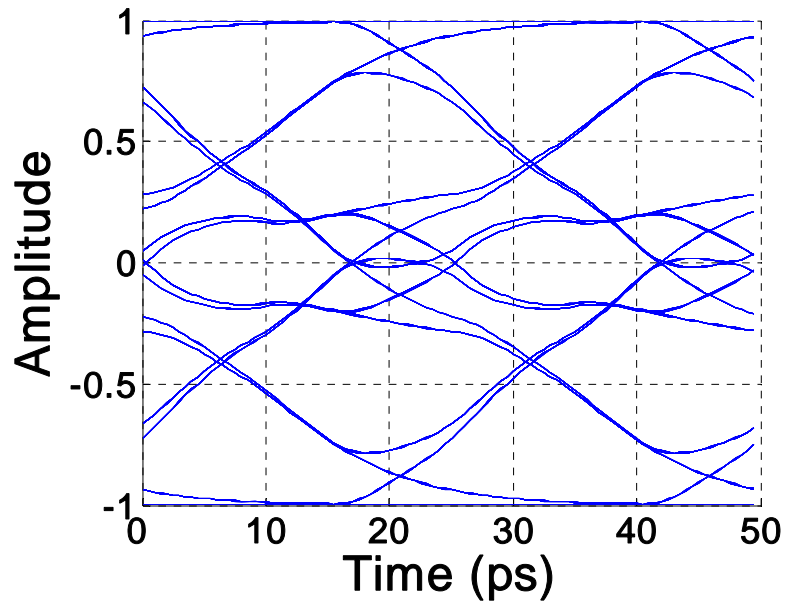
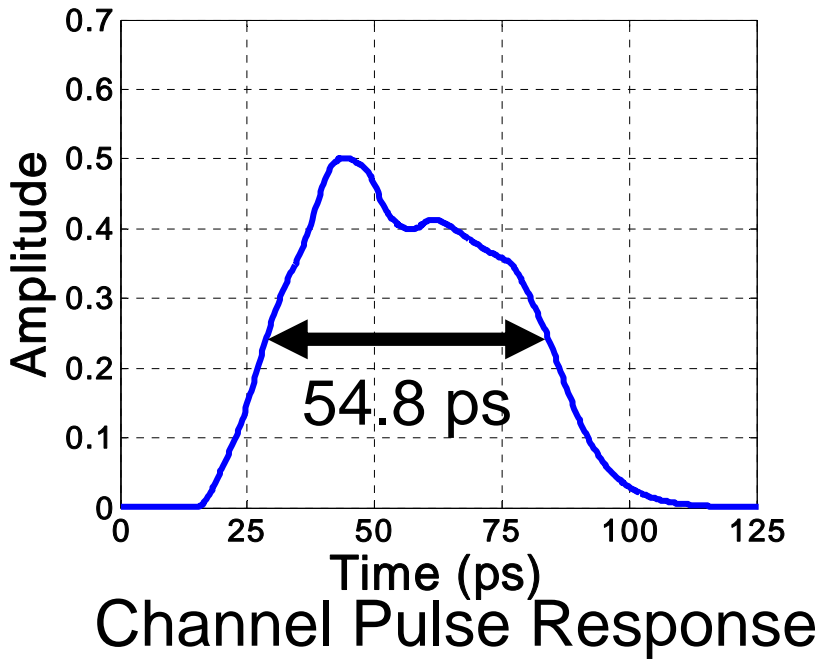


Definition: ISI Penalty



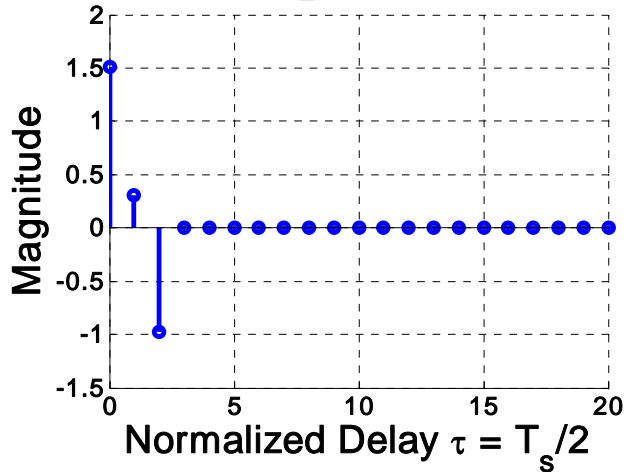
$$\text{ISI Penalty} = 10 \cdot \log_{10}(A_0/A_n)$$

Example Channel

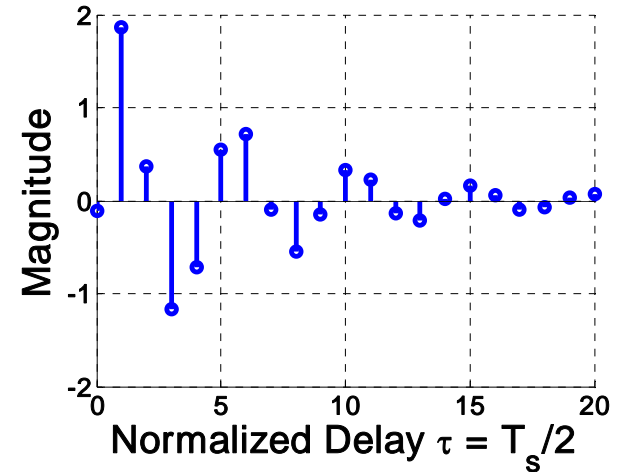
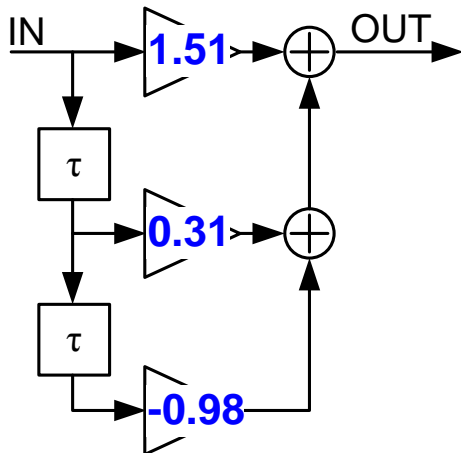


Unequalized Channel
ISI Penalty = 20.3 dB
Data Dependent (DD)
Jitter_{pp} = 21.4 ps

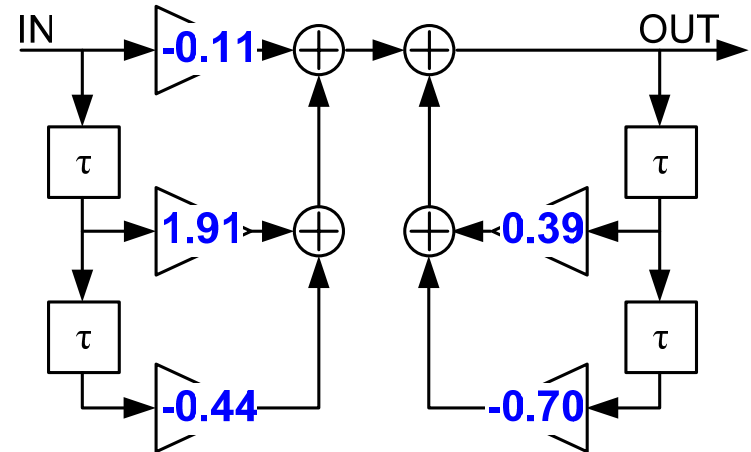
Equalizer Performance



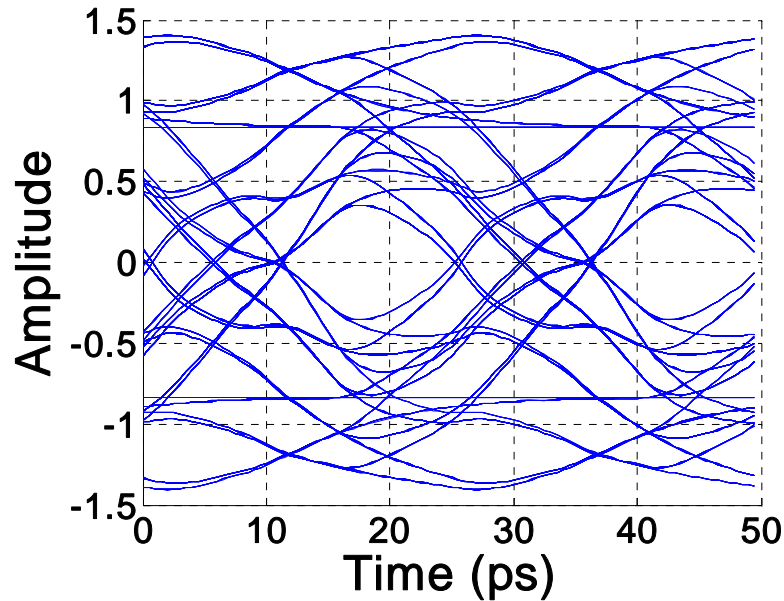
3-Tap FIR



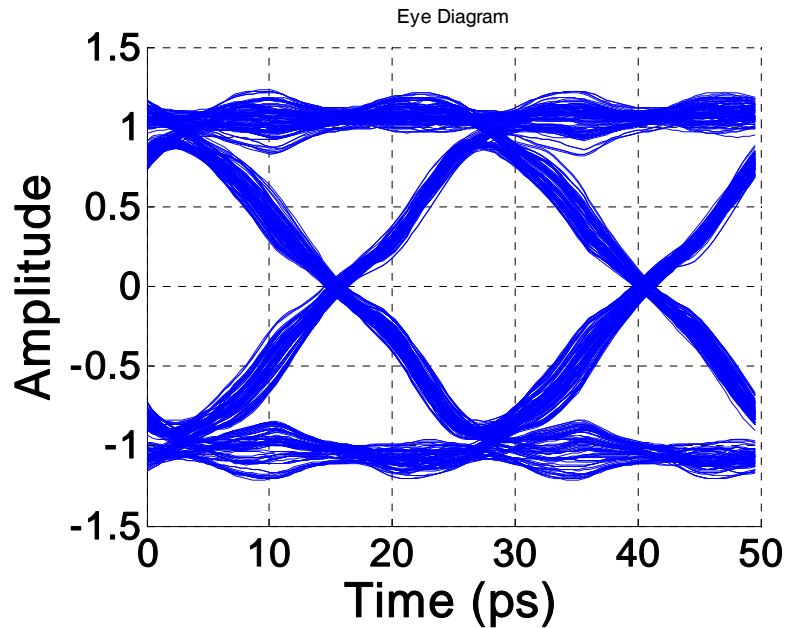
IIR Equalizer



Equalizer Performance

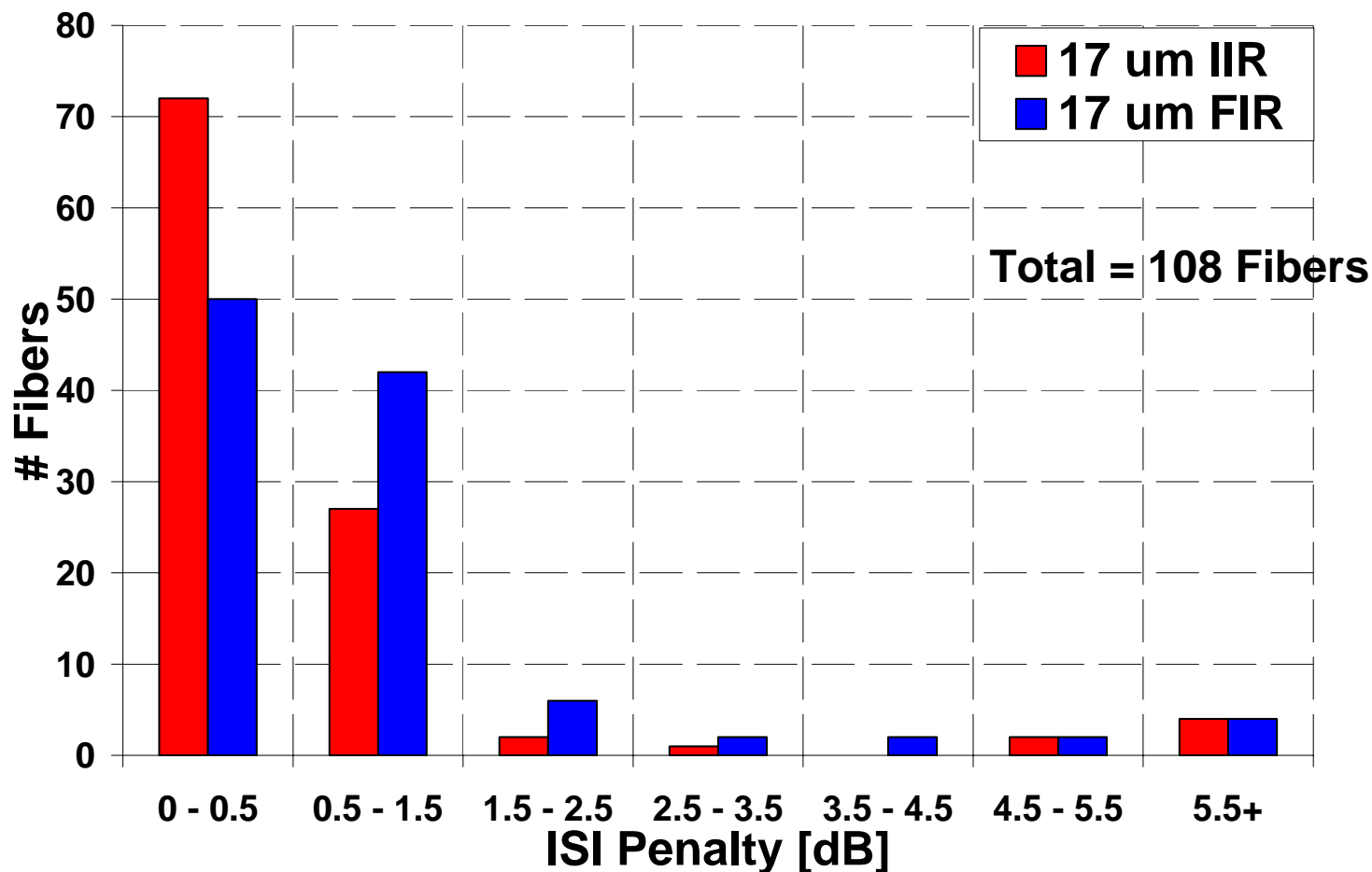


3-Tap FIR Equalized
ISI Penalty = 3.9 dB
DD Jitter_{pp} = 11.4 ps

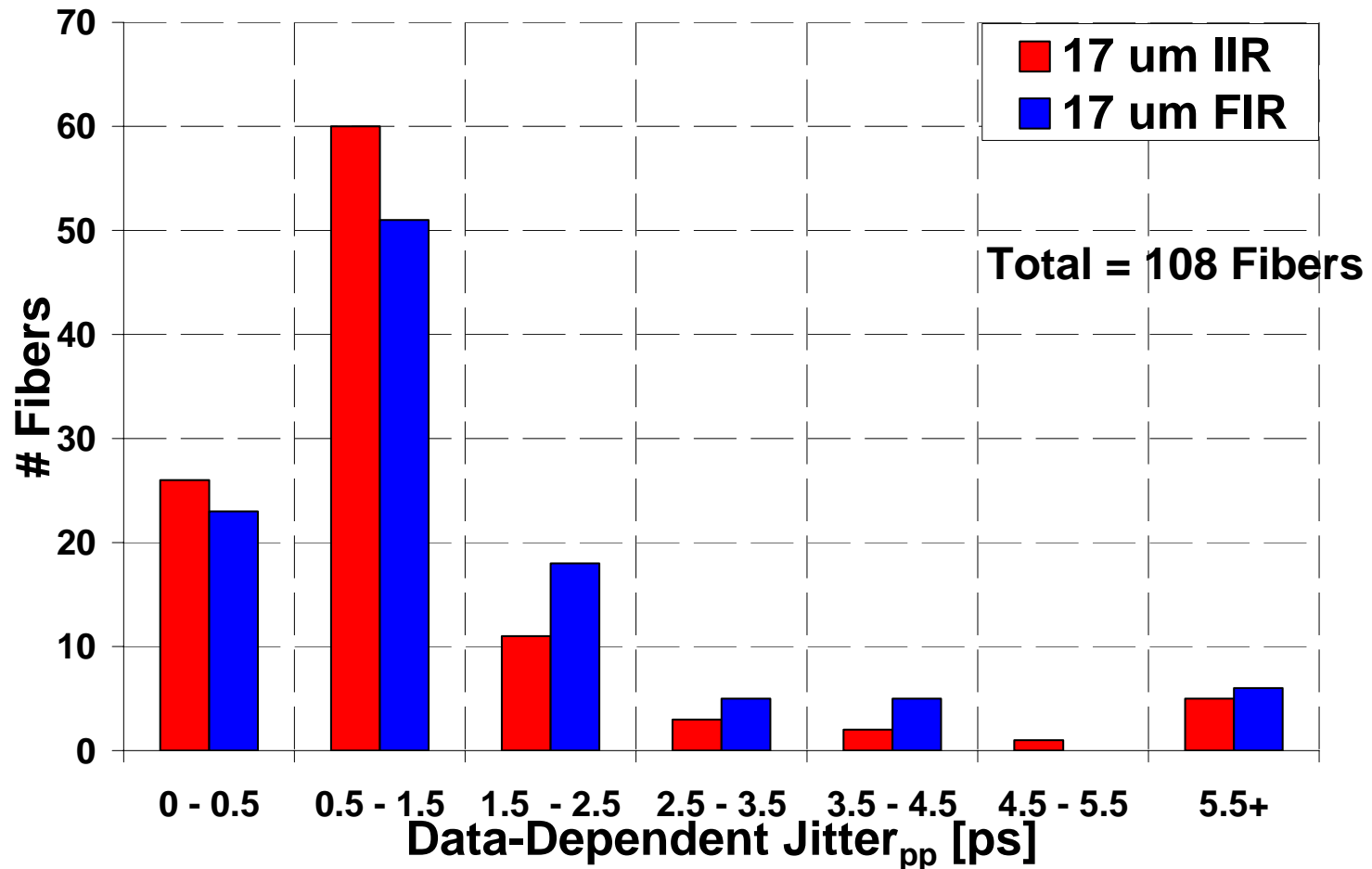


IIR Equalized
ISI Penalty = 1.1 dB
DD Jitter_{pp} = 3.3 ps

Statistical Analysis – ISI Penalty



Statistical Analysis - Jitter



Conclusion

- Introduced IIR equalizer for intermodal dispersion compensation
- Demonstrated the effectiveness of the IIR equalizer over the FIR equalizer
- Statistical analysis shows that an IIR equalizer equalizes 90% of the 50 m MMF links at 40 Gb/s
 - < 2.5 dB of ISI penalty for the 5% worst case fibers
 - < 3.75 ps of data-dependent peak-to-peak jitter

Questions?