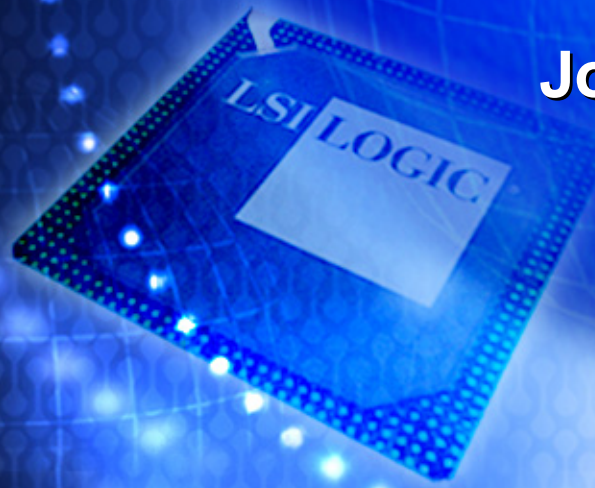# 10GBASE-KR Transmit Equalizer Tap Range and Resolution

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Joe Caroselli
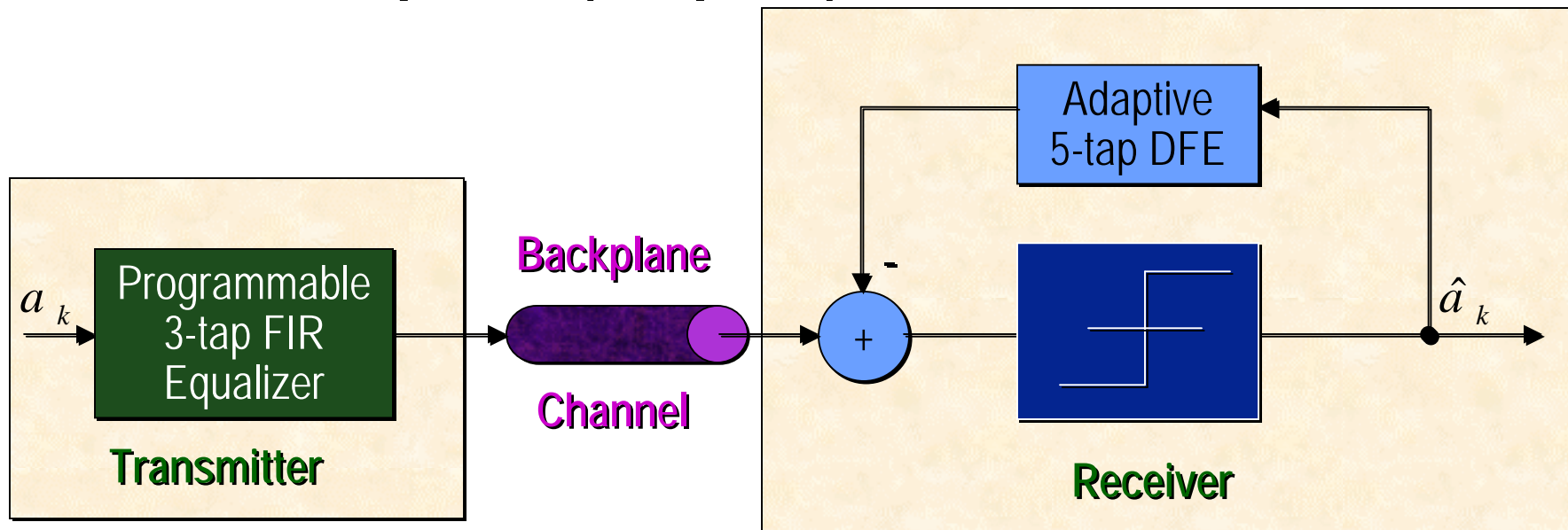
LSI Logic

LSI LOGIC

Scope and Purpose

- **This presentation is related to LSI Logic comments on 10GBASE-KR transmit equalizer requirements.**

- **Investigate the impact of transmit equalization setting range and accuracy on link performance in terms of slicer SNR.**
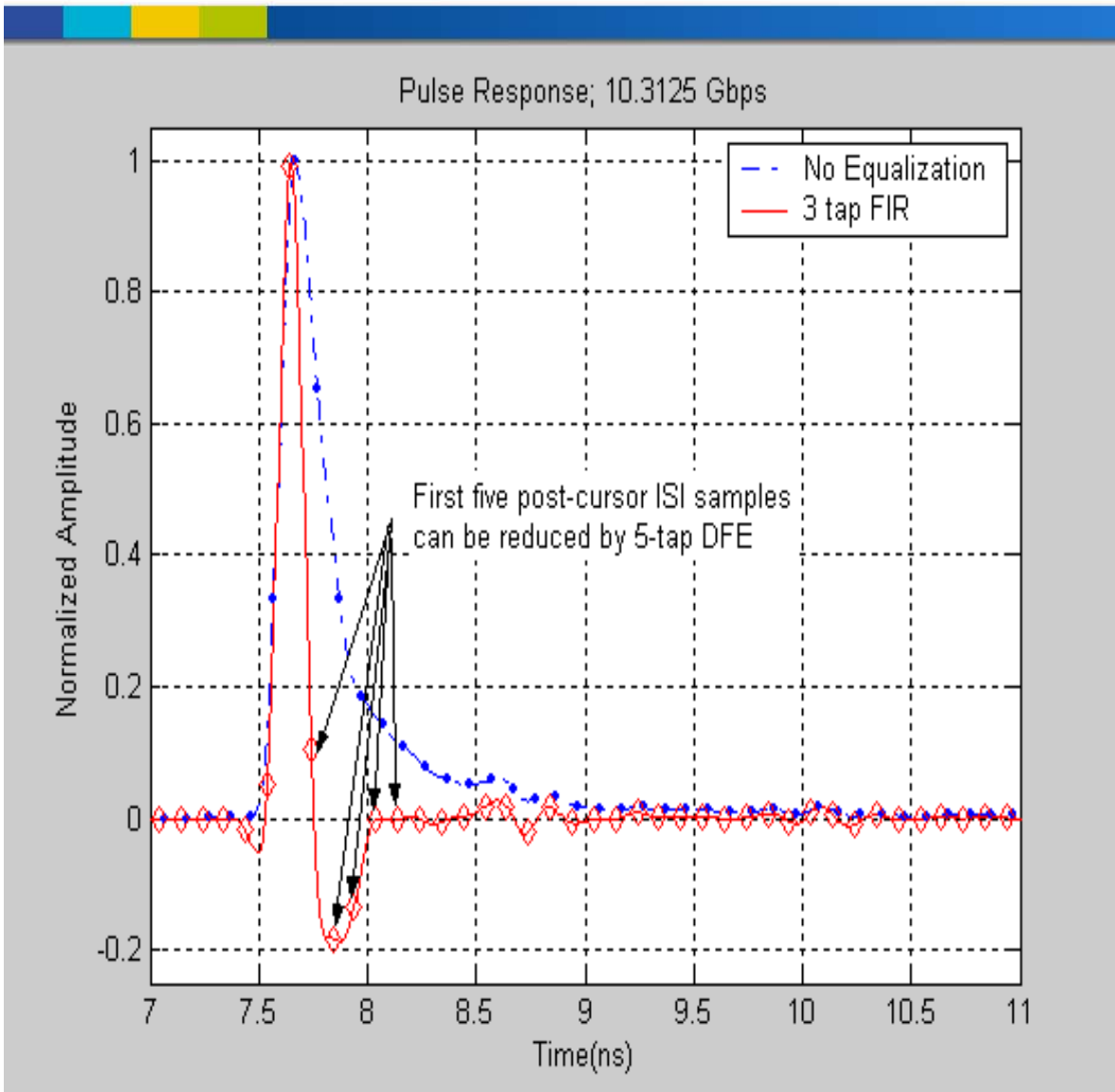
System Model

- **1/T=10.3125GHz**
- **TX: 3-tap transmit FIR (programmable)**
- **RX: 5-tap DFE (adaptive)**

3-Tap TX FIR Filter Reduces Pre- and Post-cursor ISI

LSI LOGIC

Pulse Response; 10.3125 Gbps

First five post-cursor ISI samples can be reduced by 5-tap DFE

Legend: No Equalization, 3 tap FIR

Axes: Normalized Amplitude (1, 0.8, 0.6, 0.4, 0.2, 0, -0.2) vs Time(ns) (7, 7.5, 8, 8.5, 9, 9.5, 10, 10.5, 11)

- c_{-1} is to reduce pre-cursor ISI.

- c_1 is to reduce post-cursor ISI.

- 5-tap DFE at RX can further reduce the first five post-cursor ISI taps.

3-Tap FIR Transmit Equalizer

- **c_1 and c_{-1} are always negative and c_0 is always positive.**

- **$-c_{-1} + c_0 - c_1 = 1$**

Simulation Overview
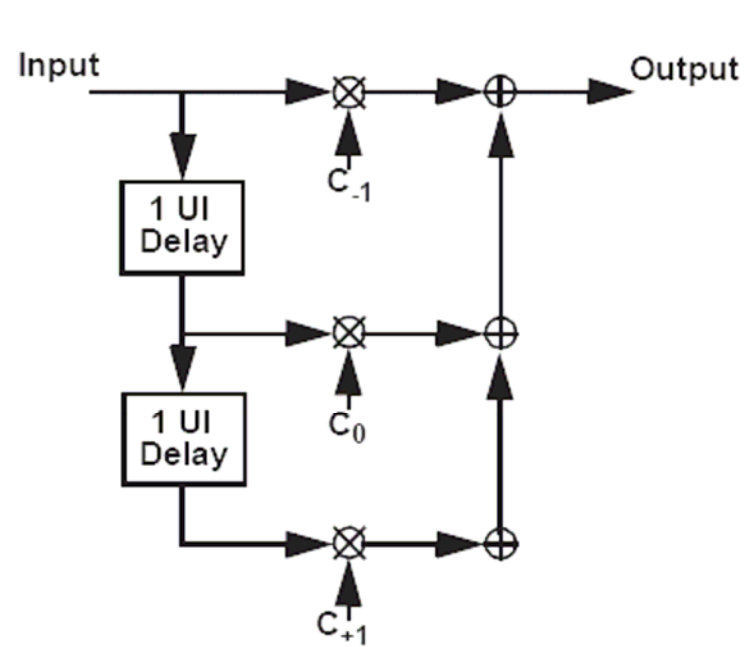
- **Analytic model is used to get slicer SNR at optimal sampling point.**
  - ◆ **Includes**
    - **Intersymbol Interference**
    - **Tx Jitter**
    - **Electronics (White) Noise**
    - **Crosstalk**
  - ◆ **Does Not Include**
    - **Receiver Sensitivity**
    - **Duty Cycle Distortion**
    - **Other Sources of DJ**

Simulation Overview (Continued)

- **The effect of one near-end crosstalk aggressor (the worst one) is considered.**

- **A simple RC model with pole at 0.75*baud rate is used for the transmitter.**

- **Mellitz capacitor-like package model included on both transmitter and receiver.**

- **Only DJ is from ISI.**
  - ◆ **No DCD, PJ included**

- **0.010UI σ RJ added.**

- **Signal-To-Electronics Noise Ratio 45dB.**
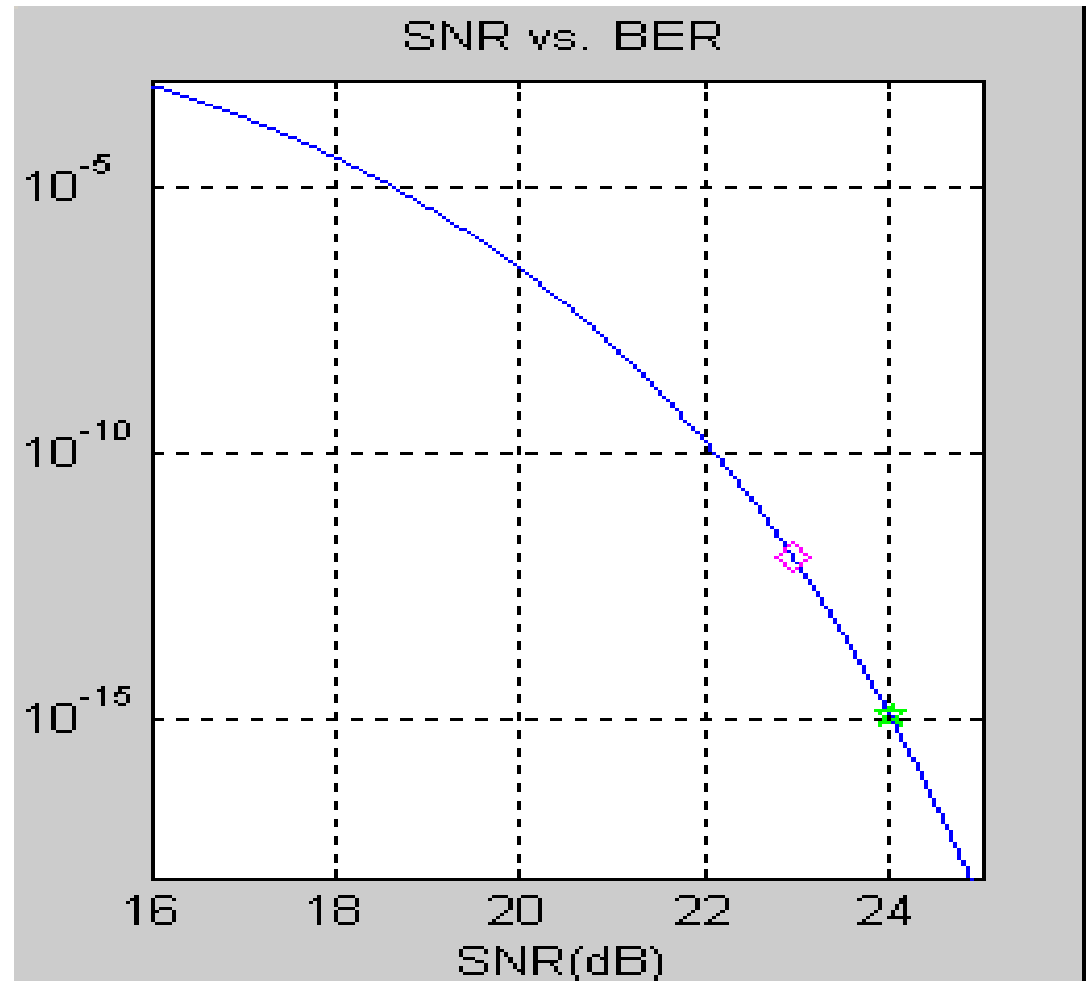
- **DFE tap values are ideal.**
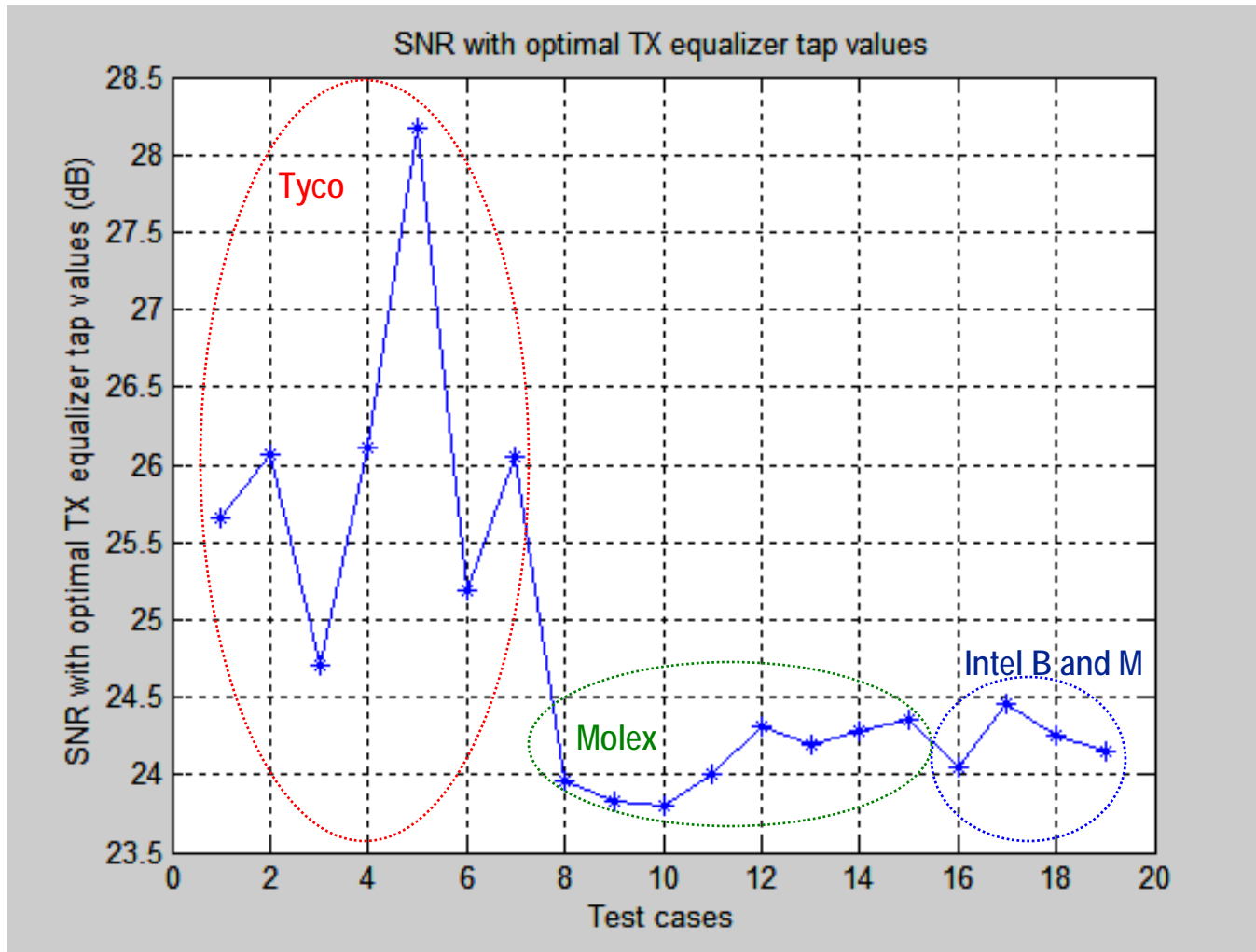
Required SNR
SNR Required at Slicer for 10^{-15} BER

$$SNR = \frac{d^2_{min}}{\sigma^2}$$

$$\mathrm{Pr}_{err} \approx \frac{1}{2} erfc\left(\frac{\sqrt{SNR}}{2\sqrt{2}}\right)$$

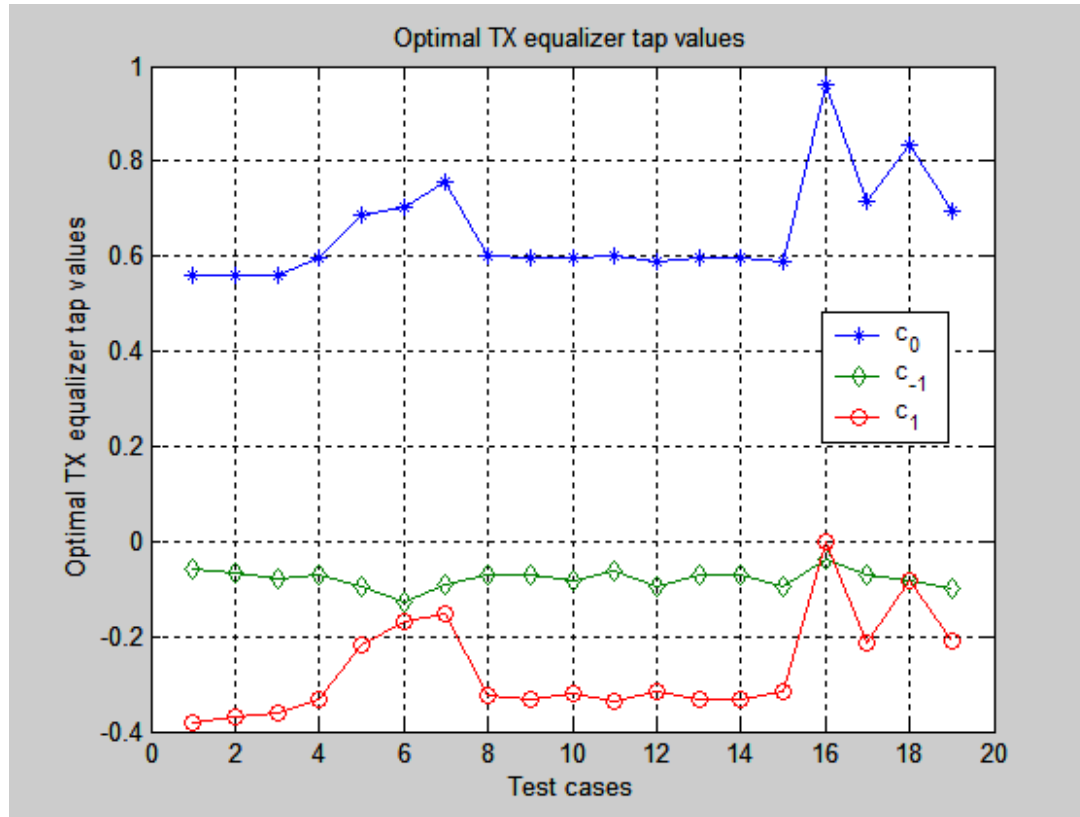- Approximately 23dB is required for an error rate of 10^{-12}

SNR vs. BER

SNR Results Summary
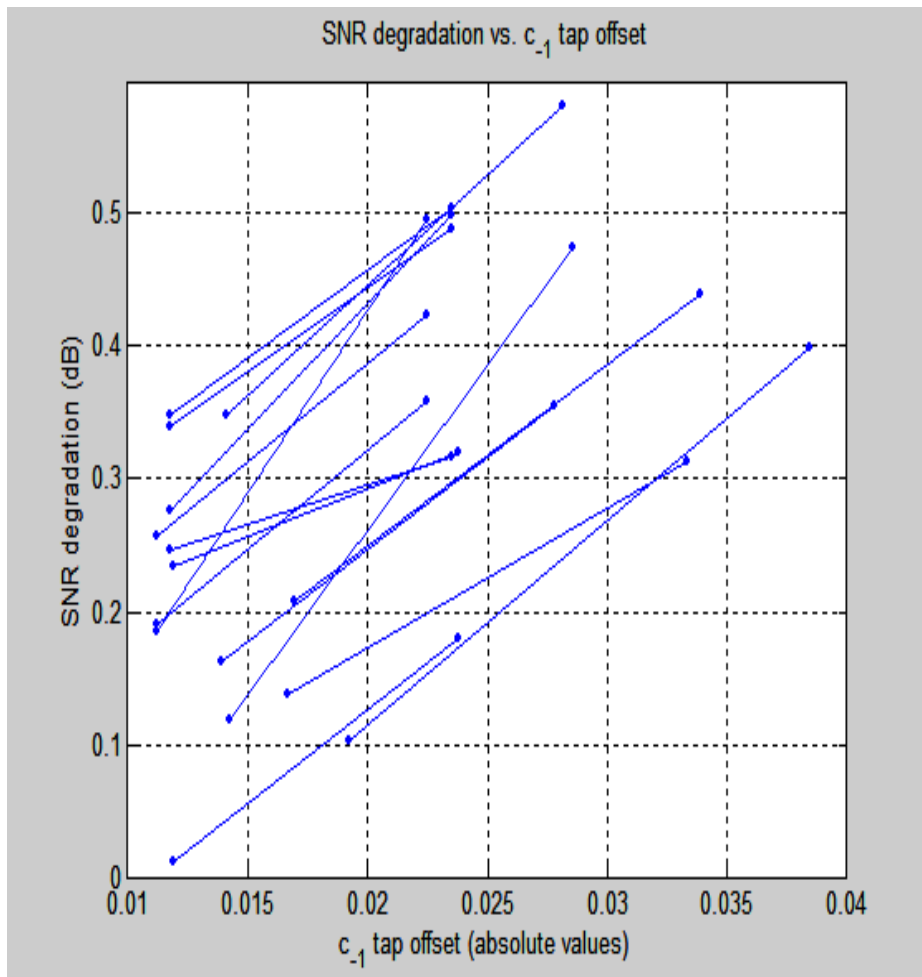
Tap Weight Range


Optimal TX equalizer tap values

- **Our simulation results show the required tap weight ranges are comparable to the current spec.**
  - ◆ c_{-1} up to -0.175
  - ◆ c_1 up to -0.375

C_{-1} Tap Weight Resolution vs. SNR Degradation

SNR degradation vs. c_{-1} tap offset

- **SNR performance is quite sensitive to C_{-1} tap resolution.**
  - ◆ **Reducing pre-cursor ISI mainly relies on C_{-1} tap.**
- **Minimum resolution of 0.025 is required.**

C_1 Tap Weight Resolution vs. SNR Degradation

SNR degradation vs. c_1 tap offset
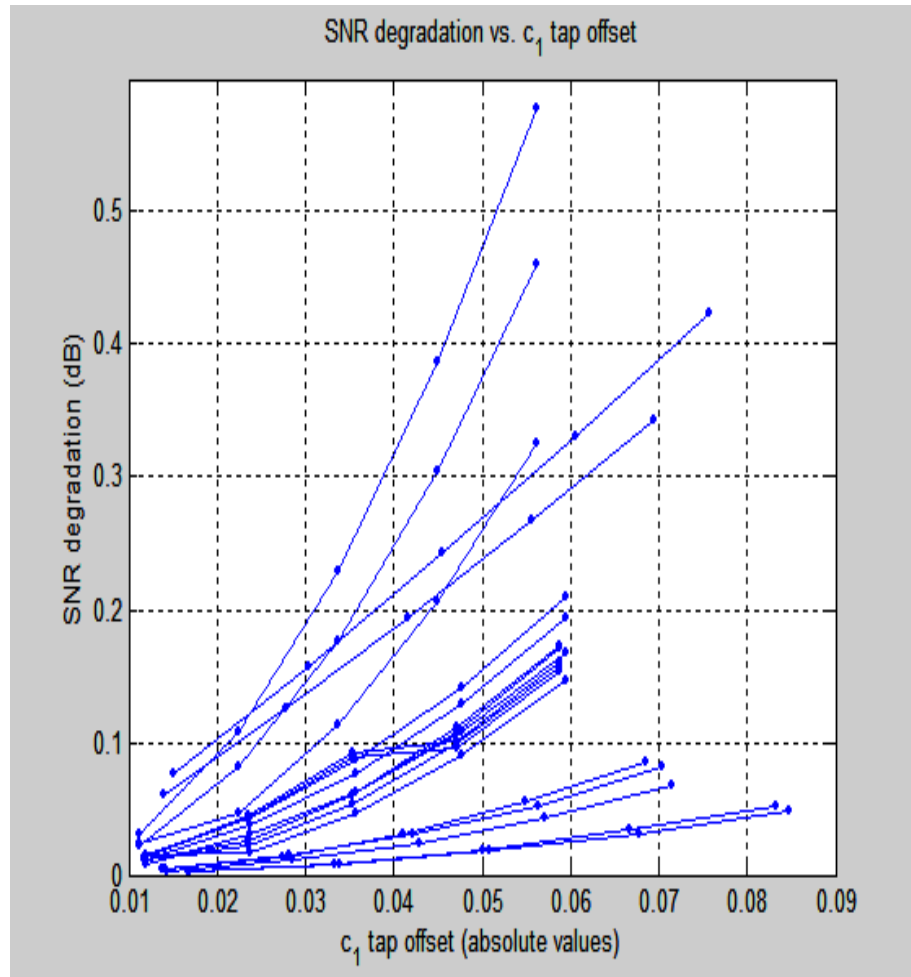
- **Performance is not quite sensitive to C_1 as to C_{-1}.**
  - ◆ **The same amount of tap weight offset of C_1 only causes approximately half SNR degradation of C_{-1}.**
- **DFE at the receiver can further reduce post-cursor ISI.**
- **To get the same amount of performance accuracy, the step size of C_1 can be twice large of C_{-1}.**

Conclusion and Recommendations

- **Tap weight resolution requirements for C_1 and C_{-1} are not the same.**

- **To remove post-cursor ISI accurately, there is trade-off between C_1 resolution and DFE tap resolution. However, DFE can be fully adaptive, which is the easier way to obtain the optimal equalization.**

- **The current specification requirement of minimum 128 states TX equalizer settings seems too large for some applications without TX coefficient training process.**

- **We suggest to reduce C_1 resolution to 0.05.**

  - ◆ **C_{-1} has 8 settings from 0 to −0.175 with step size of at least 0.025.**

  - ◆ **C_1 has 8 settings from 0 to −0.375 with step size of at least 0.05.**