

# Worst Case Channel Modeling and Emulation for Electronic Dispersion Compensation

Kevin Witt, Vitesse Semiconductor

Badri Gomatam, Vitesse Semiconductor

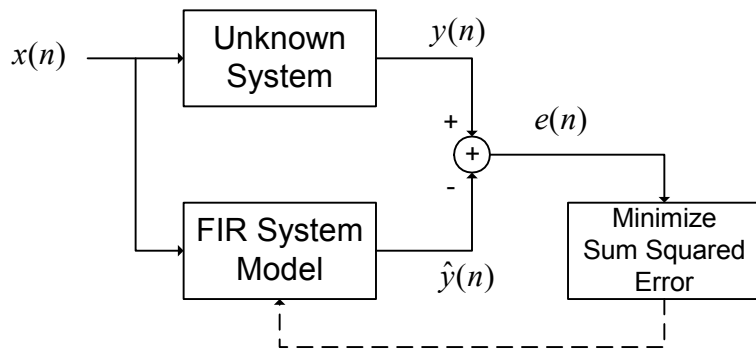
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- Objectives of this presentation
  - Provide a channel modeling methodology.
  - Compare simulated and measured results.
  - Propose an electrical channel emulator for EDC compliance testing.
  
- Background
  - The MMF channel model is a statistical problem.
  - Multiple Electronic Dispersion Compensation (EDC) vendors cannot practically share “worst case” fibers for compliance testing.
  - An electrical compliance test was proposed at the Vancouver Intern Meeting.
  - This presentation expands the channel modeling portion of the compliance test proposal.

- Modeling Methodology
  - System Identification Based on FIR Model [1]
  - Use Pulse response to generate FIR System Model
  - FIR model used to generate PRBS patterns



$$\hat{y}(n) = \sum_{i=0}^N b_i x(n-i)$$

$$e(n) = y(n) - \sum_{i=0}^N b_i x(n-i)$$

In Matrix Form (data set length = M)

$$X = \begin{bmatrix} x(1) & 0 & 0 & 0 & 0 \\ x(2) & x(1) & 0 & 0 & 0 \\ x(3) & x(2) & x(1) & \dots & 0 \\ \dots & \dots & \dots & \dots & \dots \\ x(M) & x(M-1) & x(M-2) & \dots & x(M-N) \end{bmatrix}$$

$$e = y - Xb$$

$$e^H e = (y - Xb)^H (y - Xb)$$

Yields the LSE Solution

$$b = [b_0 \quad b_1 \quad \dots \quad b_{N-1}]^T = (X^H X)^{-1} X^H y$$

[1] Advanced Digital Signal Processing, Proakis, 1992

- Modeling Methodology (continued)
  - Fiber model length scaling (802.3z Data set)
    - Dispersion is proportional to fiber length
    - The model is time scaled to mimic length scaling

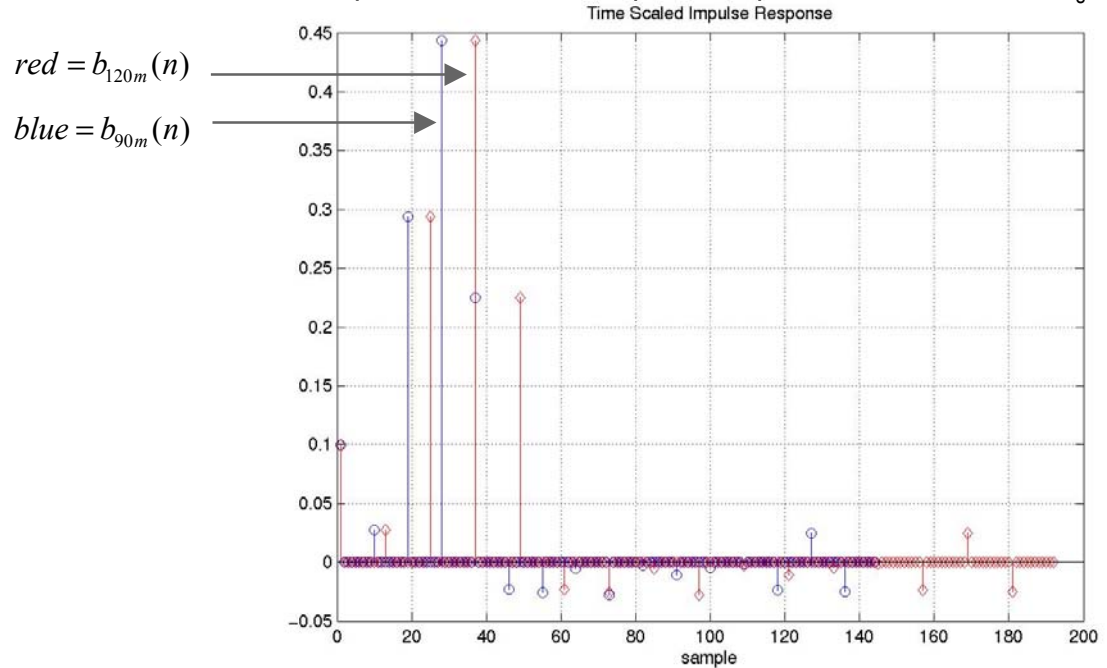
Continuous Time

$$b_{L_2}(t) = b_{L_1}\left(t \frac{L_2}{L_1}\right)$$

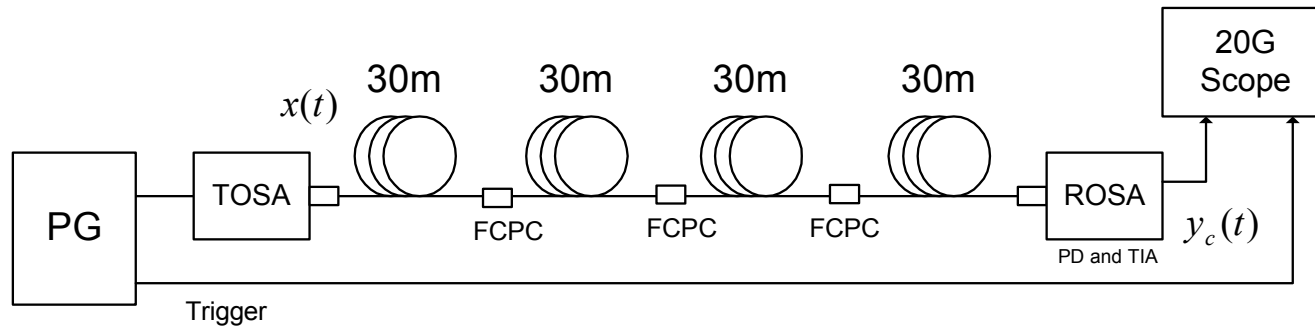
Discrete Time

$$b_{L_2}(n) = b_{L_1}\left(\text{rnd}\left(n \frac{L_2}{L_1}\right)\right)$$

Example 850nm, 120m impulse response scaled to 90m,  $T_s=4\text{ps}$



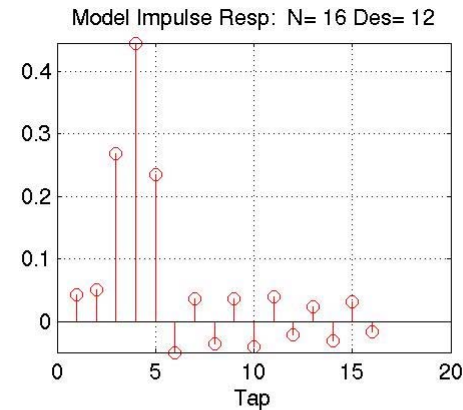
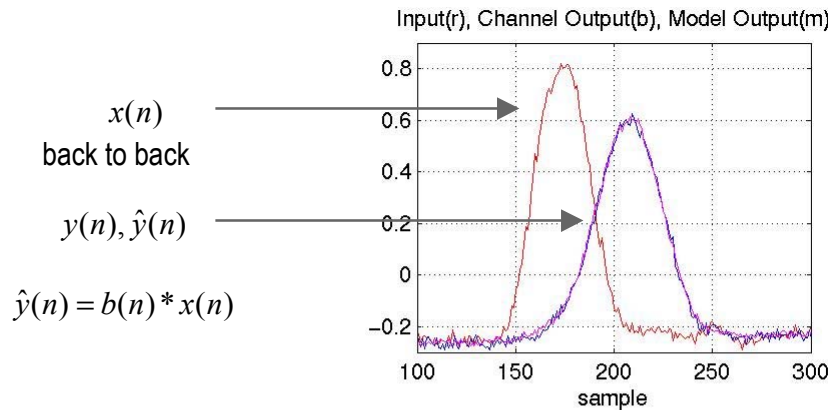
- Optical Measurement Test Bench
  - 62.5um MMF Fiber 160MHz.KM
  - wavelength = 850nm
  - 0, 30m, 60m, 90m, 120m length



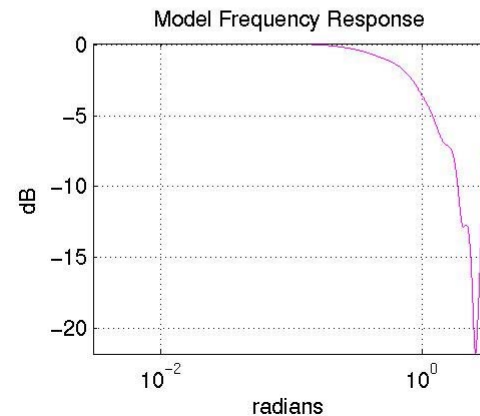
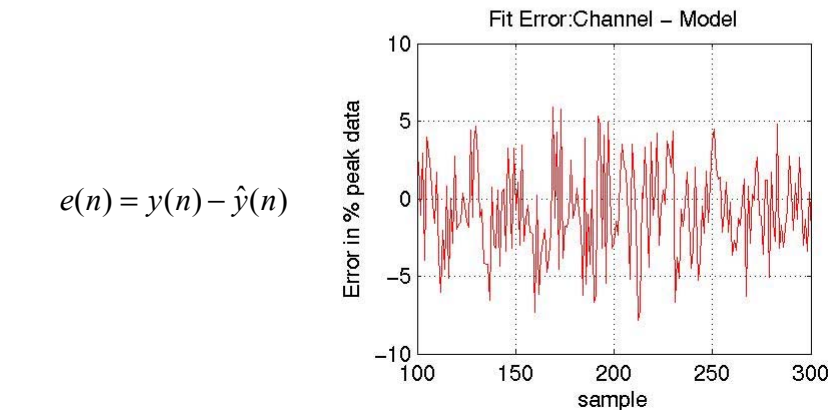
- Data Collection
  - Pulse and PRBS-7 patterns
  - Back-2-Back, 90m and 120m

# Worst Case Channel Modeling and Emulation for EDC

- Measured vs. Modeled Pulse response
  - Fiber Length 90m
  - 16 tap at T/2 spacing,  $T_s=4\text{ps}$



$$[b_0 \ b_1 \ \dots \ b_{15}]$$

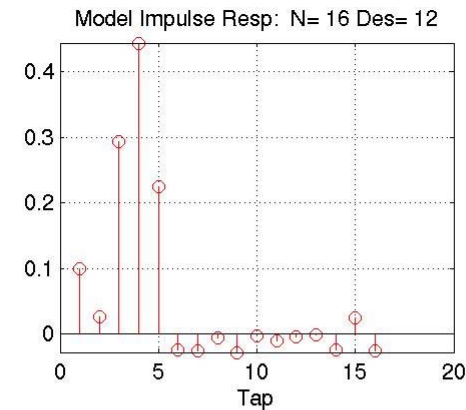
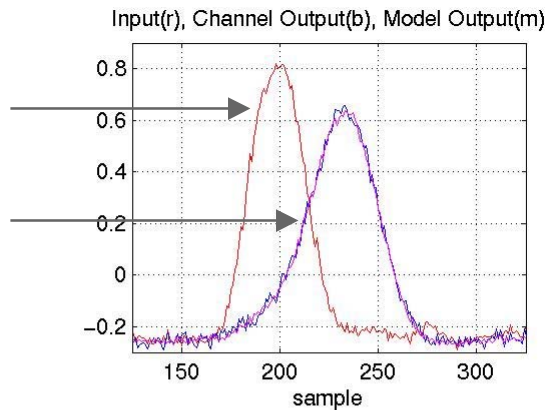


$$B(\omega) = B(z) \Big|_{z=e^{j\omega}}$$

# Worst Case Channel Modeling and Emulation for EDC

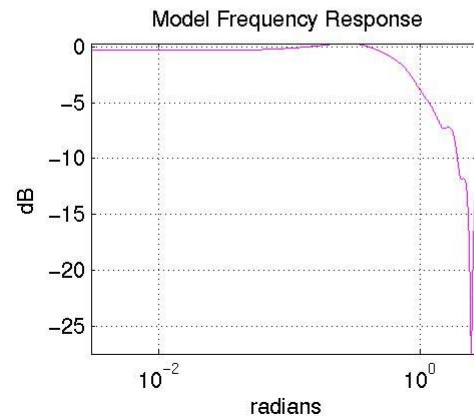
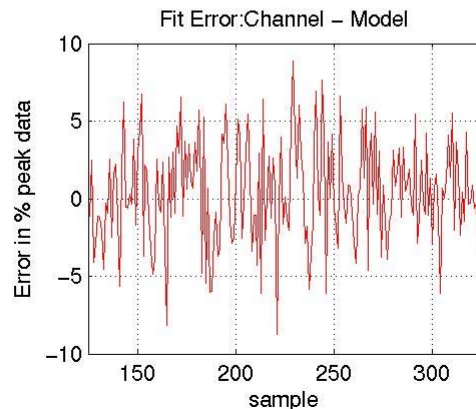
- Measured vs. Modeled Pulse response
  - Fiber Length 120m
  - 16 tap at T/2 spacing,  $T_s=4\text{ps}$

$x(n)$   
 back to back  
 $y(n), \hat{y}(n)$   
 $\hat{y}(n) = b(n) * x(n)$



$[b_0 \ b_1 \ \dots \ b_{15}]$

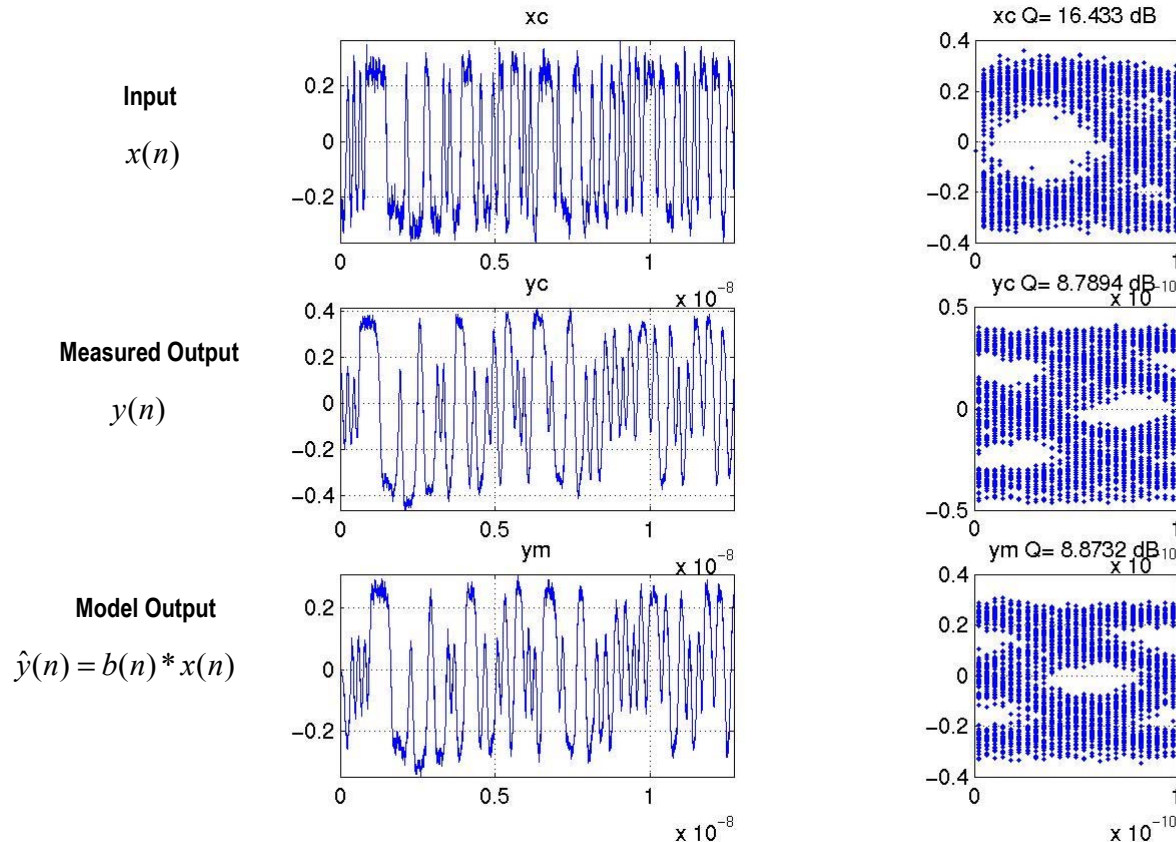
$e(n) = y(n) - \hat{y}(n)$



$B(\omega) = B(z)|_{z=e^{j\omega}}$

# Worst Case Channel Modeling and Emulation for EDC

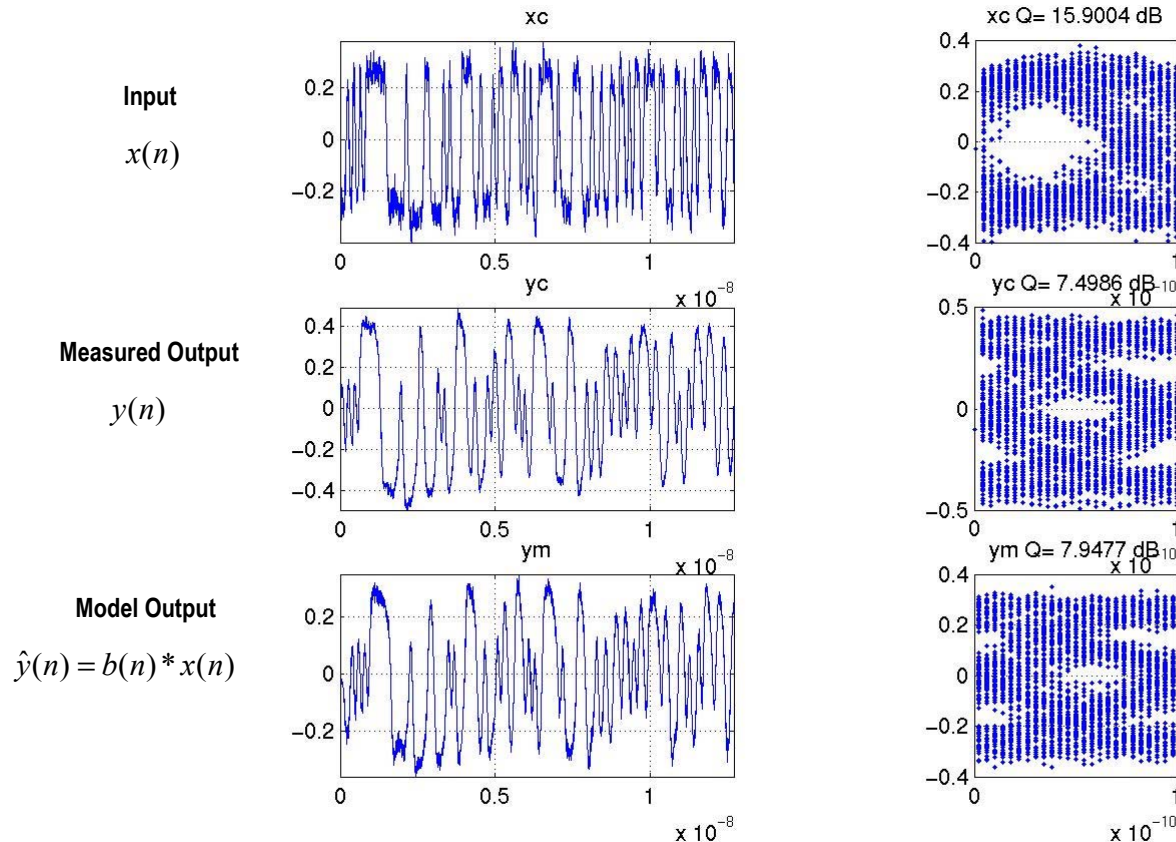
- Measured vs. Modeled PRBS response
  - Fiber Length 90m
  - 16 tap at T/2 spacing - Model based on Pulse response





# Worst Case Channel Modeling and Emulation for EDC

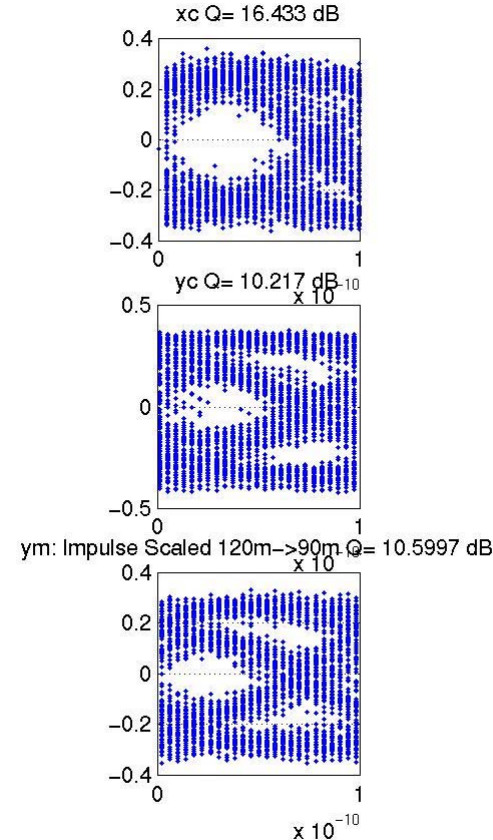
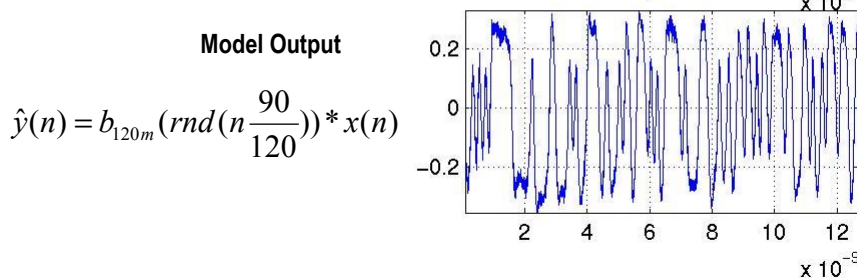
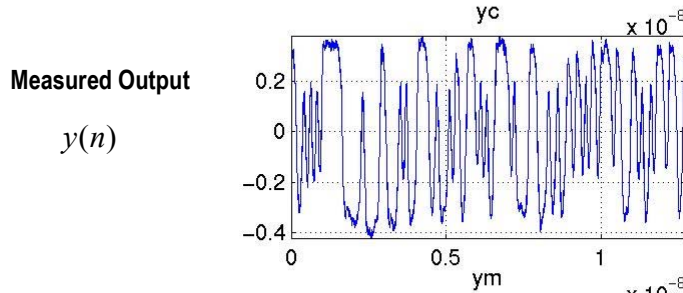
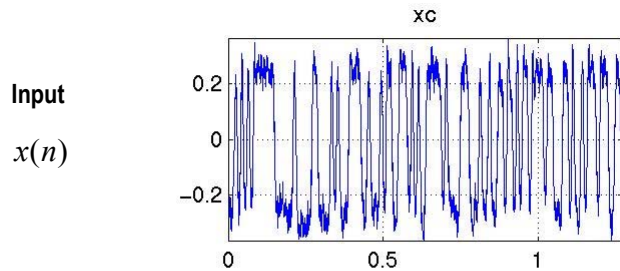
- Measured vs. Modeled PRBS response
  - Fiber Length 120m
  - 16 tap at T/2 spacing - Model based on Pulse response



# Worst Case Channel Modeling and Emulation for EDC

- Measured vs. Modeled PRBS response ( Fiber length Scaling)
  - Fiber Length 90m measured
  - 16 tap at T/2 spacing based on 120m model scaled to 90m

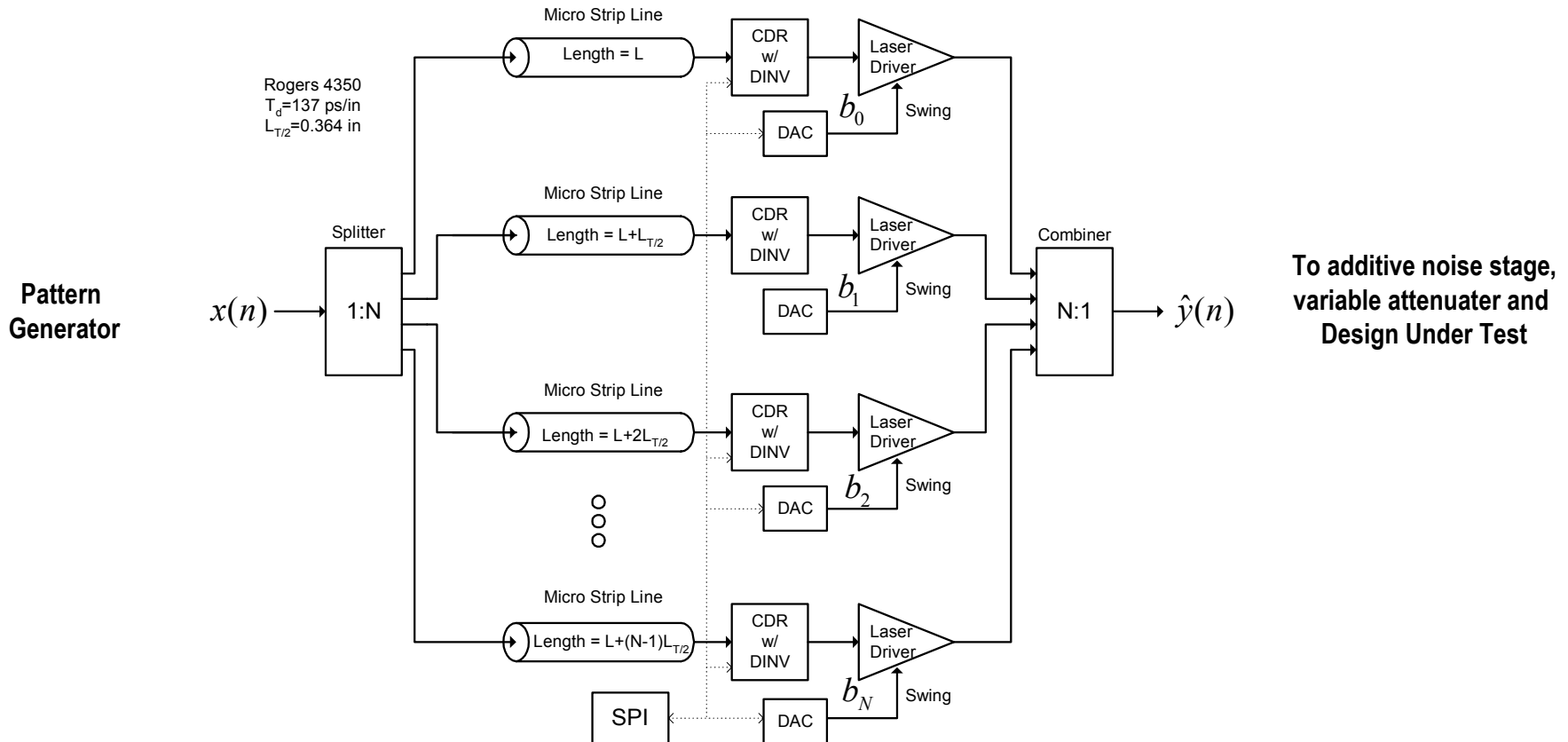
$$b_{90m}(n) = b_{120m}\left(\text{rnd}\left(n \frac{90}{120}\right)\right)$$



# Worst Case Channel Modeling and Emulation for EDC

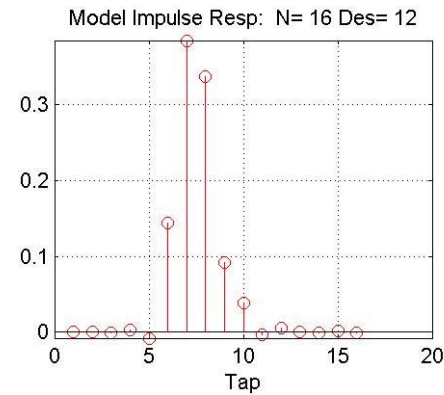
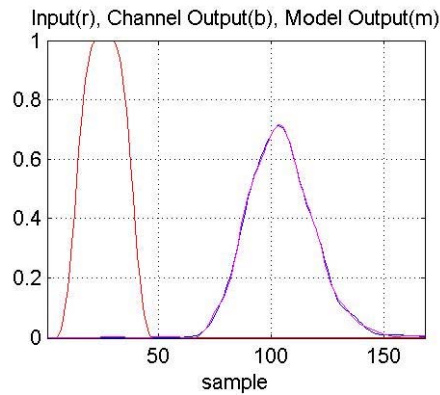
- Electronic Channel Emulator Block Diagram

- A cost effective solution can be may with XFP CDRs with data invert and laser drivers with adjustable output swing.
- Optimal # Taps and Tap spacing (TBD)



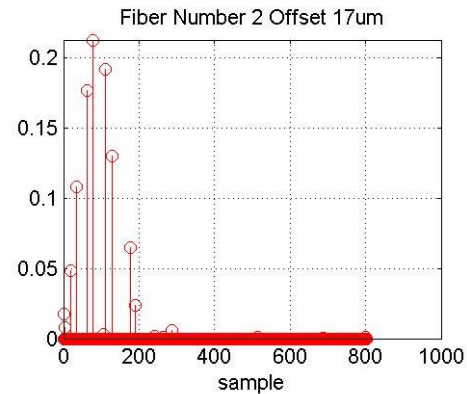
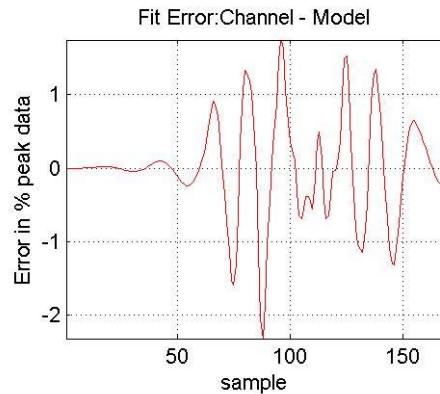
- Example Channel Emulator Simulation Result
  - Example: University of Cambridge impulse response: Fiber Number 2, Offset 17um
  - First Determine a reduced order model to fit the pulse response of the model

Theoretical and reduced order model Pulse response



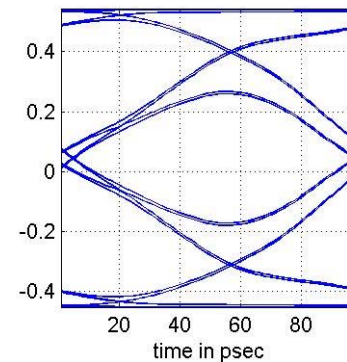
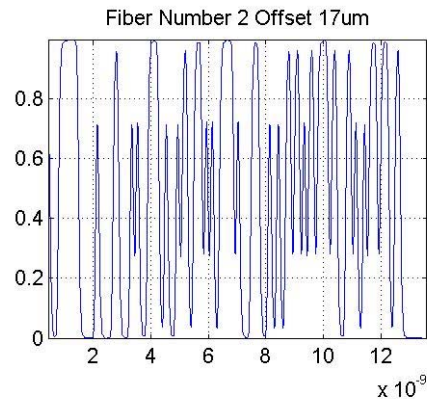
16 Tap T/2 fit of Theoretical Impulse response

Fit Error

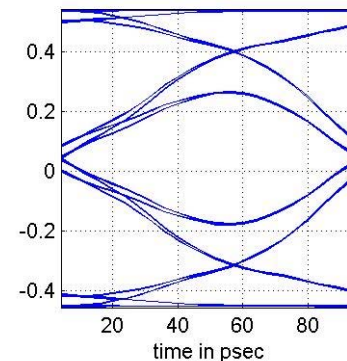
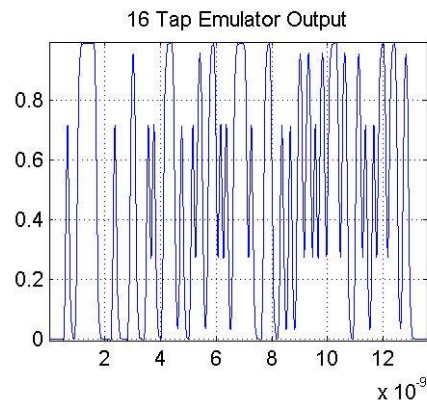


Theoretical Impulse response 20 Modes arbitrary spacing

- Example Channel Emulator Simulation Result ( Continued)
  - Example: University of Cambridge impulse response: Fiber Number 2, Offset 17um



**Theoretical  
Response to PRBS7  
Waveform**



**Reduced Order Model  
Response to PRBS7  
Waveform**

- Summary
  - Reduced order Channel Models based on pulse response match the measured response well for the measured data.
  - Scaling the Channel model based on pulse response match the measured response well for the measured data.
  - A cost effective electronic implementation appears reasonable.