Worst Case Channel Modeling and Emulation for Electronic Dispersion Compensation

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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

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

In Matrix Form (data set length = M)

\[ X = \begin{bmatrix} x(1) & 0 & 0 & 0 & 0 \\ x(2) & x(1) & 0 & 0 & 0 \\ x(3) & x(2) & x(1) & \ldots & 0 \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ x(M) & x(M-1) & x(M-2) & \ldots & x(M-N) \end{bmatrix} \]

\[ e = y - Xb \]
\[ e^H e = (y - Xb)^H (y - Xb) \]

Yields the LSE Solution

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

• 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

\[ b_{L_2}(t) = b_{L_1}(t \frac{L_2}{L_1}) \]

Continuous Time

\[ b_{L_2}(n) = b_{L_1}(n \frac{L_2}{L_1}) \]

Discrete Time

Example 850nm, 120m impulse response scaled to 90m, \(T_s=4ps\)

- red = \(b_{120m}(n)\)
- blue = \(b_{90m}(n)\)
Worst Case Channel Modeling and Emulation for EDC

- 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, $T_s=4$ps

\[ \hat{y}(n) = b(n) \ast x(n) \]

\[ e(n) = y(n) - \hat{y}(n) \]

Input($i$), Channel Output($o$), Model Output($m$)

Model Impulse Resp: $N=16$ Dels=12

\[
\begin{bmatrix}
  b_0 & b_1 & \ldots & b_{15}
\end{bmatrix}
\]

\[
B(\omega) = B(z)\bigg|_{z=e^{j\omega}}
\]
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

$$y(n), \hat{y}(n)$$

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

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

Fit Error: Channel – Model

Model Impulse Resp: $N=16$ Des= 12

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

Model Frequency Response

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

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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

\[
x(n) = b(n) * x(n)
\]
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

\[ y(n) = b(n) * x(n) \]
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

\[
b_{90m}(n) = b_{120m}(\text{rnd}(n \frac{90}{120}))
\]
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)

![Electronic Channel Emulator Block Diagram](image)
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
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.