Parametric characterization and Channel models for worst-case MMF channels

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Channel Model Abstraction for MMF: Objective

- Abstract channel models commonly used for different communications systems
  - Stochastic, very diverse range of channels such as wireless channels
  - Reduce infinitude of possibilities to small # of parameters
- Use simple signal processing blocks as parametric realizations of range of worst-case MMF channels
- Applications:
  - Guide in architectural design of EDC
  - Lab-based or simulation-based compliance tests for EDC-based links or modules.

Parametric Channel Models

- Parametric Channel Models for emulating worst-case MMF channels:
  - M-tap FIR Model
  - LPF model
  - Gaussian Impulse Response Model cascaded with multiple Dirac Delta impulse responses
    - May be suitable only for simulations
  - LPF cascaded with N-Dirac Delta Function Model or N-tap FIR model

Parametric Channel Models: General Form

- General Form:

$$h_{MMF}(t) = \sum_{i=1}^{N} c_i \, p(t - i\tau)$$

Where:

{ci} – tap coefficients to be determined

p(t) – pulse shape (possibly LPF impulse response)

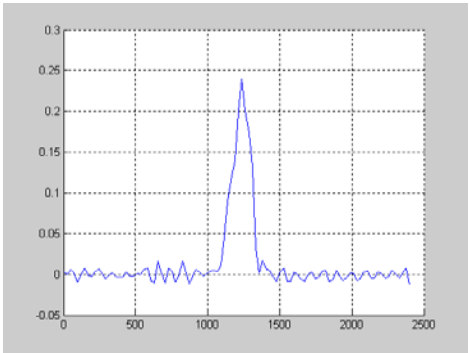
N – No of FIR taps (or no of Dirac Delta functions in model) to be determined

τ- tap spacing to be determined

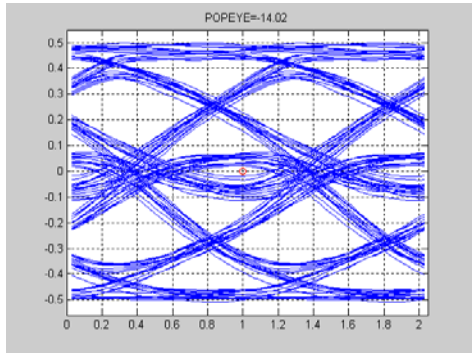
Guidelines for Parameter Selection

- Parameters {N, p(t), τ } selected so as to have
  - Trade-off between complexity v/s frequency resolution
  - For certain “worst-case” MMF channels, high time and/or frequency resolution required at certain frequency range (between 1GHz and 2 GHz)
    - Constrains p(t), τ
    - Sharper time resolution implies smaller tap-spacing
    - Sharper frequency resolution constrains p(t), tap-spacing, N
  - Total span of cascade of filters should cover the span of the MMF channel impulse response (determines N.(span of p(t)). τ).
- Tap coefficients {ci}
  - May be selected based on different criteria of “goodness” between actual channel and channel model such as Least Mean Squares based.

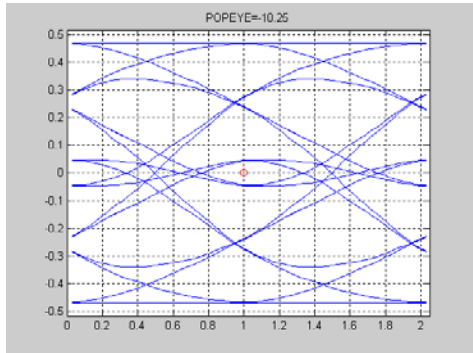
Channel Waveform Generation of Worst-Case MMF Channel 1: Simulation-based Results



Impulse response of DMD-challenged MMF1

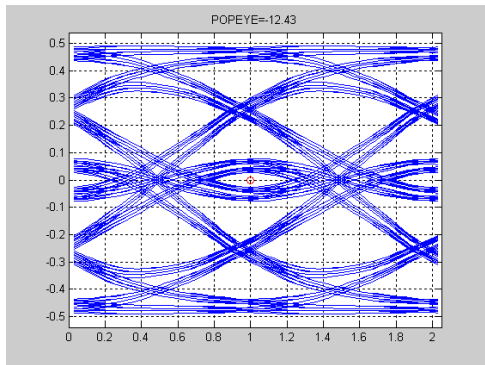


Simulated waveform eye (o/p from MMF1)

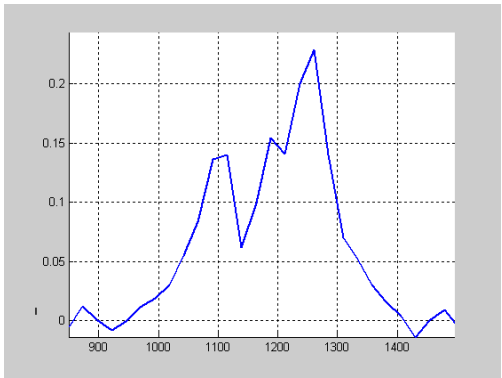


8 FIR tap-based output (1/3 symbol-spaced)

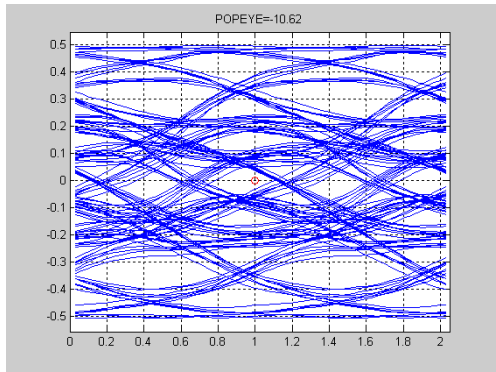
16 FIR tap-based output (1/3 symbol-spaced)



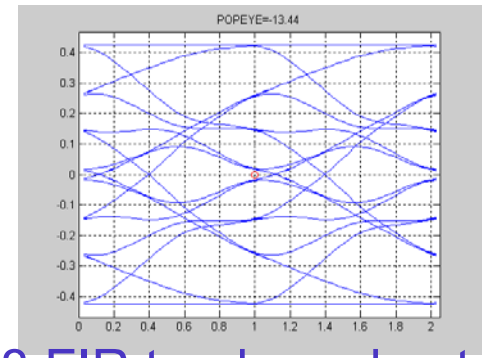
Channel Waveform Generation of Worst-Case MMF Channel 2: Simulation-based Results



Impulse response of DMD-challenged MMF2



Simulated waveform eye (o/p from MMF2)



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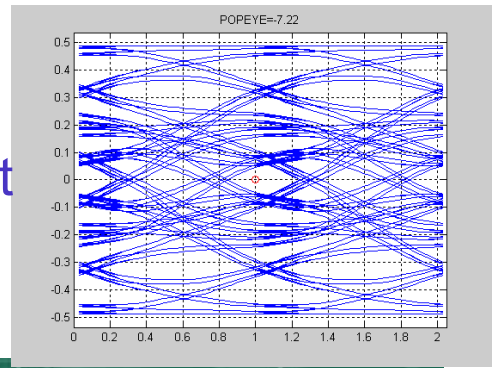
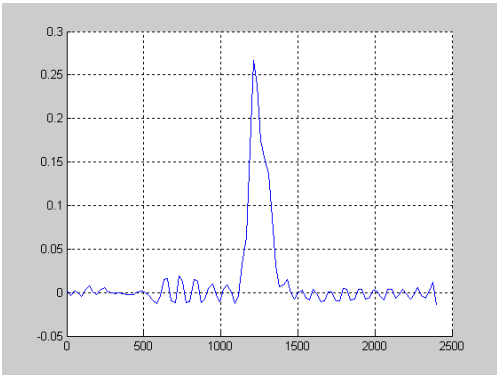
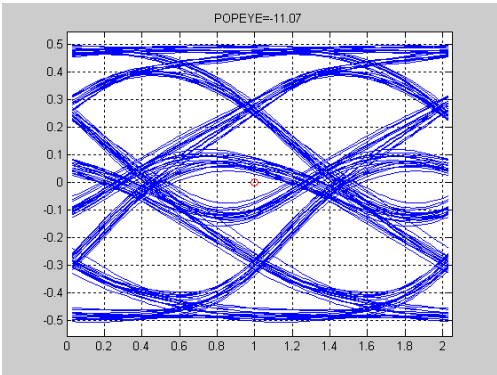
16 FIR tap-based output (1/3 symbol-spaced)



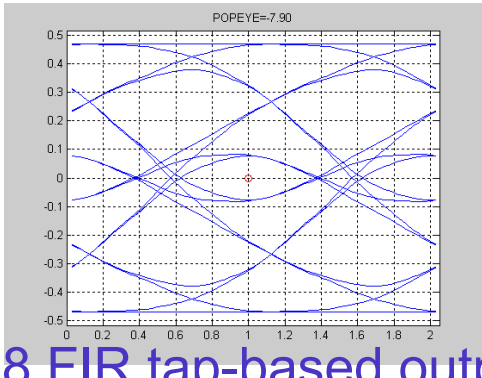
Channel Waveform Generation of Worst-Case MMF Channel 3: Simulation-based Results



Impulse response of DMD-challenged MMF3



Simulated waveform eye (o/p from MMF3)



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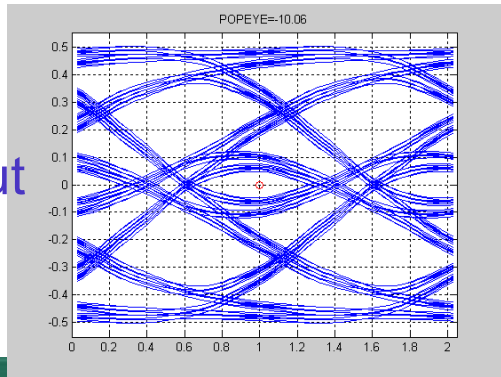
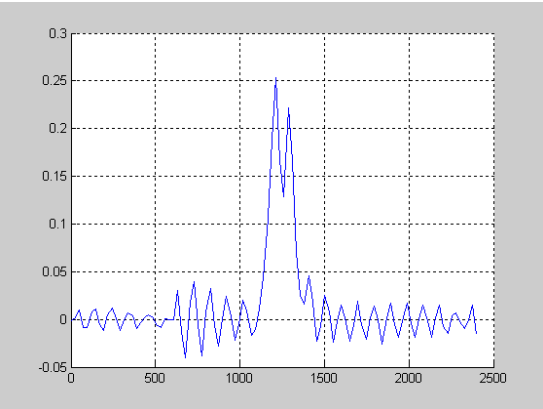
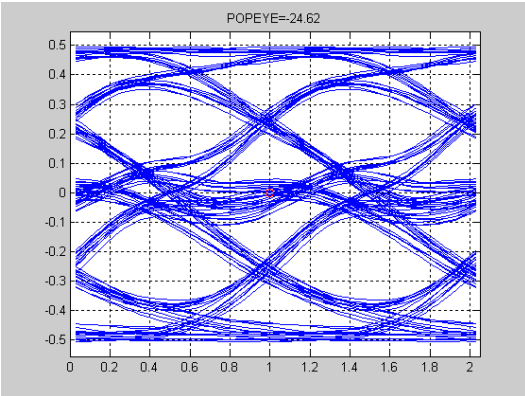
16 FIR tap-based output (1/3 symbol-spaced)



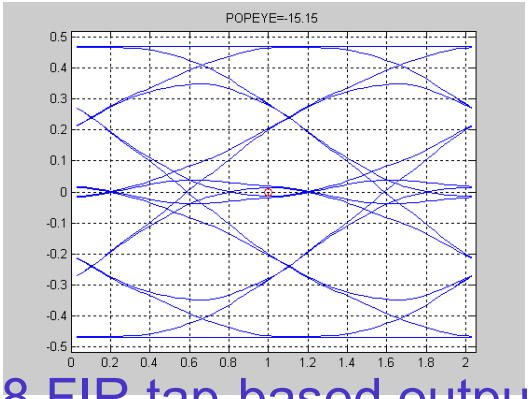
Channel Waveform Generation of Worst-Case MMF Channel 4: Simulation-based Results



Impulse response of DMD-challenged MMF4

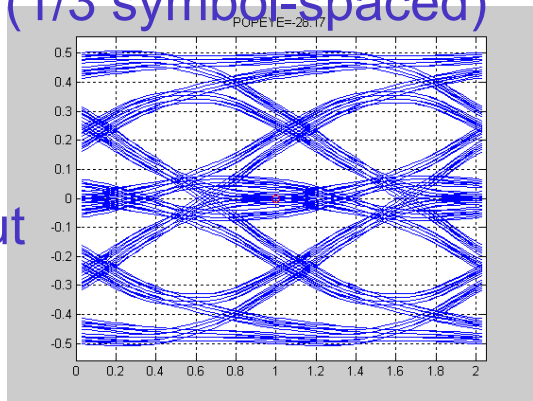


Simulated waveform eye (o/p from MMF4)



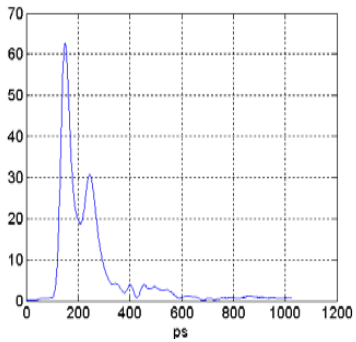
8 FIR tap-based output (1/3 symbol-spaced)

16 FIR tap-based output (1/3 symbol-spaced)

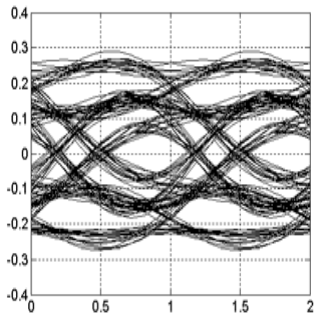


Channel Waveform Generation for MMF (experimental):

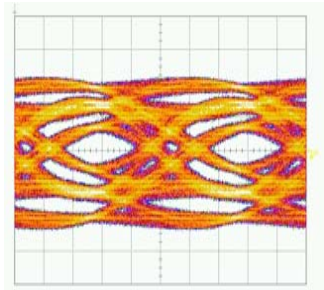
(LPF cascaded with 4-Dirac Delta Model)



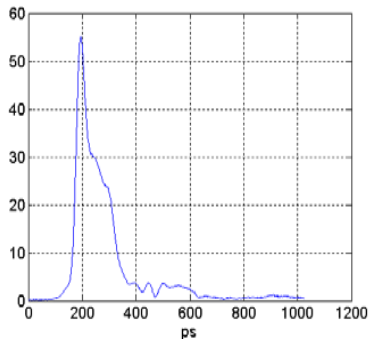
Fiber Impulse Response (N04A1002S3p.dat)



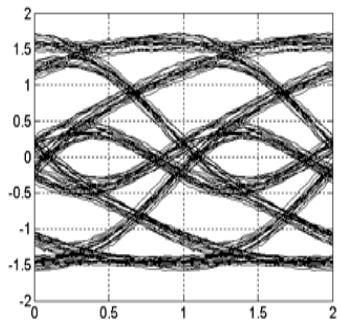
Simulated eye of waveform



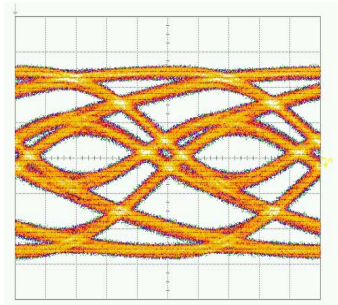
Emulated waveform eye using LPF with 4-tap FIR



Fiber Impulse Response (LG010401L4f.dat)



Simulated eye of waveform



Emulated waveform eye using LPF with 4-tap FIR

Observations

- Tap spacing of 1/3 symbol period provides sufficient time resolution of worst case MMF channels. No need to use smaller tap spacing.
- 8-tap FIR provides adequate realization of worst-case MMF channels. Further improved performance possible with
  - cascading a LPF with appropriate bandwidth and rolloff order or
  - Increasing number of taps to 12-16.

- From complexity/MMF coverage standpoint recommended to use a LPF with 3 dB bandwidth ~1.5 to 2 GHz with a small number of taps (~8 taps).

Conclusions

- Recommended to constrain further evaluations of worst-case MMF channel models within a simple framework of simple signal processing blocks.
- An FIR filter with ~8 taps with ½ symbol spacing cascaded with a LPF should be sufficient.
- Time-varying channel effects due to modal noise can easily be captured by varying FIR tap coefficients from 1 configration to another configuration over a certain time period.