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Finite Equalizer Performance for TP3 Stressed Sensitivity Test on Gen67YY

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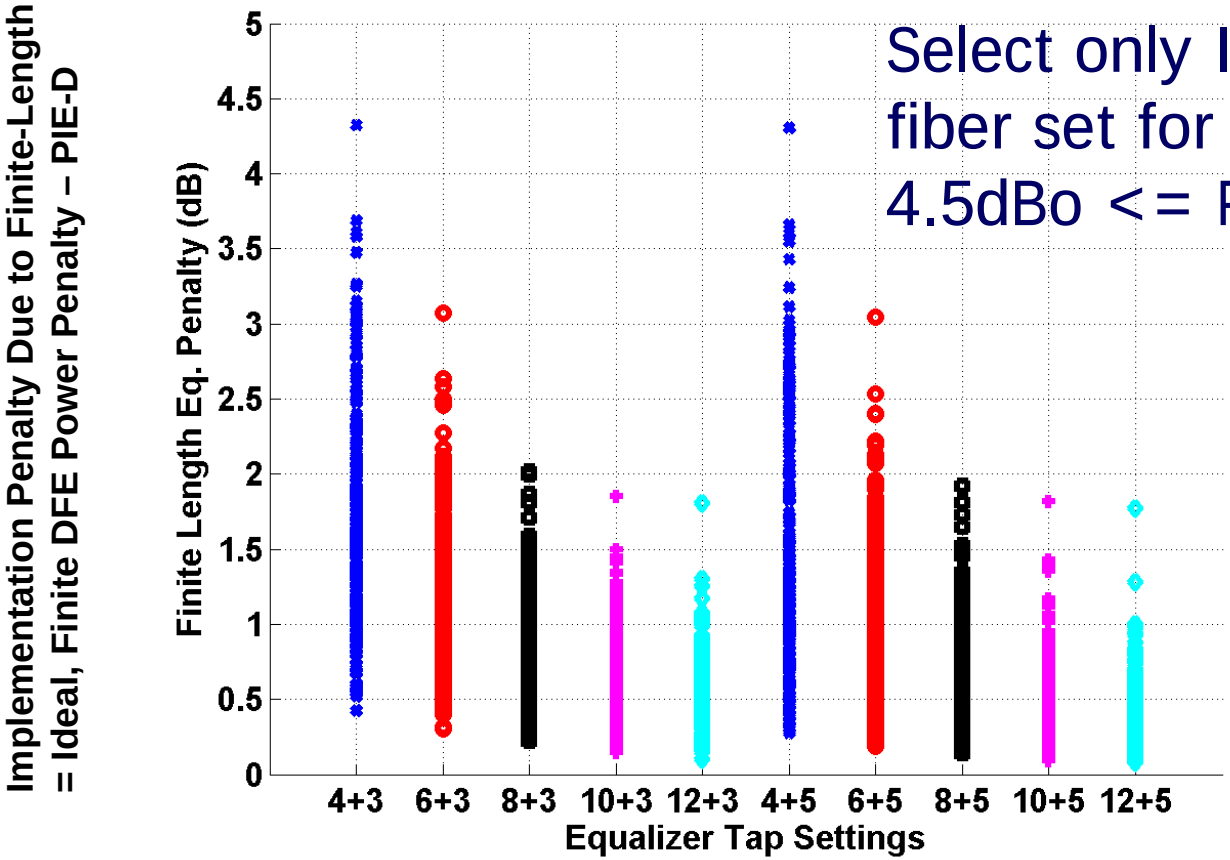
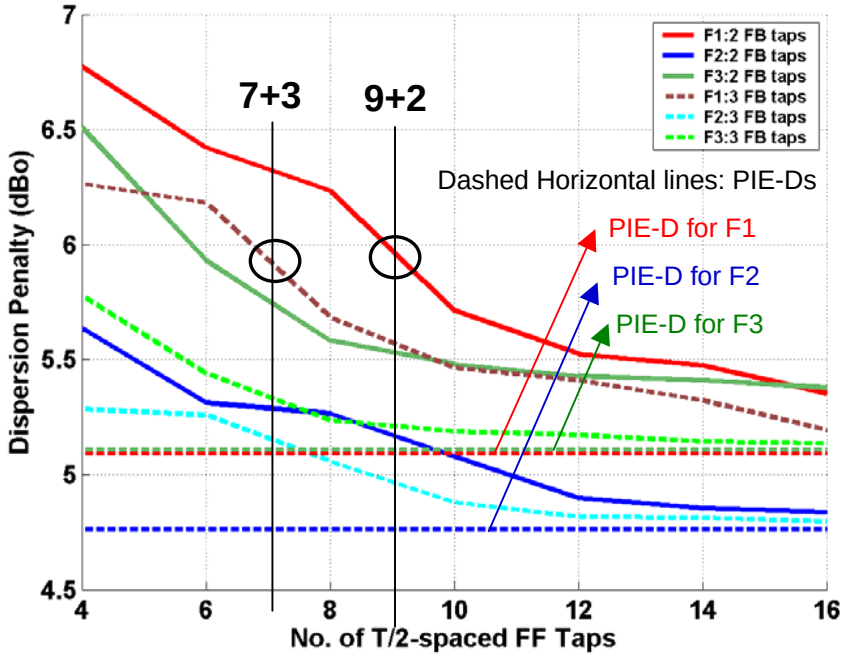
Motivation



Select only IPR's from OFS1998 fiber set for which
4.5dBo <= PIE-D <= 5.0dBo

- A set of impulse responses selected to have a narrow range of PIE-D will spread over a much broader range of penalties for finite DFE architectures, with the spread increasing for shorter equalizers
- IPRs intended to test EDC capability must be assessed for their ability to challenge shorter equalizers.

Minimum Complexity Equalizer for the TP3 Test Pulses



Assumptions:

- 6.5 dB is available for dispersion penalty
- 0.5 dB is sufficient to cover the difference between the ideal and actual implementation of the equalizer circuit.
- **An equalizer is considered to work if power penalty is less than 6dB.**

Note: we obtain PIE-D's of ~5.1dB for the pre- and post-cursor IPR's in the draft

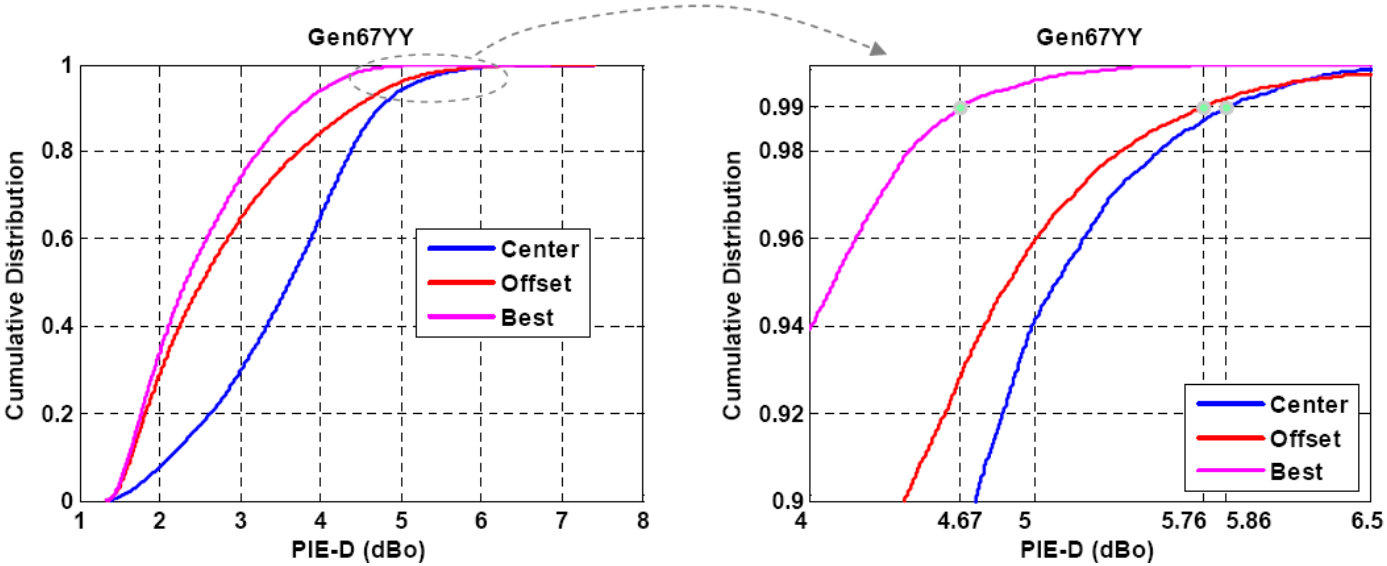
- Fiber nomenclature and corresponding PIE-Ds:
  - Fiber F1: pulse with pre-cursor ISI, PIE-D curve is red dashed, horizontal line
  - Fiber F2: symmetric pulse, PIE-D curve is blue dashed, horizontal line
  - Fiber F3: pulse with post-cursor ISI, PIE-D curve is green dashed, horizontal line
- Minimum complexity finite-length DFEs that satisfies total penalty < 6.0dBo (see left panel) for TP3 test impulse responses:
  - Allocates 0.5 dB to hardware penalty alone, leaving 1.5dB for finite length effects
  - **7 FF taps (T/2-spaced) + 3 FB taps** (interpolated) (has a ~0.1dB margin from 6.0dBo)
  - **9 FF taps (T/2-spaced) + 2 FB taps** (interpolated) (has a ~0.1dB margin from 6.0dBo)

Objectives and Methodology

- Goal: To evaluate the performance of finite-length DFEs the installed fiber base as represented using the Monte Carlo Gen67yy model, and compare with the TP3 IPRs in the current draft.
- Monte Carlo Model : version Gen67YY
  - Only fibers of Gen67YY with OFLBW > 500MHz-km are considered
  - Of 5000 fibers, 4159 pass the OFLBW constraint
- Two connectors in the link simulation:
  - Both connectors have a Rayleigh distributed offset with mean 3.58μm, truncated at 7μm
  - Both connectors are located at the beginning of the link
- Procedure:
  - Compute PIE-Ds for the fiber set
    - Determine the penalty to obtain 99% coverage of the Monte Carlo fiber set
  - Compute penalties for specific equalizer configurations:
    - All feedforward taps are T/2 spaced
    - Number of feedforward taps are 4, 6, 8, 10 and 12
    - Number of feedback taps is either 3 or 5
  - Determine coverage curves in each case
  - Also find penalty at 99% coverage point and coverage at penalty of 6.0dB and 6.5dB
- Joint Launch penalty computation:
  - For every pair of OSL offset and CL offset, determine the minimum of the two penalties for a given fiber (link)
  - 7 offsets for OSL x 4 offsets for CL => 28 possible penalties for joint launch
  - Assume that each of these 28 possibilities is equally likely
- Validation:
  - Compare raw PIE-Ds (without connectors) at offsets 17μm, 20μm, and 23μm with those generated by Corning (John Abbott)
  - Compare coverage curves (without connectors) for PIE-Ds with those generated by JDSU (John Ewen, ewen_2_1104)
  - Compare coverage curves (with connectors) for PIE-Ds with those generated by JDSU (John Ewen, ewen_1_0105)
- Notation:
  - OSL: offset launch
  - CL : center launch
  - JT : joint launch

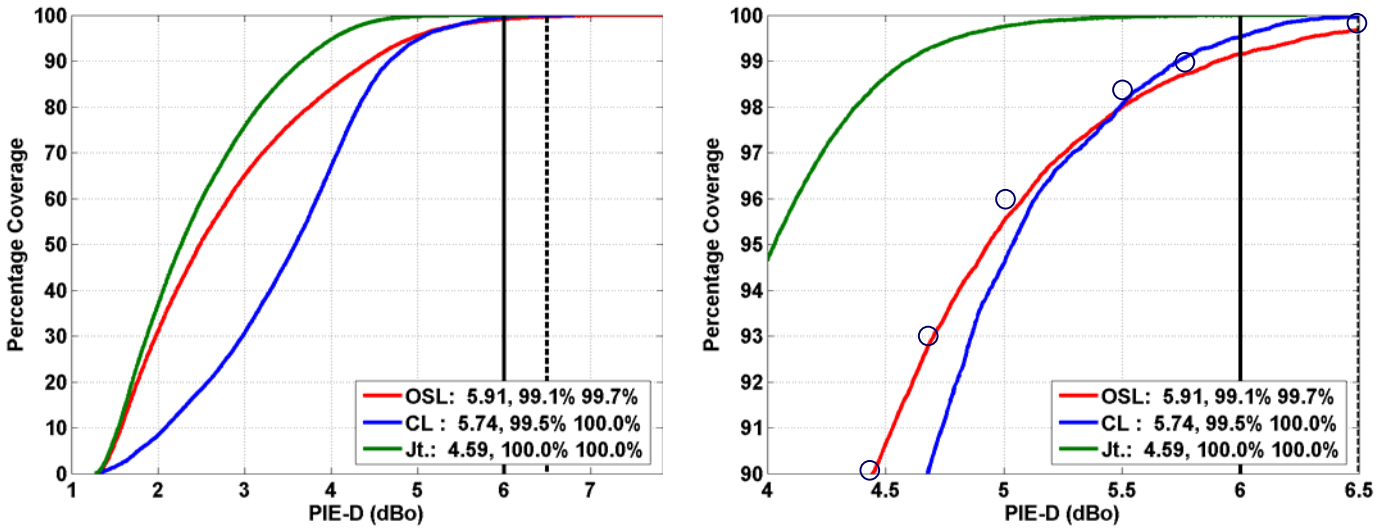
Validation against JDSU Simulation Results: with connectors

Plots from ewen_1_0105.pdf



- Plots from ewen_1_0105.pdf
  - Gen 67YY with 2 connectors
- PIE-Ds for different launches:
  - OSL : PIE-D ~ 5.76 dBo
  - CL : PIE-D ~ 5.86 dBo
  - Best/Joint: PIE-D ~ 4.67 dBo

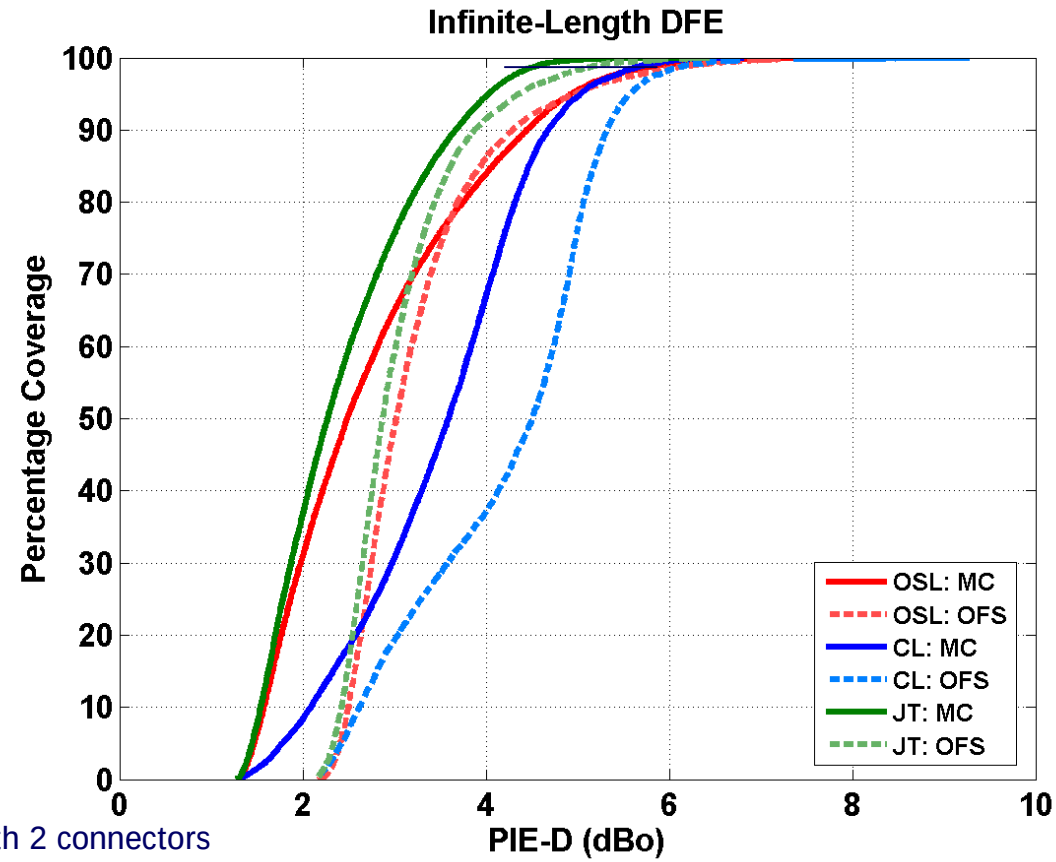
Plots from Georgia Tech Simulations



- Georgia Tech simulation results
  - Gen 67YY with 2 connectors
- PIE-Ds for different launches:
  - OSL : PIE-D ~ 5.91 dBo
  - CL : PIE-D ~ 5.74 dBo
  - Joint: PIE-D ~ 4.59 dBo

- Good match between Georgia Tech and JDSU coverage curves
- Georgia Tech PIE-Ds within 0.08-0.15dB of JDSU PIE-Ds

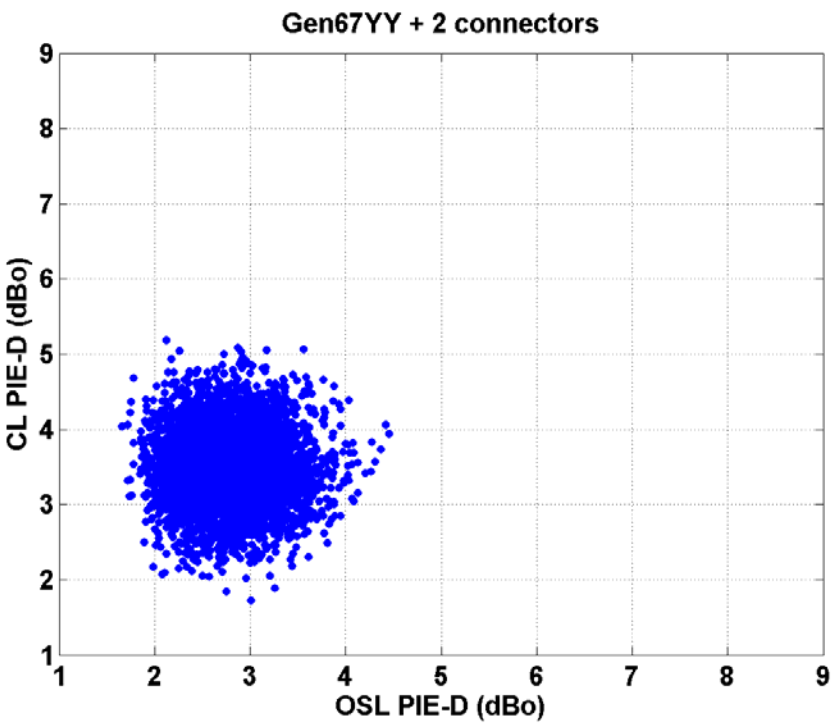
Gen67YY Monte Carlo PIE-D coverage curves are slightly optimistic compared to OFS1998 fiber model

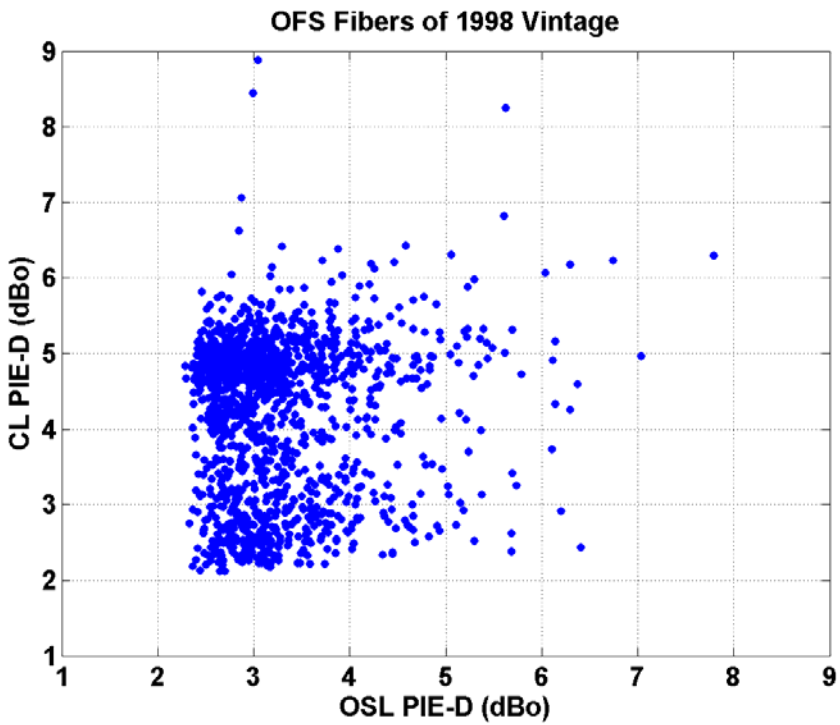


- Notation:
  - "MC" : Monte Carlo set (Gen67YY) with 2 connectors
  - "OFS": OFS Fiber set of 1998 vintage
  - "OSL": offset launch; "CL" : center launch; "JT": joint launch
- Infinite-Length DFE:
  - MC set PIE-Ds : 5.91 (OSL), 5.74 (CL), **4.59 (JT)**
  - OFS set PIE-Ds: 6.3 (OSL), 6.2 (CL), **5.2 (JT)**
- 8 T/2-spaced FF tap + 3 FB tap DFE:
  - MC set penalties: 7.01 (OSL), 11.34 (CL), **5.82 (JT)**
  - OFS set penalties: 7.6 (OSL), 10.5 (CL), **6.2 (JT)**

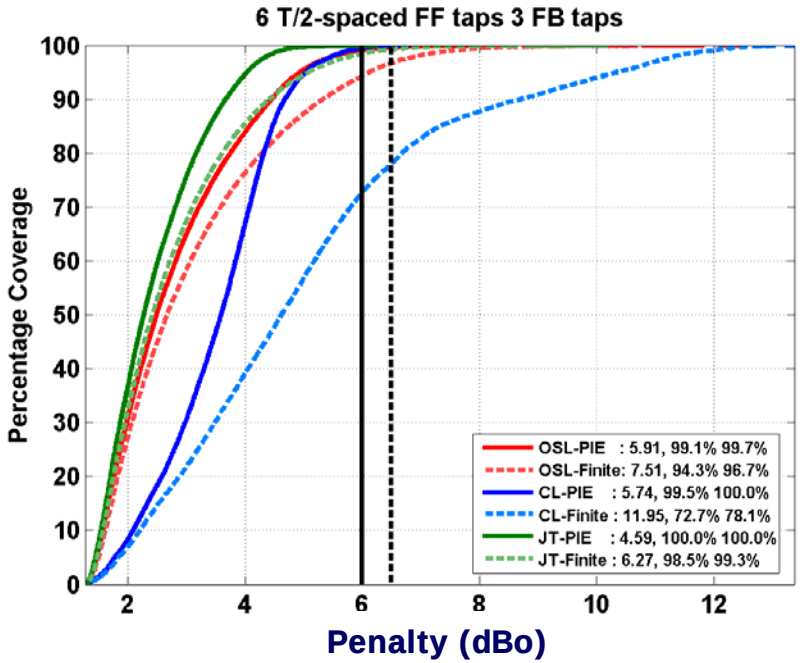
Correlation between CL and OSL

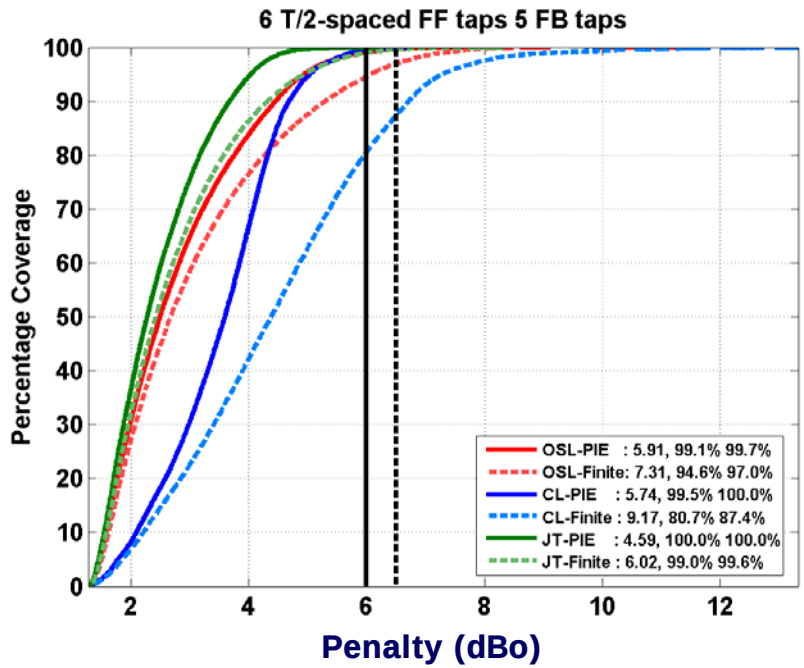
- Objective: To compare center launch and offset launch in the Monte Carlo and Measured fiber set (1998OFS fibers)
- For each fiber (in each fiber set),
  - Compute average PIE-D for each launch range (OSL and CL) separately
  - Plot min OSL PIE-D vs. min CL PIE-d as a scatter plot





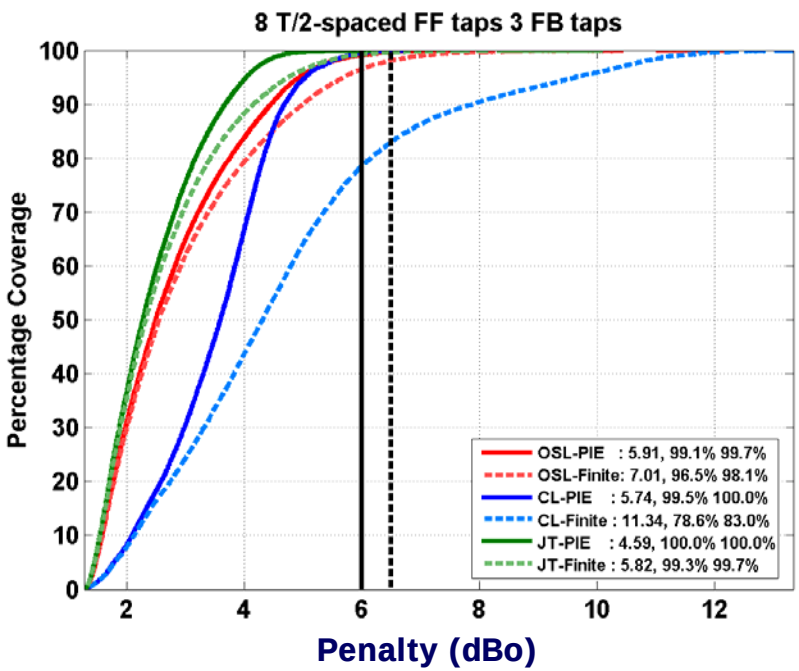
6 Feedforward Tap Equalizer

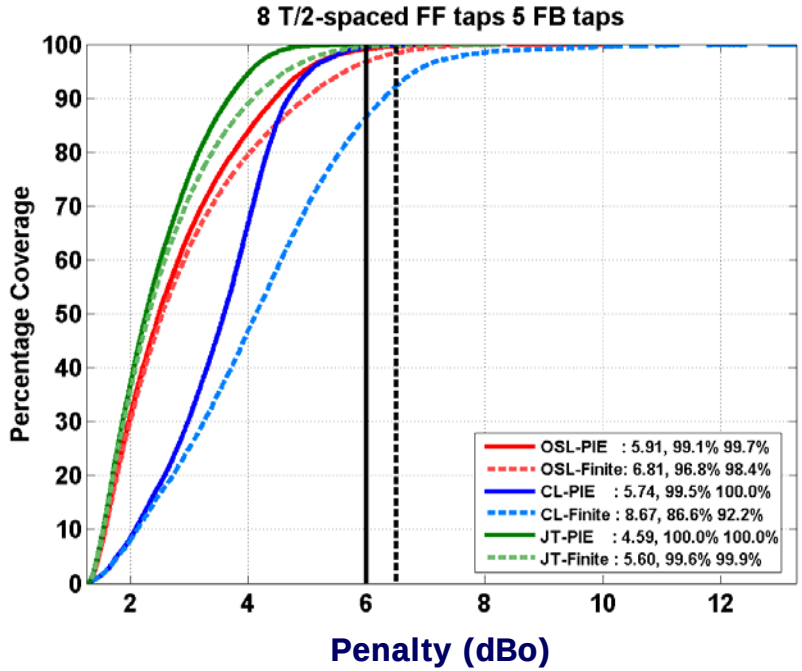




	Offset Launch		Center Launch		Joint Launch	
Number of Feedback Taps	3	5	3	5	3	5
Penalty at 99% coverage	7.51dBo	7.31dBo	11.95dBo	9.17dBo	6.27dBo	6.02dBo

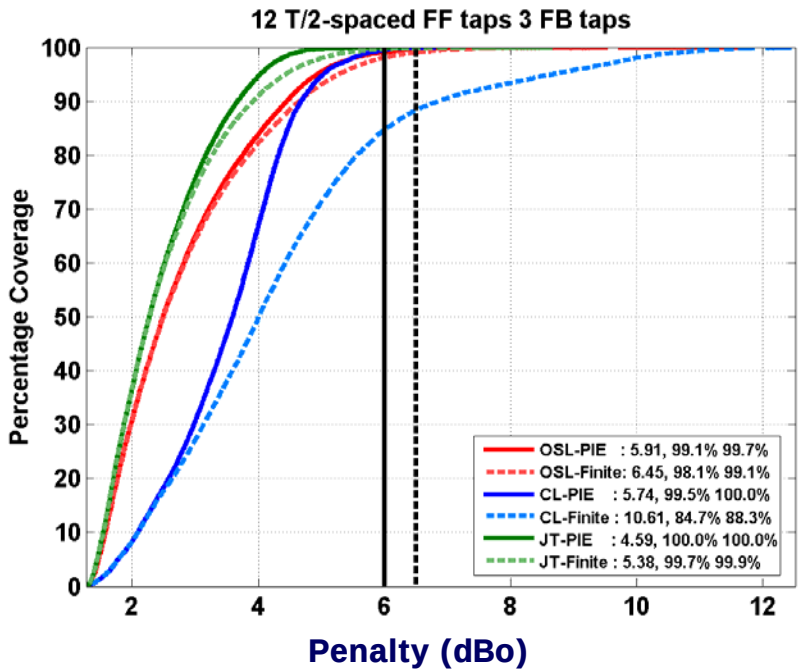
8 Feedforward Tap Equalizer: Gen67YY

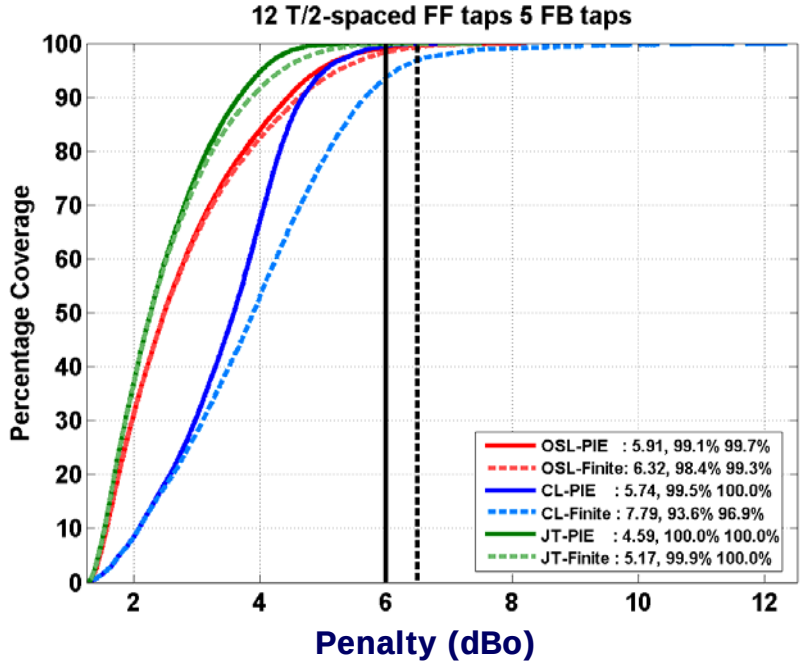




	Offset Launch		Center Launch		Joint Launch	
Number of Feedback Taps	3	5	3	5	3	5
Penalty at 99% coverage	7.01dBo	6.81dBo	11.34dBo	8.67dBo	5.82dBo	5.60dBo

12 Feedforward Tap Equalizer

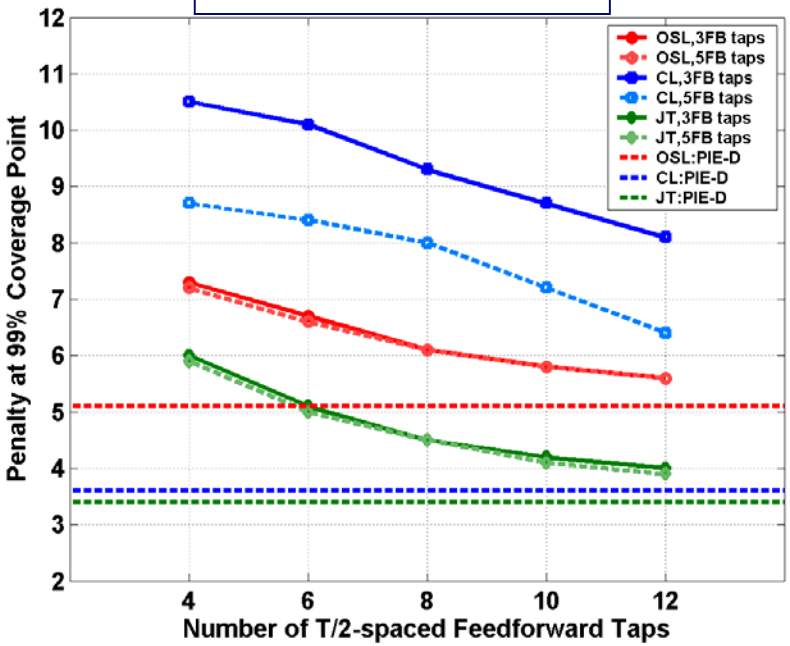




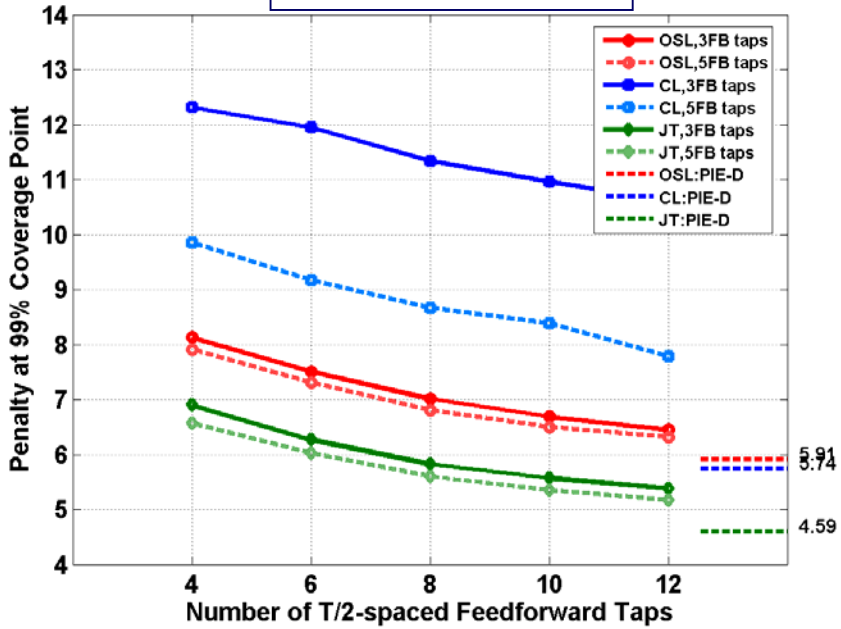
	Offset Launch		Center Launch		Joint Launch	
Number of Feedback Taps	3	5	3	5	3	5
Penalty at 99% coverage	6.45dBo	6.32dBo	10.61dBo	7.79dBo	5.38dBo	5.17dBo

Summary: Total Penalty

Without Connectors

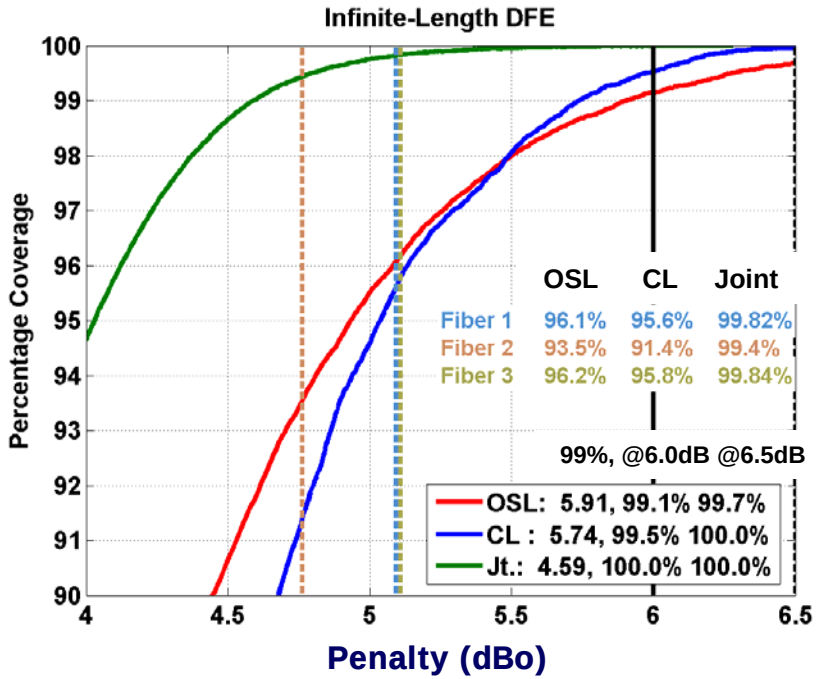


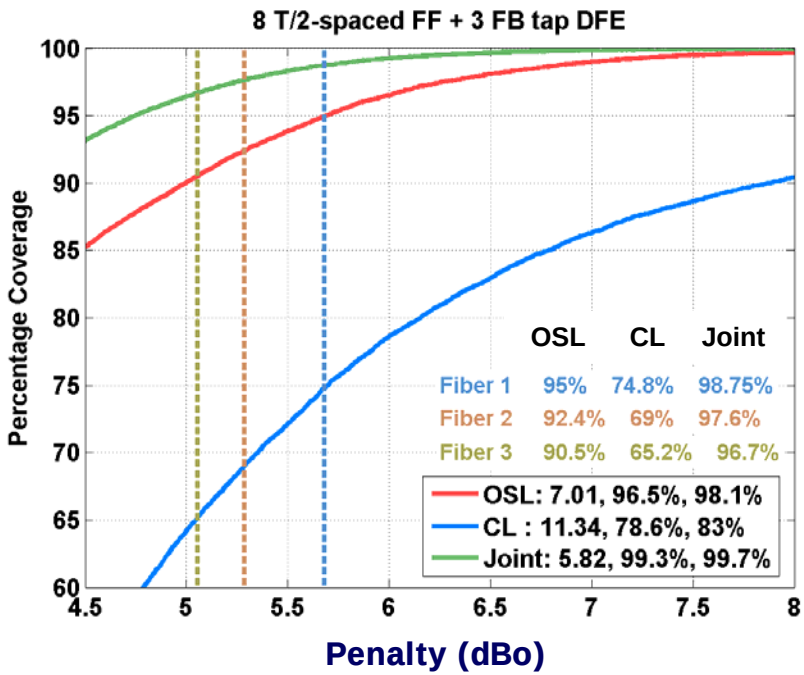
With Connectors

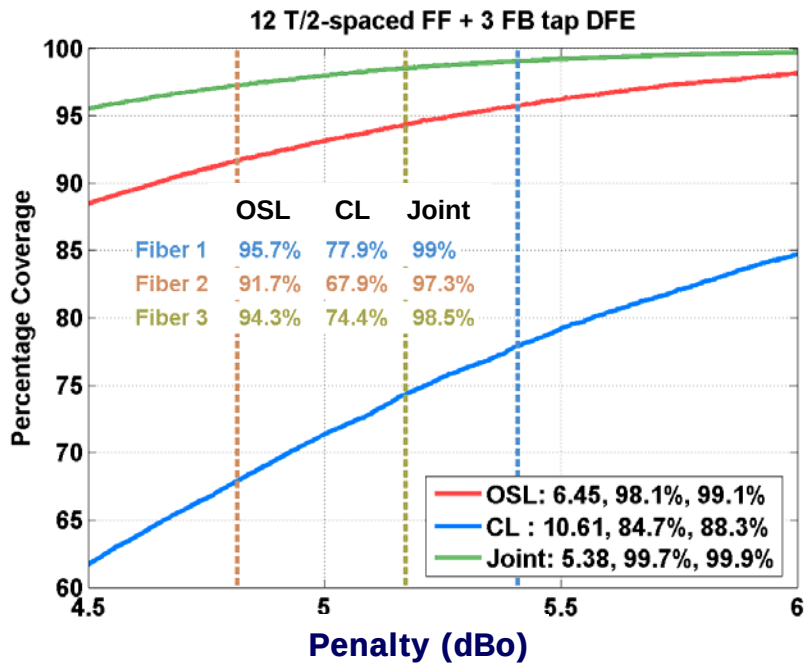


- Observations common to link without and with connectors:
  - Infinite-Length equalizers: OSL behaves much worse than CL
  - Finite-Length equalizers: OSL behaves much better than CL
  - Joint launch yields lowest total penalty
- Assume a total penalty limit of 6.0dBo (allocating 0.5dB to losses/hardware penalties etc)
- Without connectors:
  - OSL: 10FF + 3FB tap equalizer was adequate
  - CL : cannot be equalized even with a 12FF + 5FB tap equalizer
  - Joint Launch : 4FF + 3FB tap equalizer was sufficient
- With connectors:
  - OSL and CL cannot be equalized even with a 12FF + 5FB tap equalizer
  - Joint Launch : 6FF + 5FB tap (or 8FF + 3FB tap) equalizer is sufficient

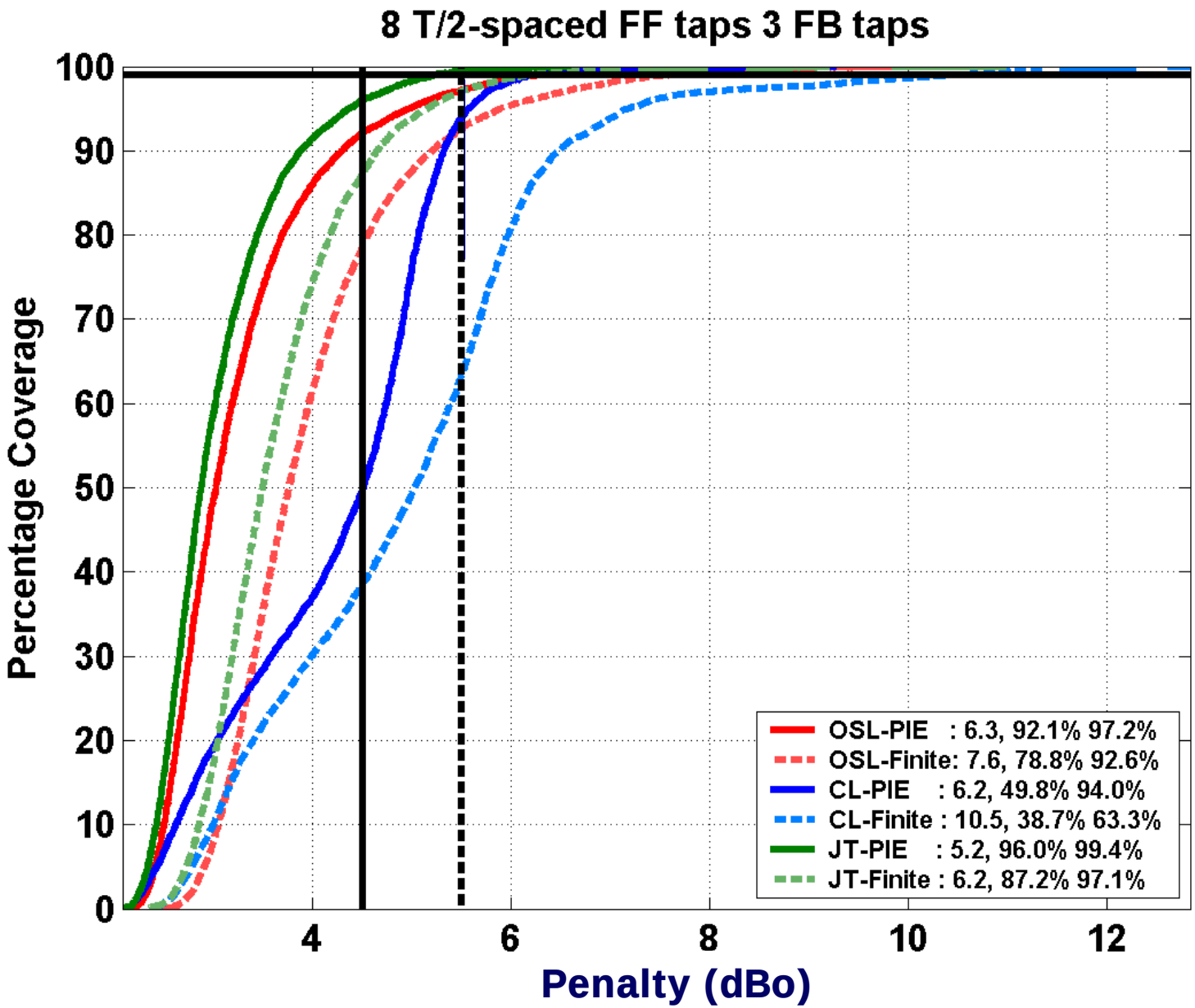
TP3 IPR's compared to Finite DFE Coverage of Gen67YY MC Model







8 Feedforward Tap Equalizer: OFS1998



Conclusions

- The reality of finite length equalizers must be considered when choosing IPR's for compliance testing.
- The minimum complexity equalizer for the current TP3 pulses is a ~ 7+3 or 9+2 DFE, assuming
  - 6.5 dB total dispersion penalty
  - 0.5 dB hardware penalty
- The Gen67YY Monte Carlo model with 2 connectors is about 0.5 dB optimistic for joint launch as compared to the 1998OFS measured fiber model.
  - Center launch is more challenging with respect to PIE-D for the OFS1998 model
  - The OSL and center launches are somewhat more correlated for the OFS1998 model
- An 11 tap DFE – either 6(T/2)+5 or 8(T/2)+3 – is required to equalize the Gen67YY Monte Carlo set (within above power budget assumptions)
- The TP3 stressed sensitivity IPRs in the draft lie between:
  - the 96 and 99%tile Joint Launch coverage points for the Gen67YY model w/ connectors
  - the 94 and 97%tile Joint Launch coverage points for the OFS1998 model
  - With pure OSL, the TP3 IPR's would be in the 89-95%tile range
- The common field practice of using center launch as default should be strongly discouraged, due to a likely ~20% failure rate (Gen67YY, finite DFE)