

Measurements Results of 25.78 GBd VCSEL Over OM3 with and without Equalization

IEEE 100GNGOPTX Study Group

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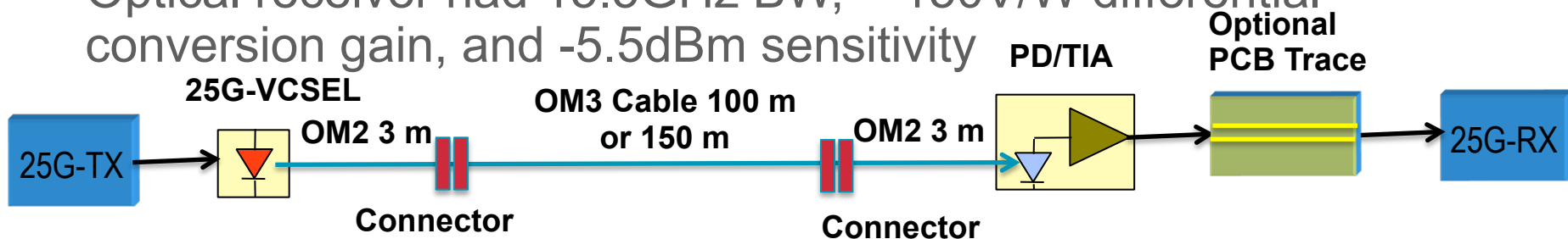


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- Test setup
- Measured and simulated eye diagrams
- Calculated WDP and pulse response
- BER plot
- Example FFE implementation

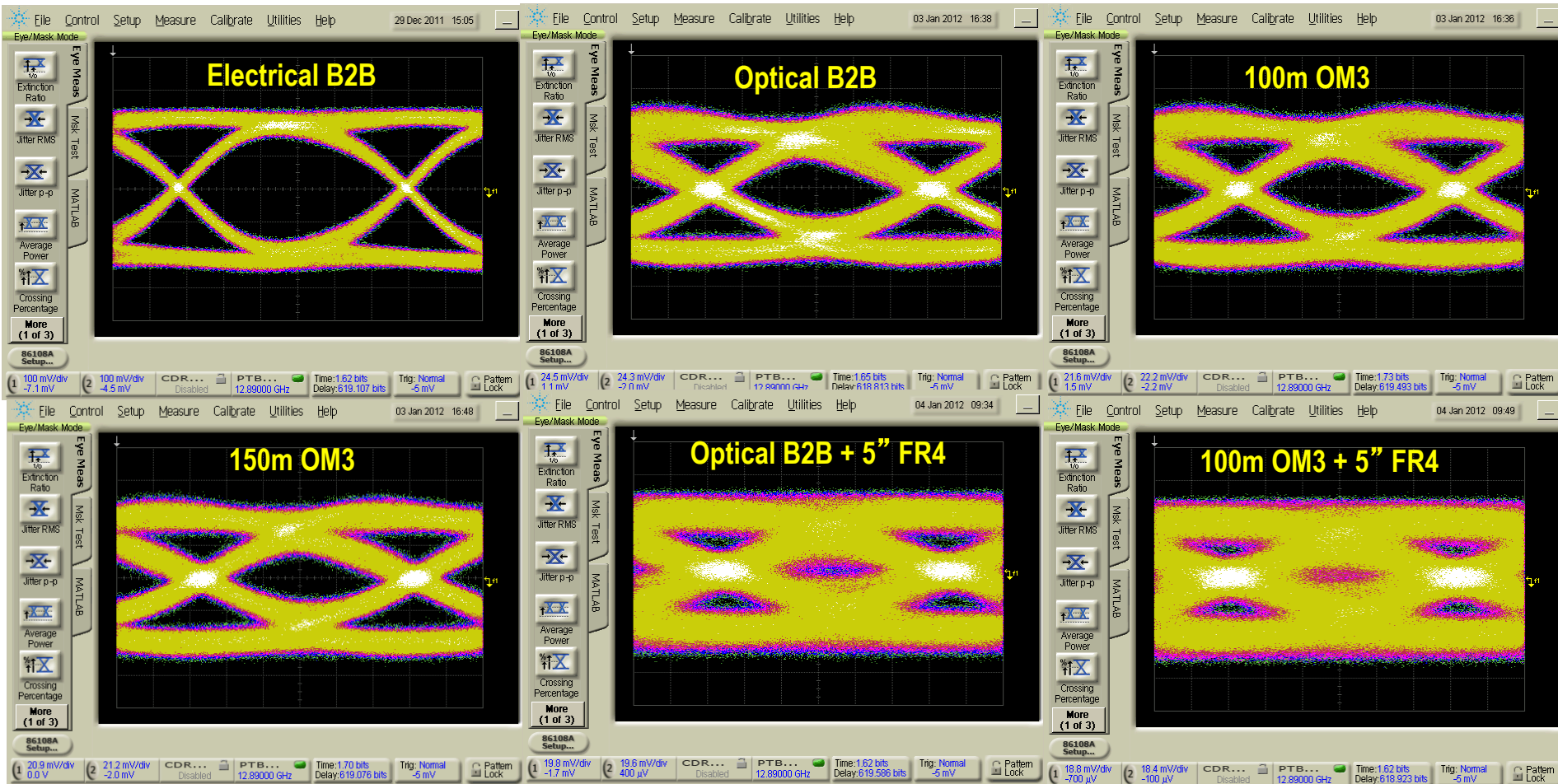
Authors are specially thankful to Jim Tatum and Jonathan King of Finisar for their contributions and providing VCSELs samples for this work.

- VCSEL was driven directly from a 25.78 GBd SerDes test chip
 - Laser was biased through bias-T and driven single-ended with 250 mVpp amplitude
 - No benefit seen by increasing de-emphasis beyond compensating for the test board
 - Laser test and reliability results are being presented at Photonics West this week by Finisar
- The VCSEL die output was collimated with NA=0.47 lens then focused with NA=0.23 lens into an 50/120 μm OM2 fiber patch cord
- VCSEL was biased at 5 mA with 5dB extinction ratio
- Optical receiver had 15.5GHz BW, $\sim 150\text{V/W}$ differential conversion gain, and -5.5dBm sensitivity



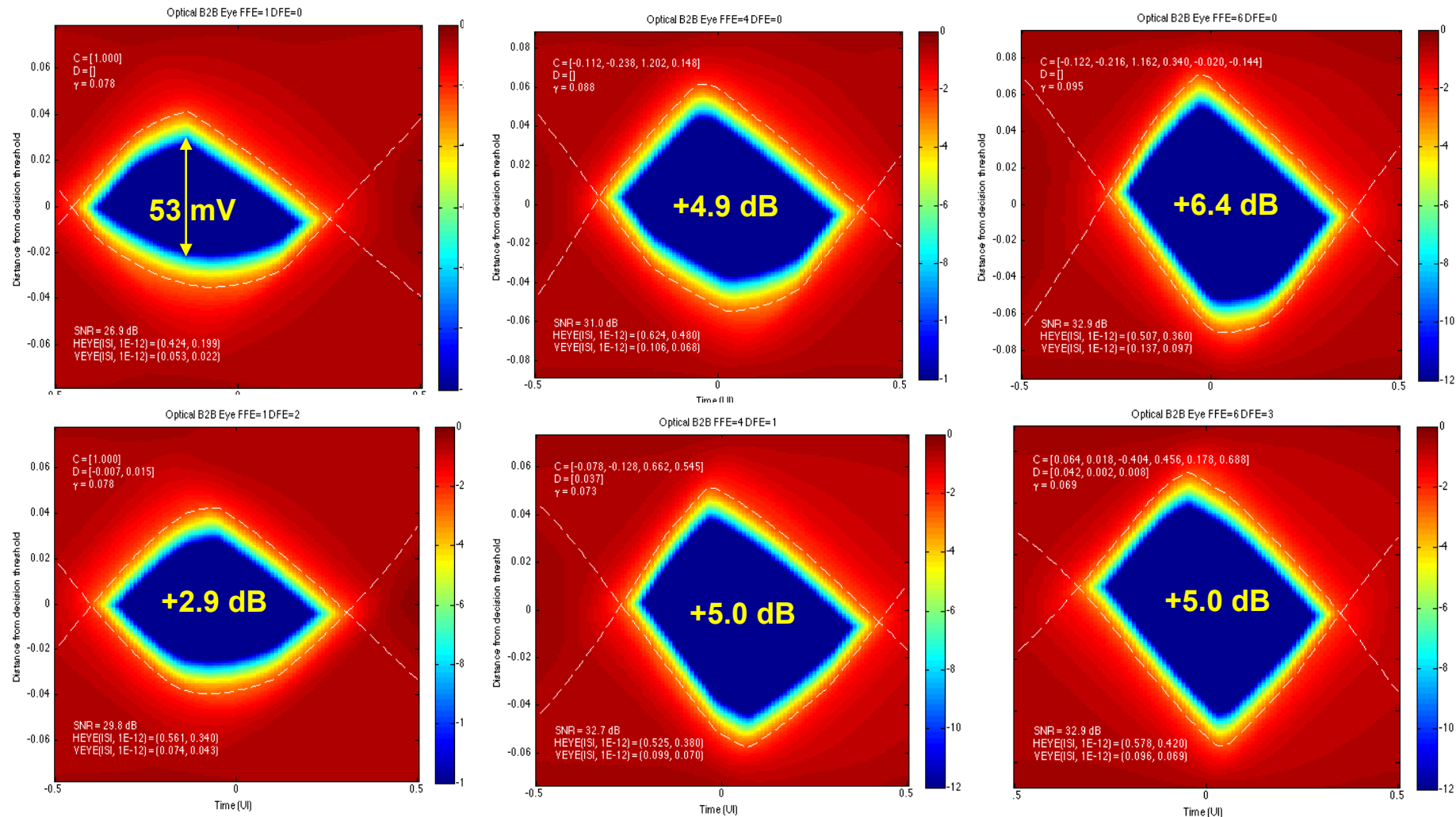
PRBS31 Eye Diagram at 25.78 GBd

- 5mA VCSEL bias current, ~ 5dB ER



PRBS9 Equalized Eye Diagram at 25.78 GBd

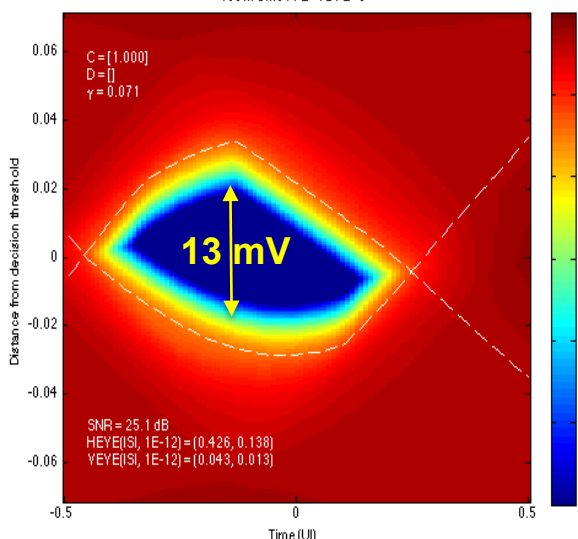
- Equalized eye diagram after 6 m of OM2 fiber
 - Relative equalized eye opening gain for various equalizer shown



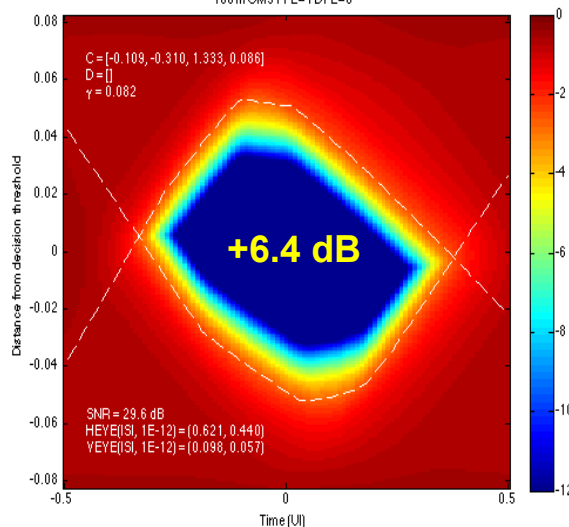
PRBS9 Equalized Eye Diagram at 25.78 GBd

- Equalized eye diagram after 100 m of OM3 + 6 m of OM2 fiber
 - Relative equalized eye opening gain for various equalizer shown

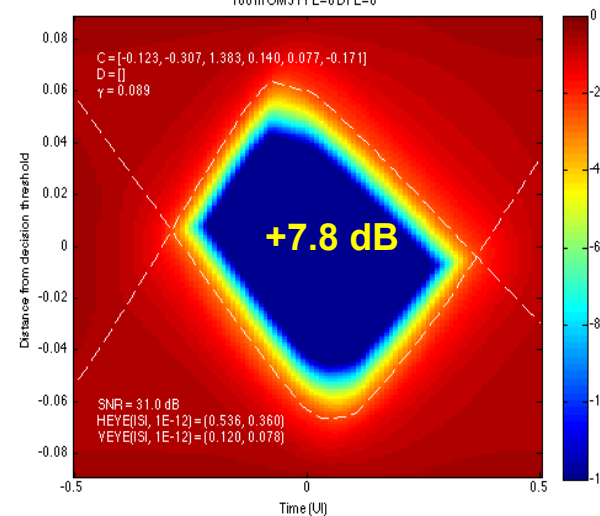
100 m OM3 FFE=1 DFE=0



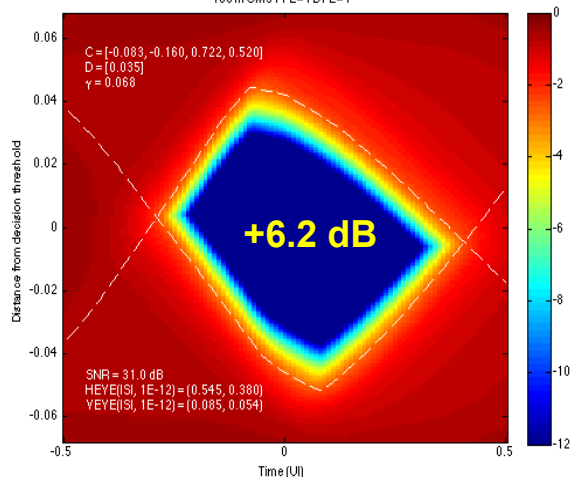
100 m OM3 FFE=4 DFE=0



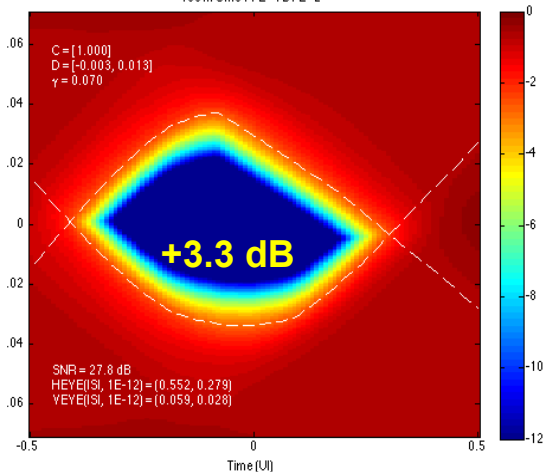
100 m OM3 FFE=6 DFE=0



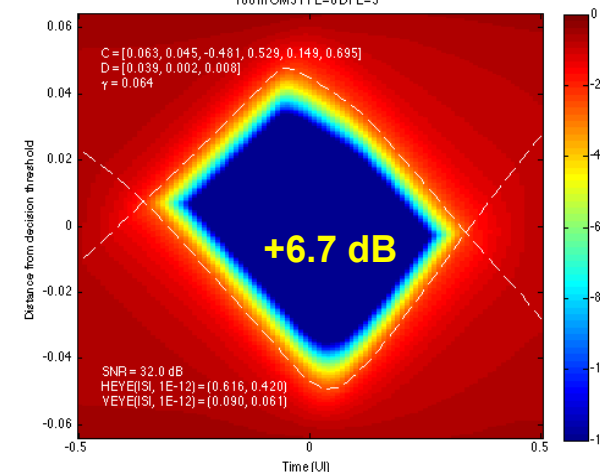
100 m OM3 FFE=4 DFE=1



100 m OM3 FFE=1 DFE=2

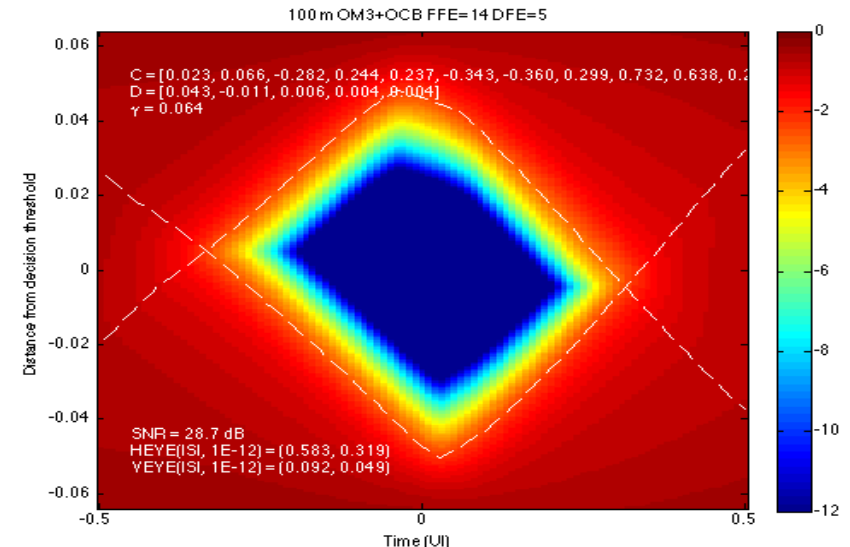
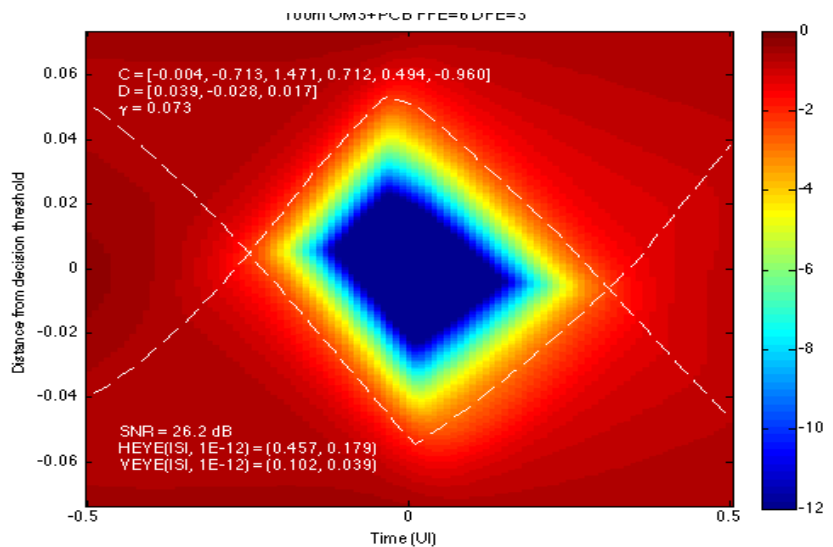
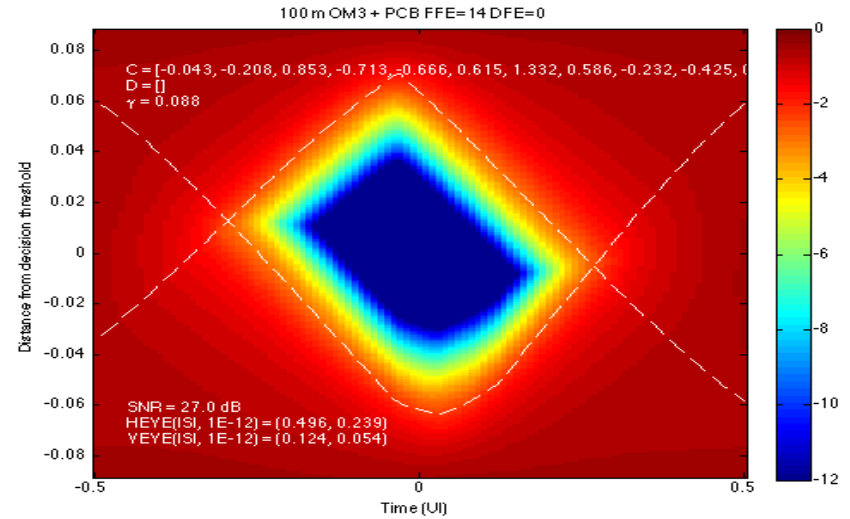
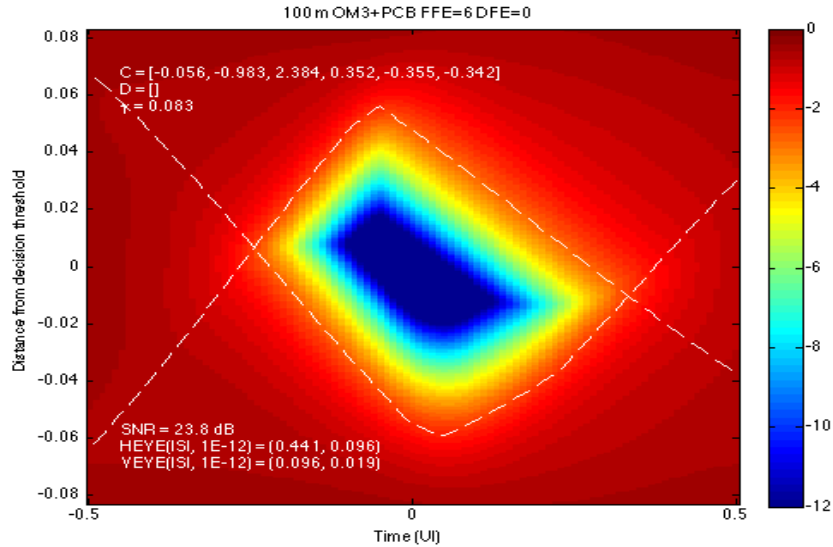


100 m OM3 FFE=6 DFE=3



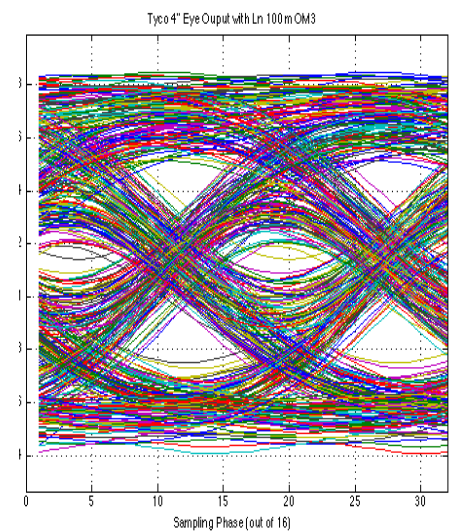
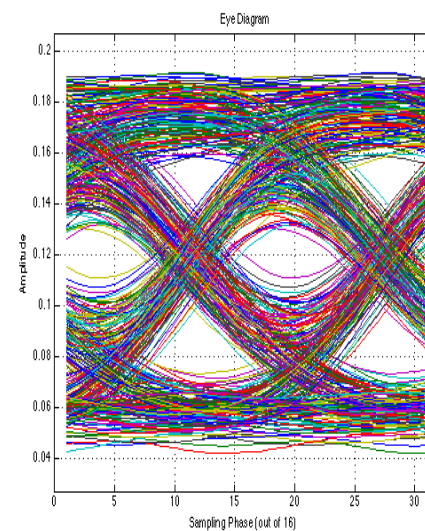
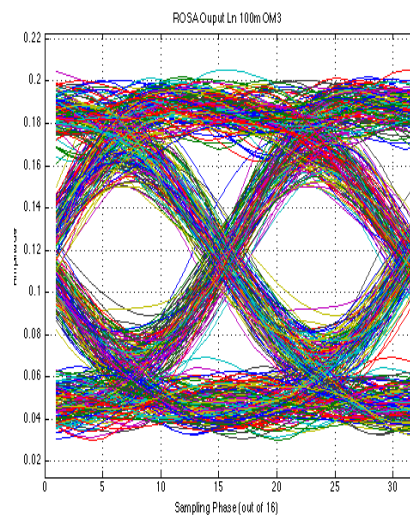
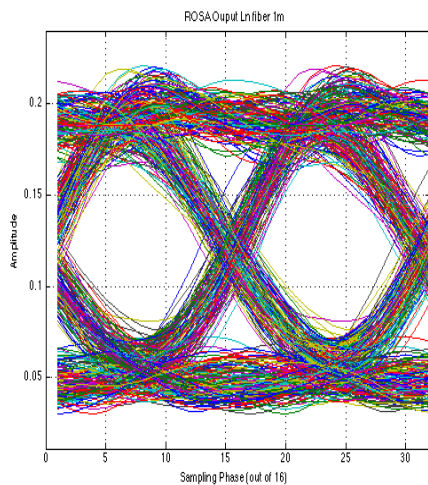
PRBS9 Equalized Eye Diagram at 25.78 GBd

- Equalized eye diagram after 100 m of OM3 fiber + 6 m of OM2+ PCB



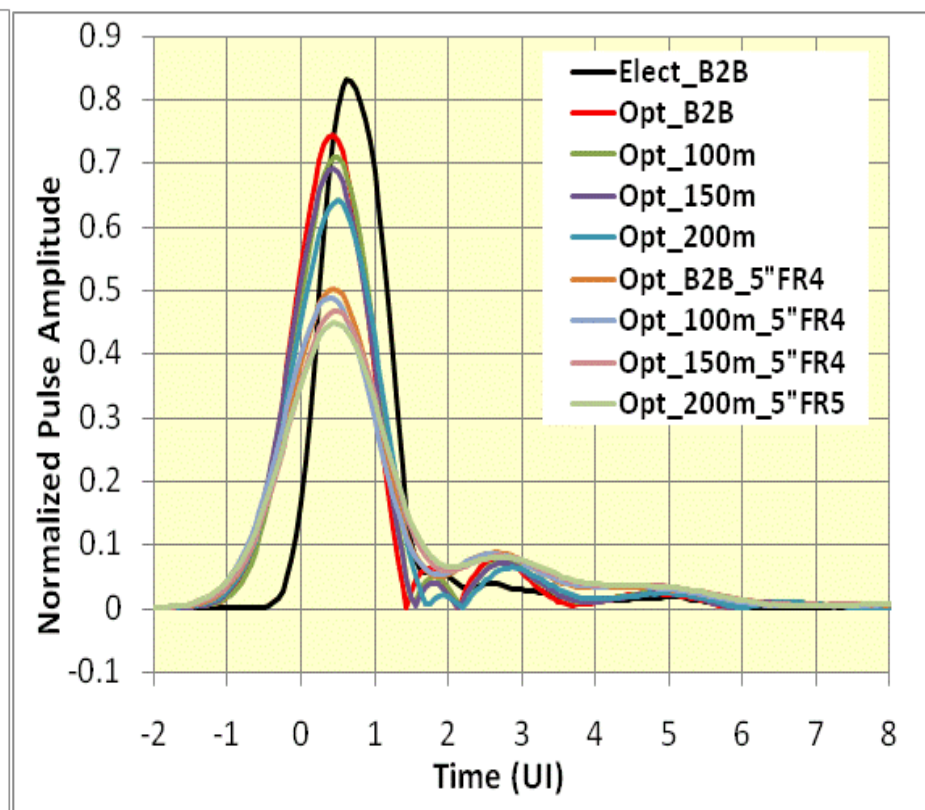
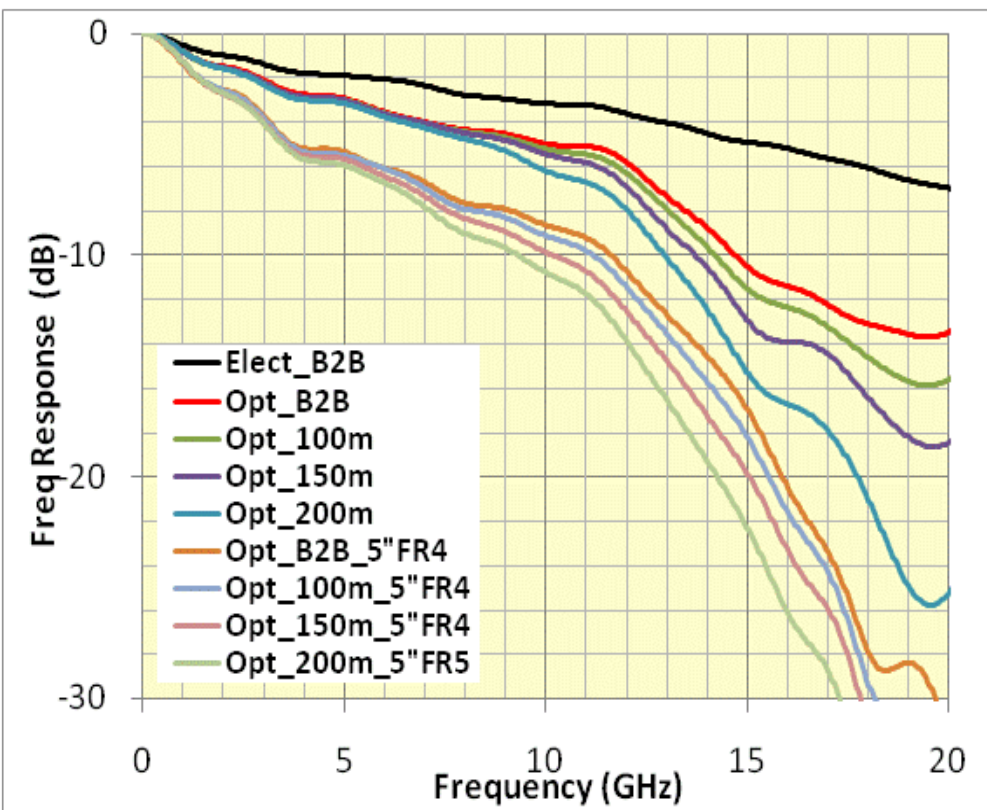
Rate Equation VCSEL Results

- Results shown respectively, for full detail see ghiasi_02_0312
 - Optical B2B
 - Optical 100 m OM3
 - Optical B2B after 7 dB channel at TP5
 - Optical 100 m OM3 and after 7 dB channel at TP5



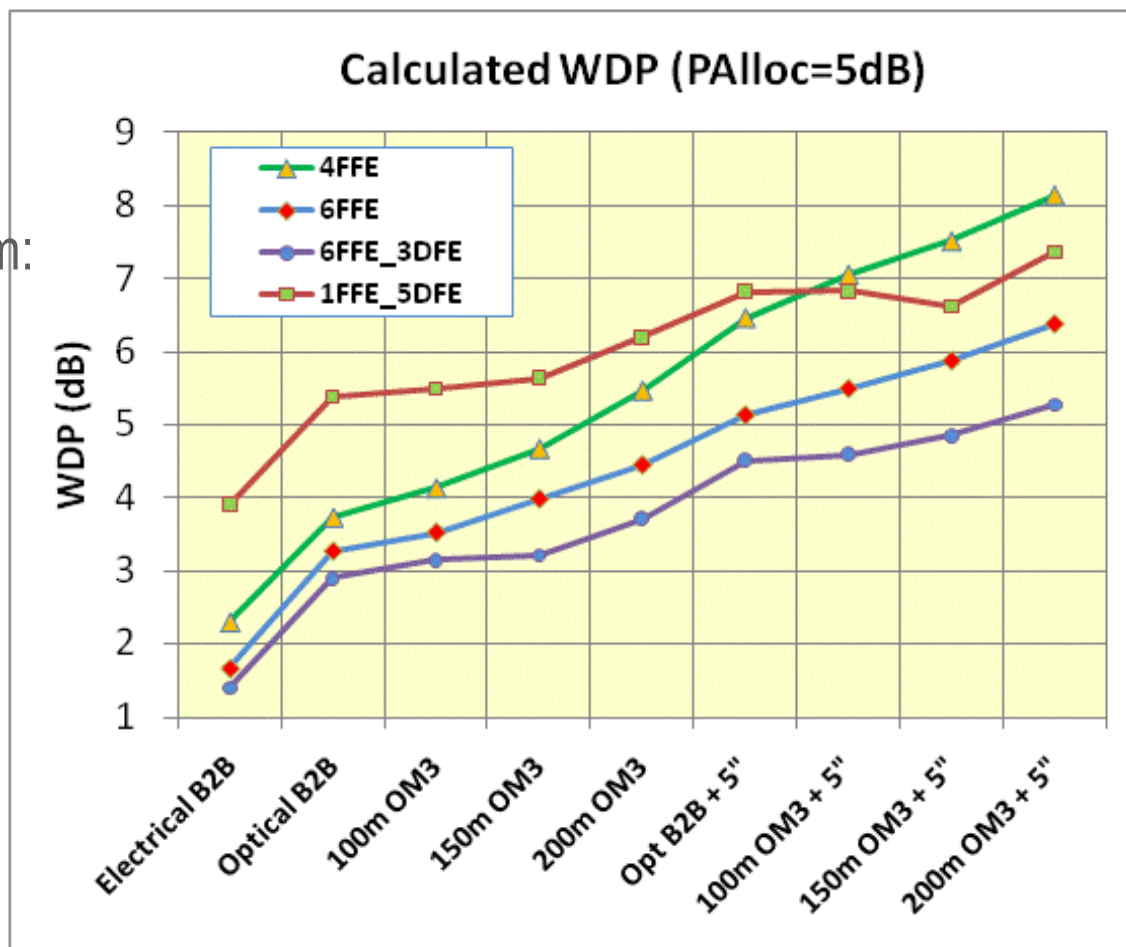
Frequency & Pulse Response

- Calculated from PRBS9 pattern
- 5" FR4 ~ 6.5dB loss at Nyquist



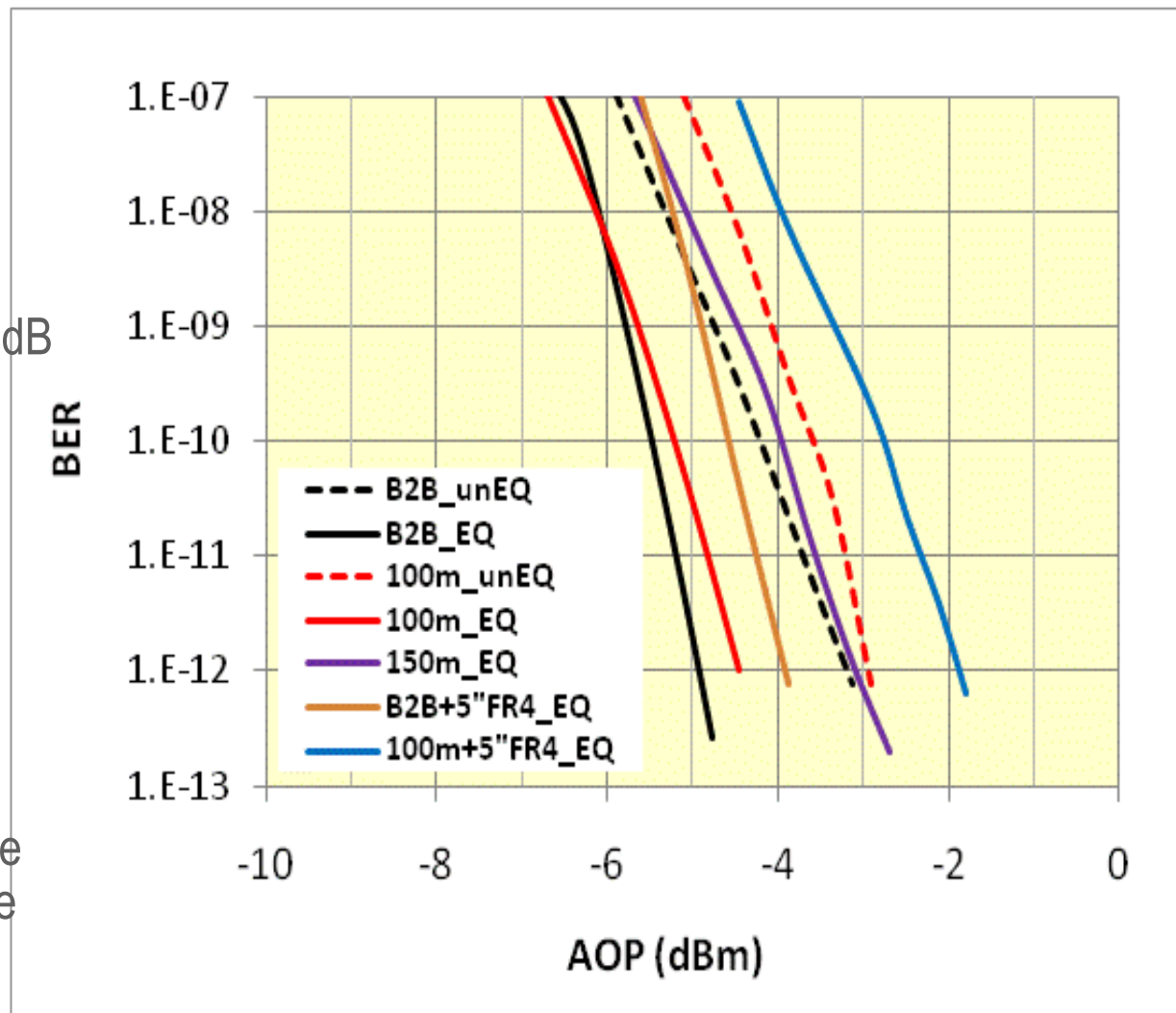
Calculated WDP for Measured Waveforms

- Calculated with SFF8431's xWDP code, Palloc set to 5dB
- Large WDP jump seen from:
 - Electrical to optical B2B
 - Addition of 5" FR4
 - Longer than 150m OM3



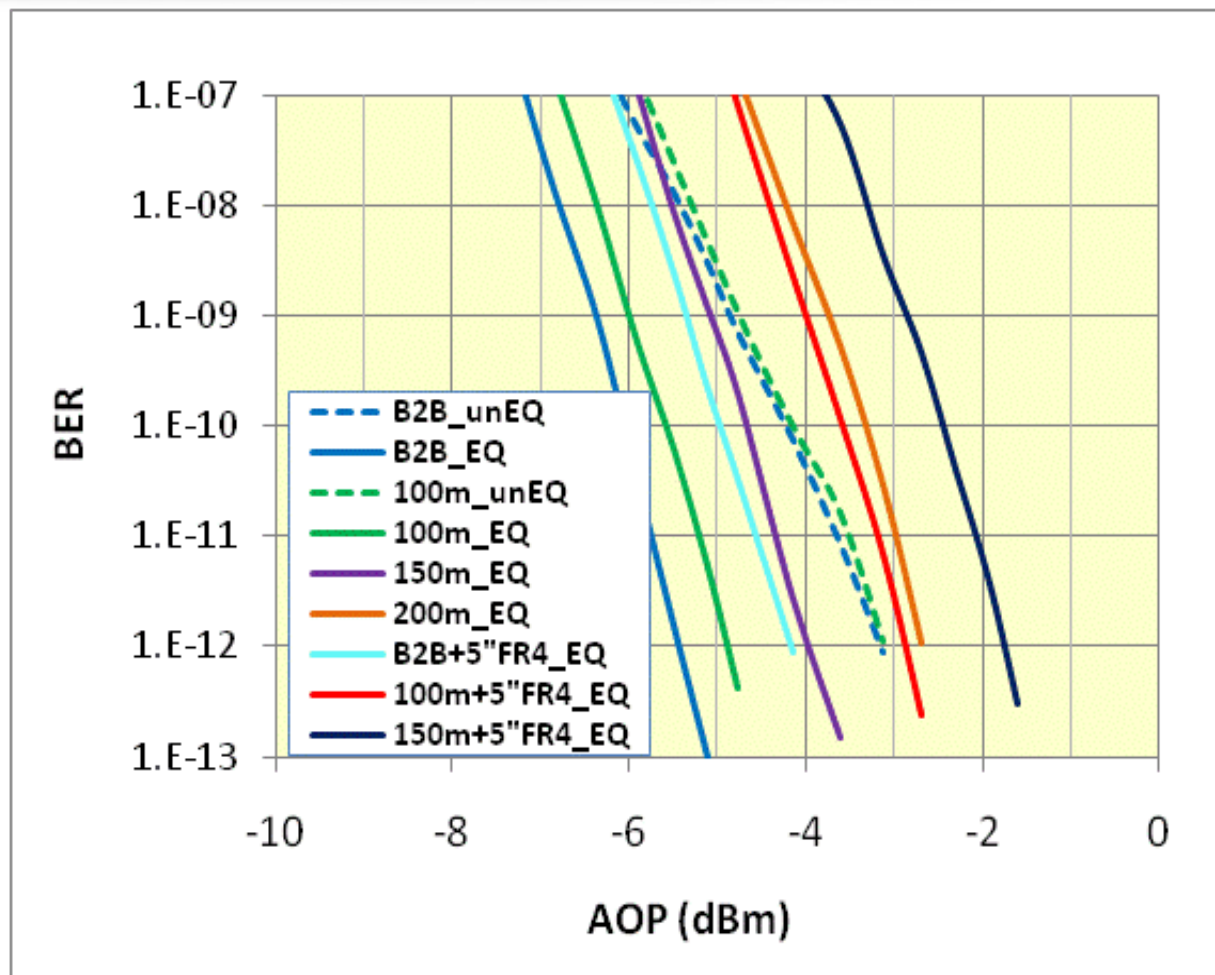
BER for Several Test Cases

- PRBS31 pattern
- Tx De-emphasis is not set
- CTLE set to compensate for 5" FR4, not used for fiber only
- Equalizer is 1 tap DFE which improves B2B sensitivity by ~ 2dB
- 150m OM3 long term BER → 99.98% EF conf level at 1E-15
- Error floor for 100m OM3 + 5" FR4 ~ 1.1E-14
- Error floor for 200m OM3 + 5" FR4 (not shown) ~ 1.5E-9
- With better fiber coupling we are seeing about 1.5 dB lower noise and expect overall sensitivity to improve by at least 1 dBo



Results After Replacing OM2 Patchcord with OM3 Patchcord

- With OM3 patchcord laser launch was better optimized
- Results are with and without 1 tap DFE
- B2B unEQ still is about -3 dBm
- B2B sensitivity with EQ improves by 1 dBm from previous results
- B2B sensitivity with EQ and without EQ improves by 2.5 dBm
- 150m OM3 long term BER → 99.98% EF conf level at 1E-15
- 100m OM3 + 5" PCB no longer has an error floor



- 25.78 GBd test chip which has both CTLE and 1-DFE was used as receiver
 - CTLE provided very little benefit at ROSA output for fiber reach up to 100 m
 - Adding 6.5 dB PCB trace loss only added 1 dB optical penalty
 - 1 tap DFE gains 2.5 dBo and link runs error free for 4 days with $<1E-15$ @ 99.98 confidence level!
- B2B results at ROSA output without EQ is comparable to the case of 150 m OM3 with just a modest 1-tap DFE
 - Spreadsheet predicts at 100 m should see error floor something need to be further investigated why we don't see error floor even at 150 m!
- Measured result shows 2.5 dBo optical gain with just 1 tap DFE but simulated result show as much as 5-8 dBo of gain
 - Assuming software equalizer is too optimistic and adding some penalty for noise enhancement 4 dBo of gain should be possible with a modest equalizer
- VCSEL and PIN/TIA are the dominant sources of penalty but a modest equalizer can reduce these inherent penalty
- Feasibility of 25.78 GBd SR link is shown with and without equalizer

Thank You