Transmitter Preemphasis: An Easier Path to 99% Coverage at 300m?

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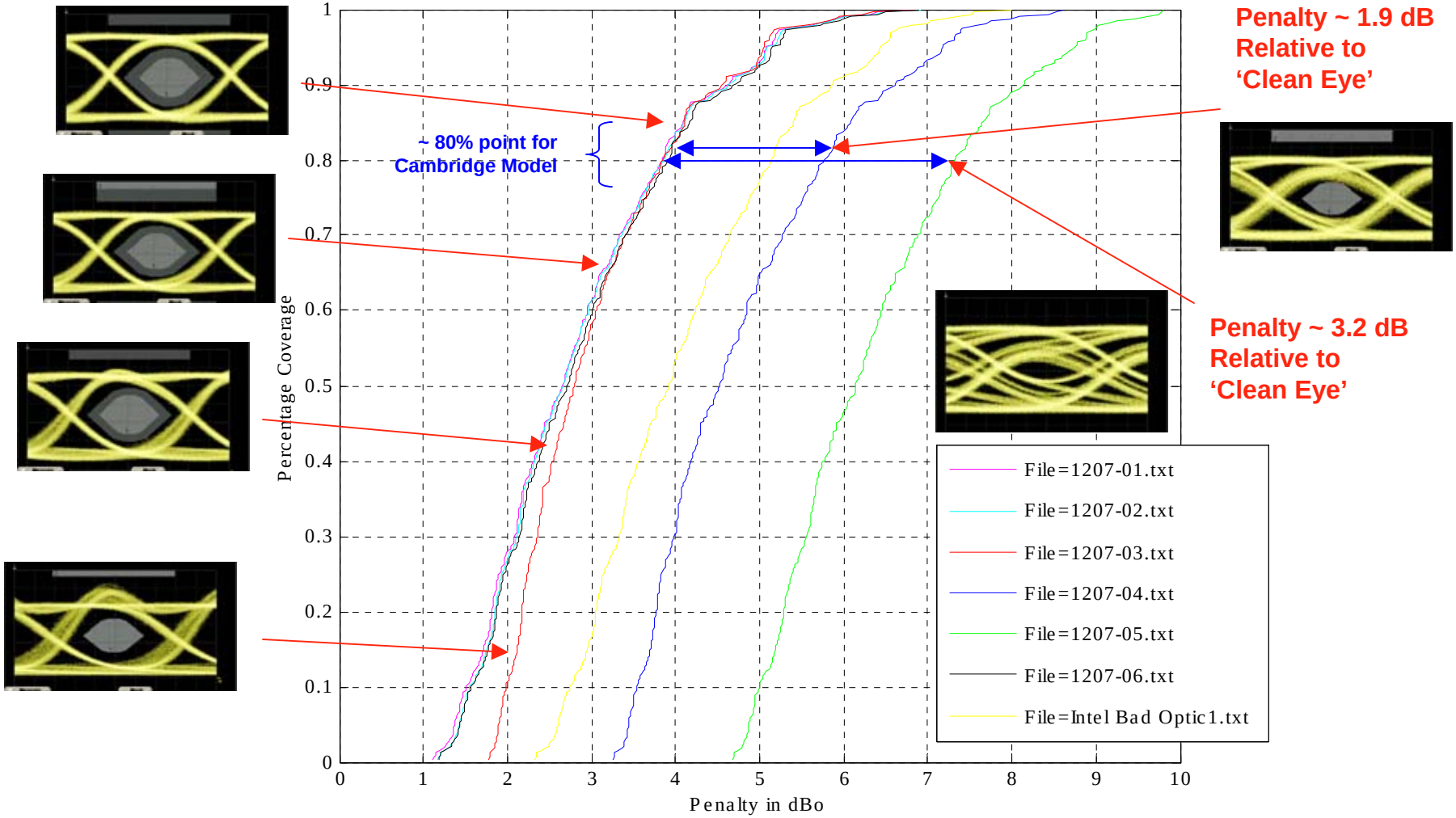
January 24, 2005

Introduction

- **Current Models Show 99% Coverage at 300m a Challenge**
  - **Penalty with Single Launch: PIE-D ~ 5.6dB**
  - **Alternative Launches Proposed, but Reliability Concern**
- **Evidence that Transmitter Preemphasis Can Reduce Penalty Significantly**
  - **Transmit Waveform Dispersion Penalty Test (TWDP) Shows Very Significant Penalty Reduction with Reasonable Degrees of Preemphasis**
  - **Appears to Hold over Full Channel Model Sets**
- **Works Somewhat Differently on MMF Links**
  - **On Copper Links, Preemphasis can Open Receive Eye**
    - **Simple, Monotonic Frequency Response**
  - **On MMF Links, Preemphasis Generally doesn't Open Receive Eye**
    - **Still Appears to Decrease the Penalty per TWDP Calculations**
- **Optical Link Experiment work started, but No Results Yet.**

Modeling Demonstration – Bad Eyes

- **Calculated TWDP Curves with Degraded Optical Eyes**



Modeling– Preemphasized Electrical Eyes

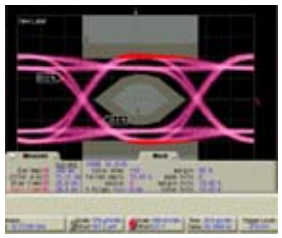
- **Calculated TWDP Curves with Preemphasized Electrical Eyes**

Case 5: Pre-emphasis ~45%

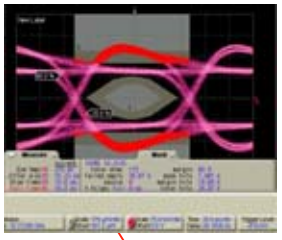
Case6: Pre-emphasis ~55-60%

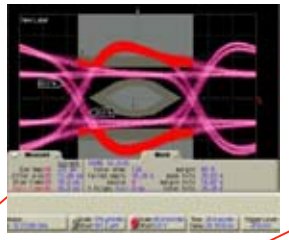
Case 4: Pre-emphasis ~25%

Penalty ~ -0.7 dB Relative to 'Clean Eye'



Penalty ~ -1.4 dB Relative to 'Clean Eye'

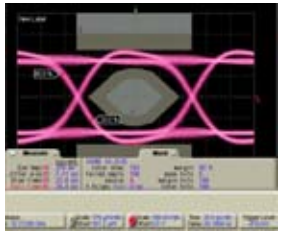




Penalty ~ -1.8 dB Relative to 'Clean Eye'

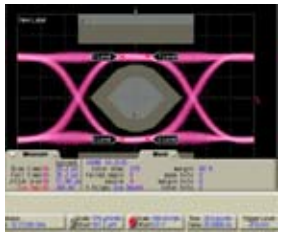
Fiber 1-108 and Offset(17, 20, 23), Butterworth 7.5G, T/2 equlazer

Penalty ~ -0.5 dB Relative to 'Clean Eye'



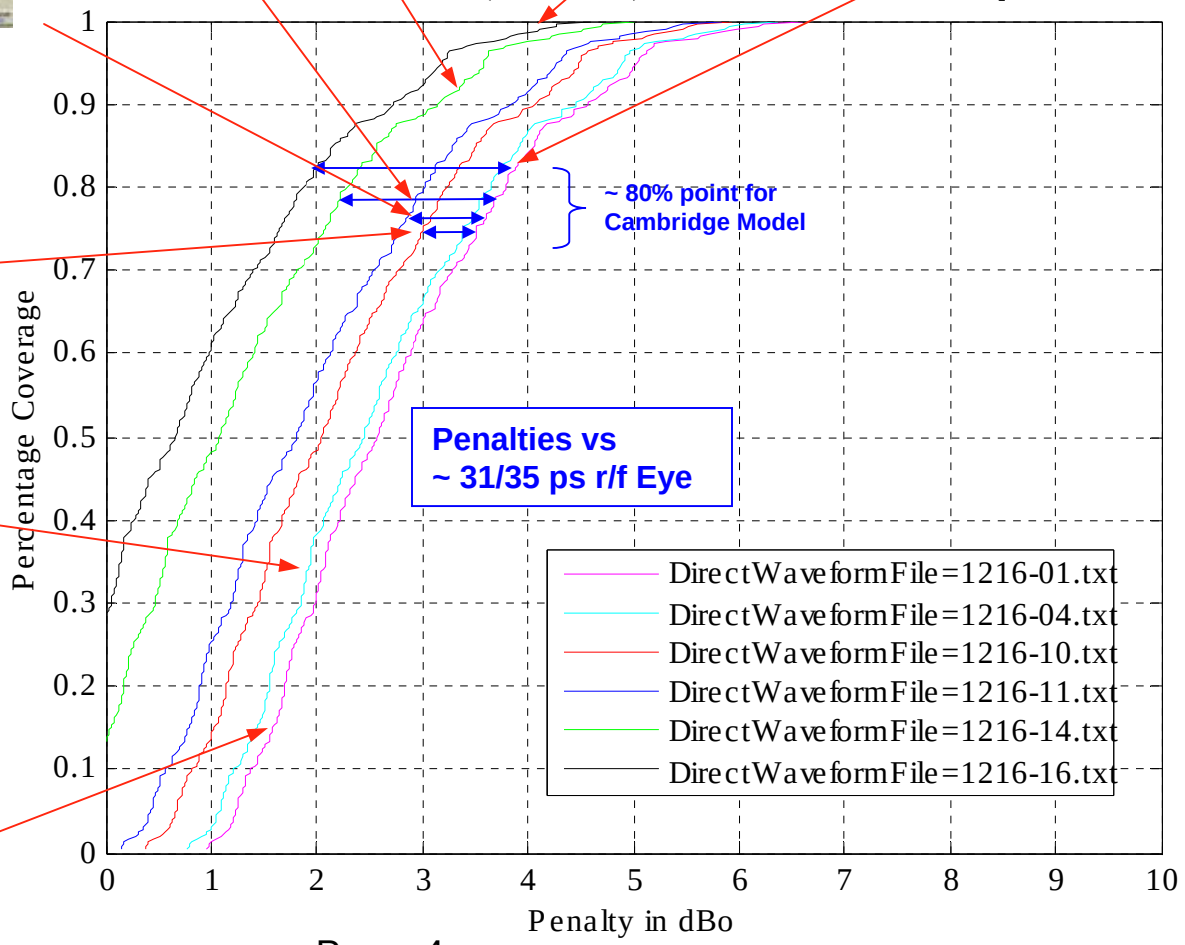
Case3: Pre-emphasis ~15%

Penalty ~ -0.2 dB Relative to 'Standard Clean Eye'

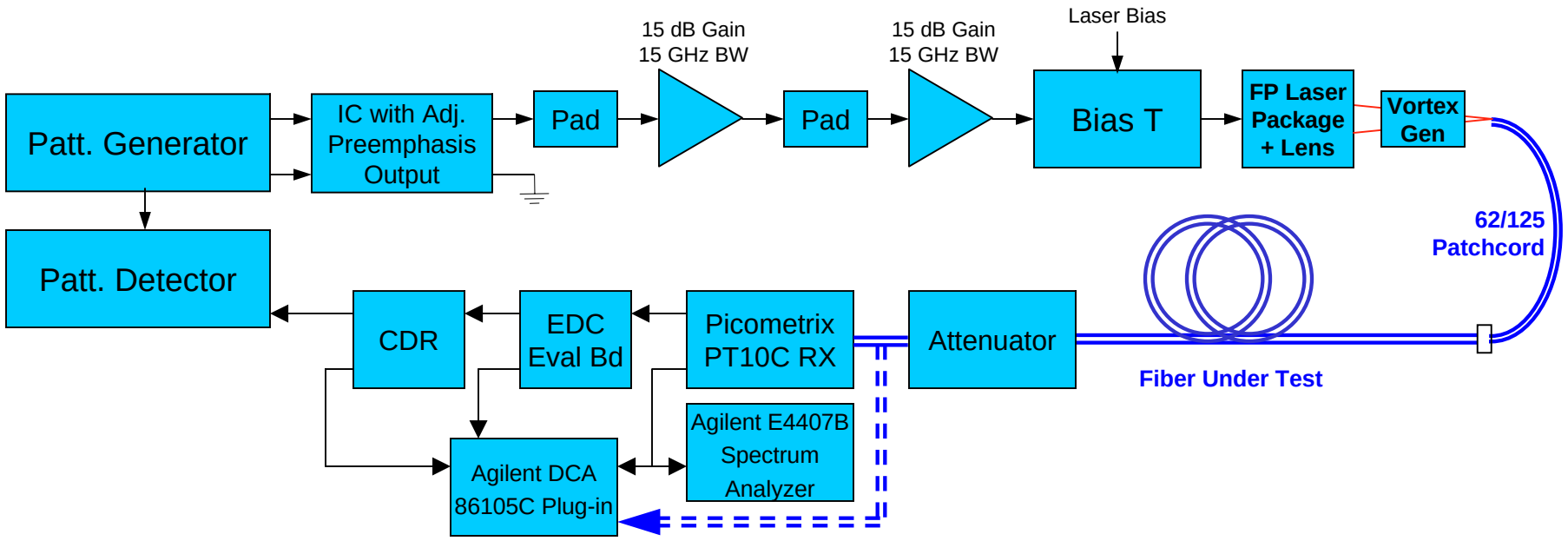


Case 2: Clean Eye tr/tf = 25/26ps

Case 1: Clean Eye tr/tf = 31/35ps



Optical Demonstration Setup

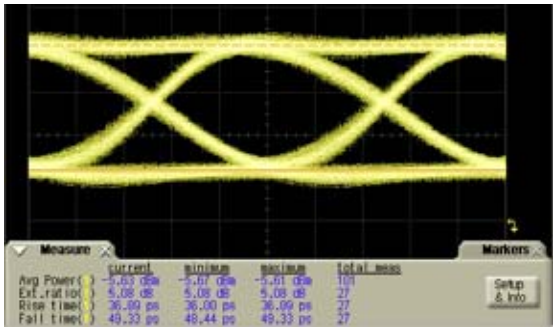


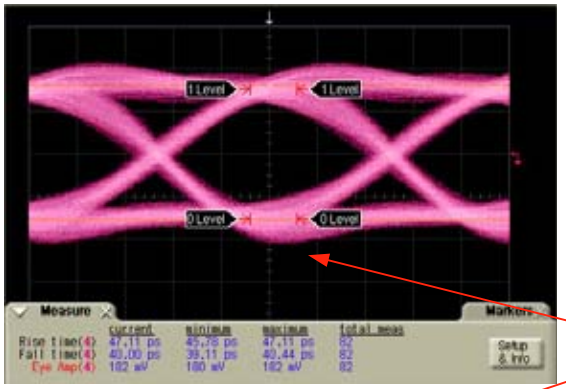
- **Goals:**
  - Measure Preemphasized Optical Eyes, Record for TWDP Analysis
  - Measure and Compare OMA, ER, Microwave Spectrum of Transmitted Eye
  - Record BER Curves for Full Link with Different Degrees of Preemphasis on Transmit Eye
  - Record Microwave Spectrum of Received Eyes

Transmit Eyes – Case 1 No preemphasis

Transmit Eye on DCA Plug-in

Pavg = -5.6 dBm at Scope





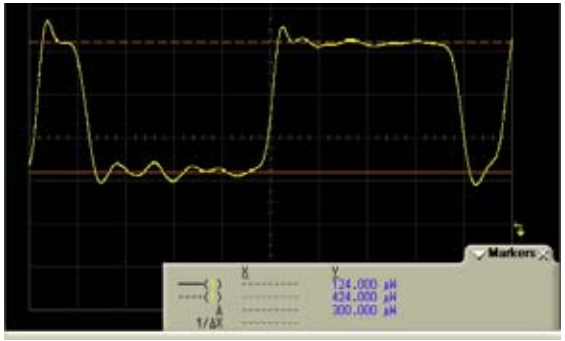
Transmit Eye from PT10C RX

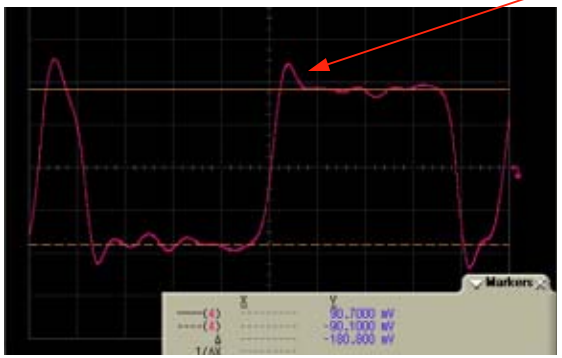
~ 182 mV swing

Note Peaking in PT10C RX

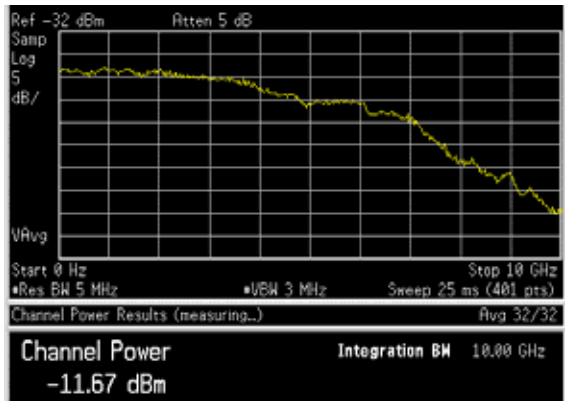
OMA = -5.2 dBm

ER = 5.34 dB





OMA waveform output from PT10C RX



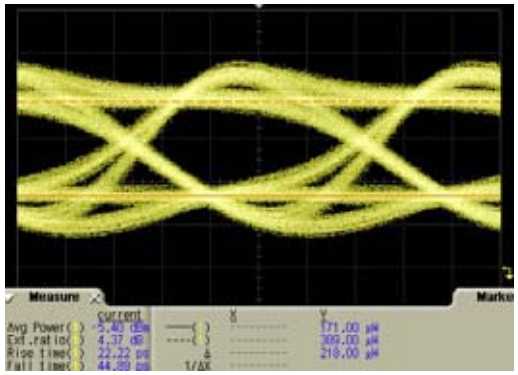
Power in Spectrum Out of PT10C RX: (PRBS31)

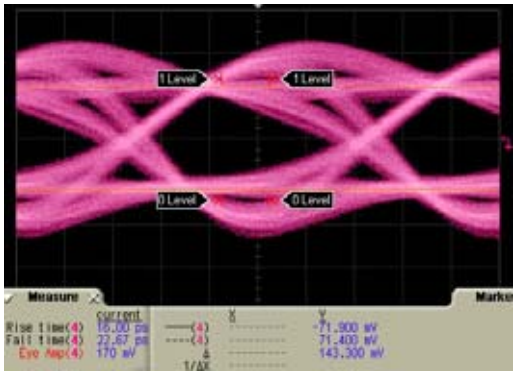
-11.67 dBm

Transmit Eyes – Case 3

Transmit Eye on DCA Plug-in

Pavg = -5.4 dBm at Scope

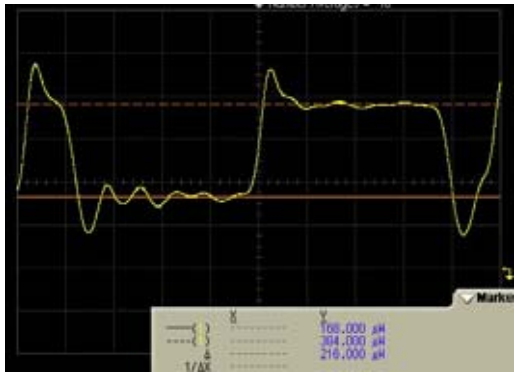


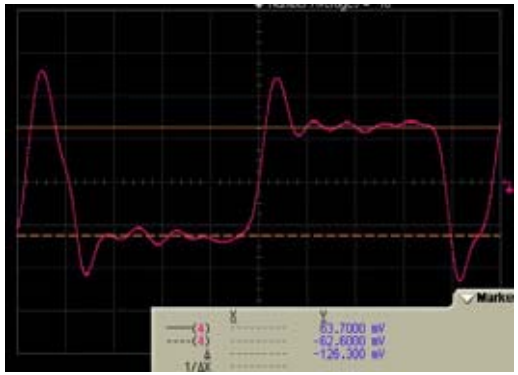


Transmit Eye from PT10C RX

OMA = -6.7 dBm

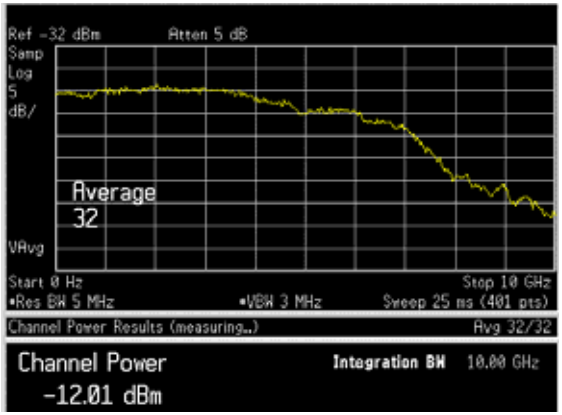
ER = 3.59 dB





OMA waveform output from PT10C RX

~ 126 mV 'OMA' swing



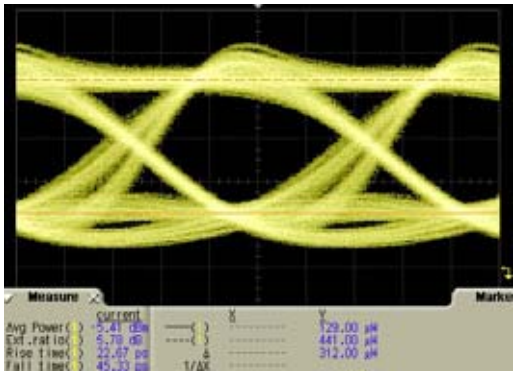
Power in Spectrum Out of PT10C RX(PRBS31):

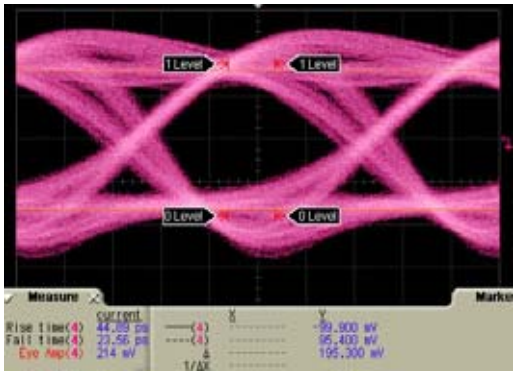
-12.01 dBm

Transmit Eyes – Case 6

Transmit Eye on DCA Plug-in

Pavg = -5.4 dBm at Scope

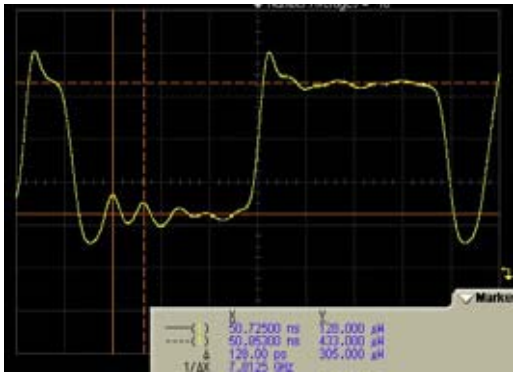




Transmit Eye from PT10C RX

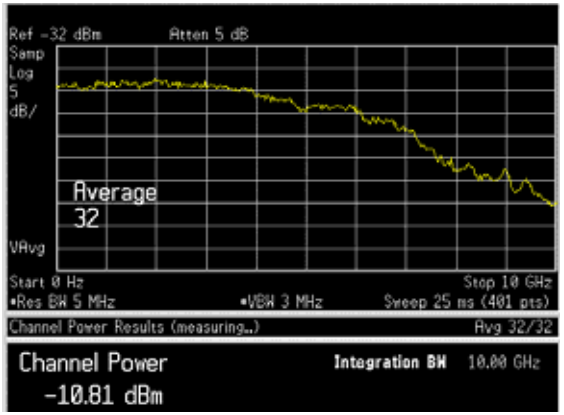
OMA = -5.2 dBm

ER = 5.29 dB



OMA waveform output from PT10C RX

~ 177 mV 'OMA' swing



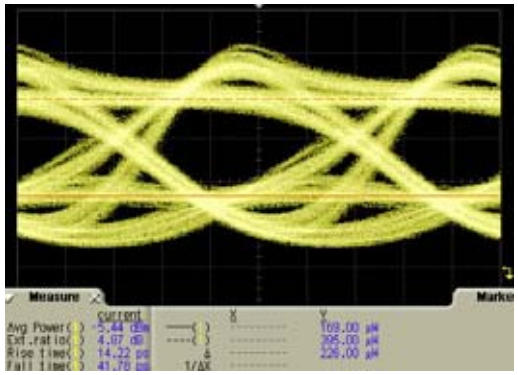
Power in Spectrum Out of PT10C RX(PRBS31):

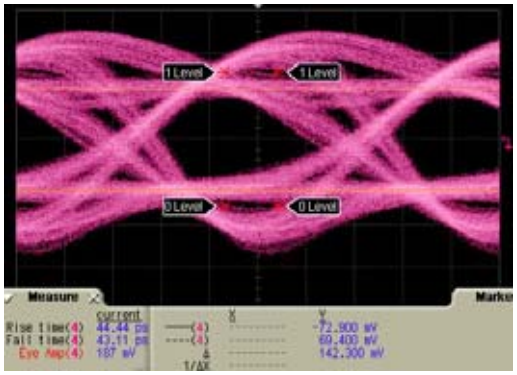
-10.81 dBm

Transmit Eyes – Case 9

Transmit Eye on DCA Plug-in

Pavg = -5.4 dBm at Scope

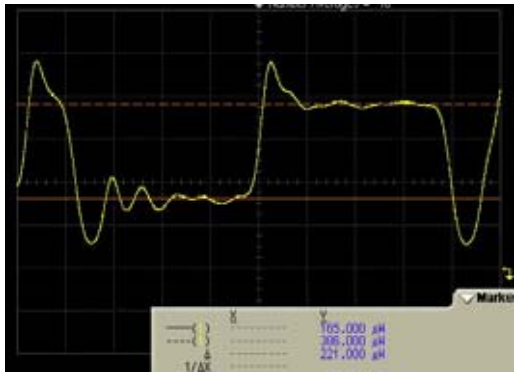


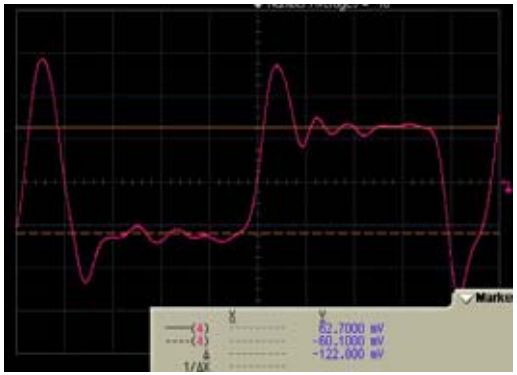


Transmit Eye from PT10C RX

OMA = -6.6 dBm

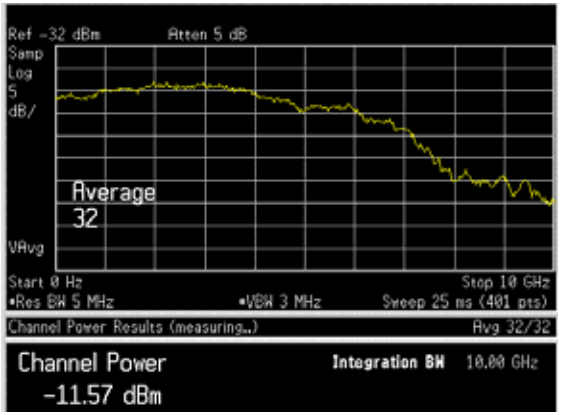
ER = 3.69 dB





OMA waveform output from PT10C RX

~ 122 mV 'OMA' swing



Power in Spectrum Out of PT10C RX (PRBS31) :

-11.57 dBm

Transmit Eyes

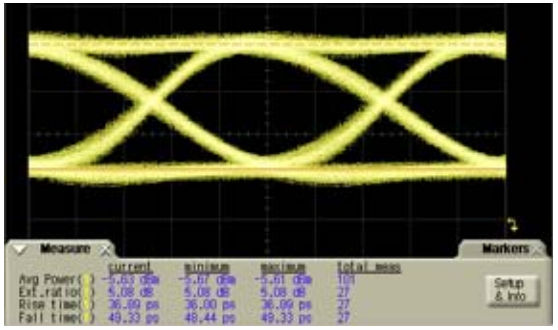
- **More Transmit Cases Available.**
- **Recorded Waveforms for All transmit Eyes Available, but Not Yet Processed for TWDP Penalty.**

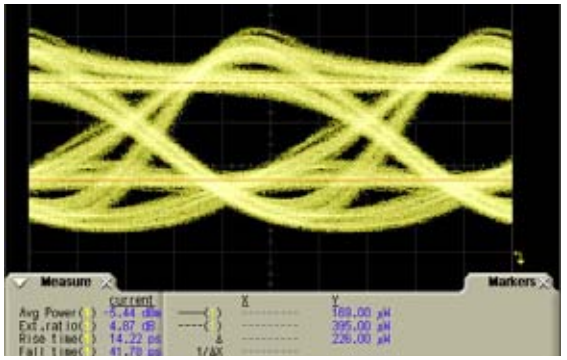
Discussion on Normalizing Eye Amplitudes

- **Is OMA a Fair Metric for Eye Amplitude for Preemphasized Eyes? - More Energy in Preemphasized Eye with Same OMA**
- **Total Energy Under Spectrum Possibly Better for This Experiment - Record Both Values for Eyes of Equal Average Power**

Transmit Eye with No Preemphasis

Pavg = -5.6 dBm at Scope



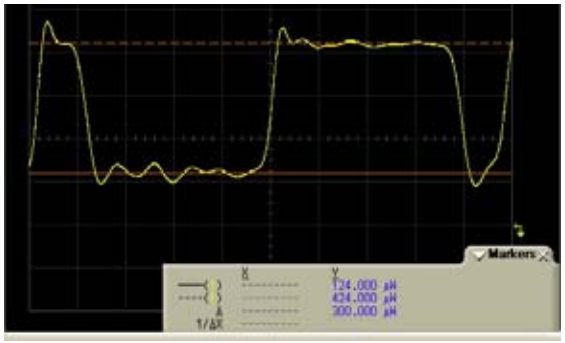


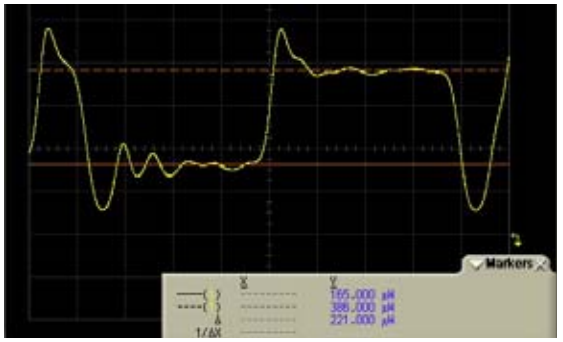
Transmit Eye with Preemphasis

Pavg = -5.46 dBm at Scope

OMA = -5.2 dBm

ER = 5.34 dB





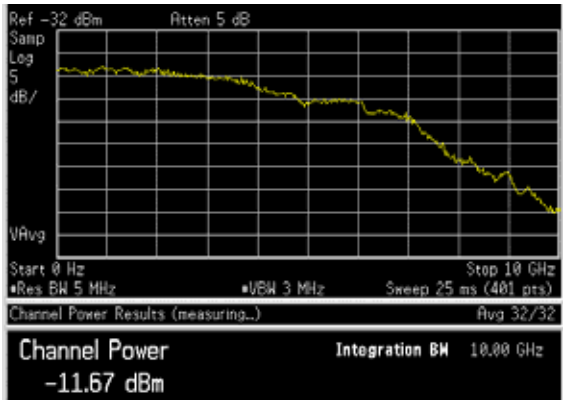
OMA = -6.6 dBm

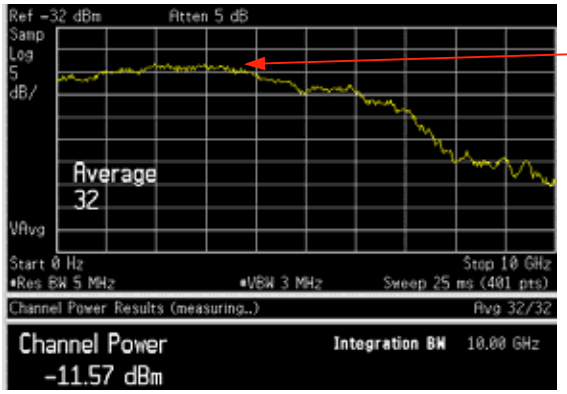
ER = 3.69 dB

Significantly Less than No Preemphasis

Power in Spectrum Out of PT10C RX:

-11.67 dBm





Note Peaked Frequency Response

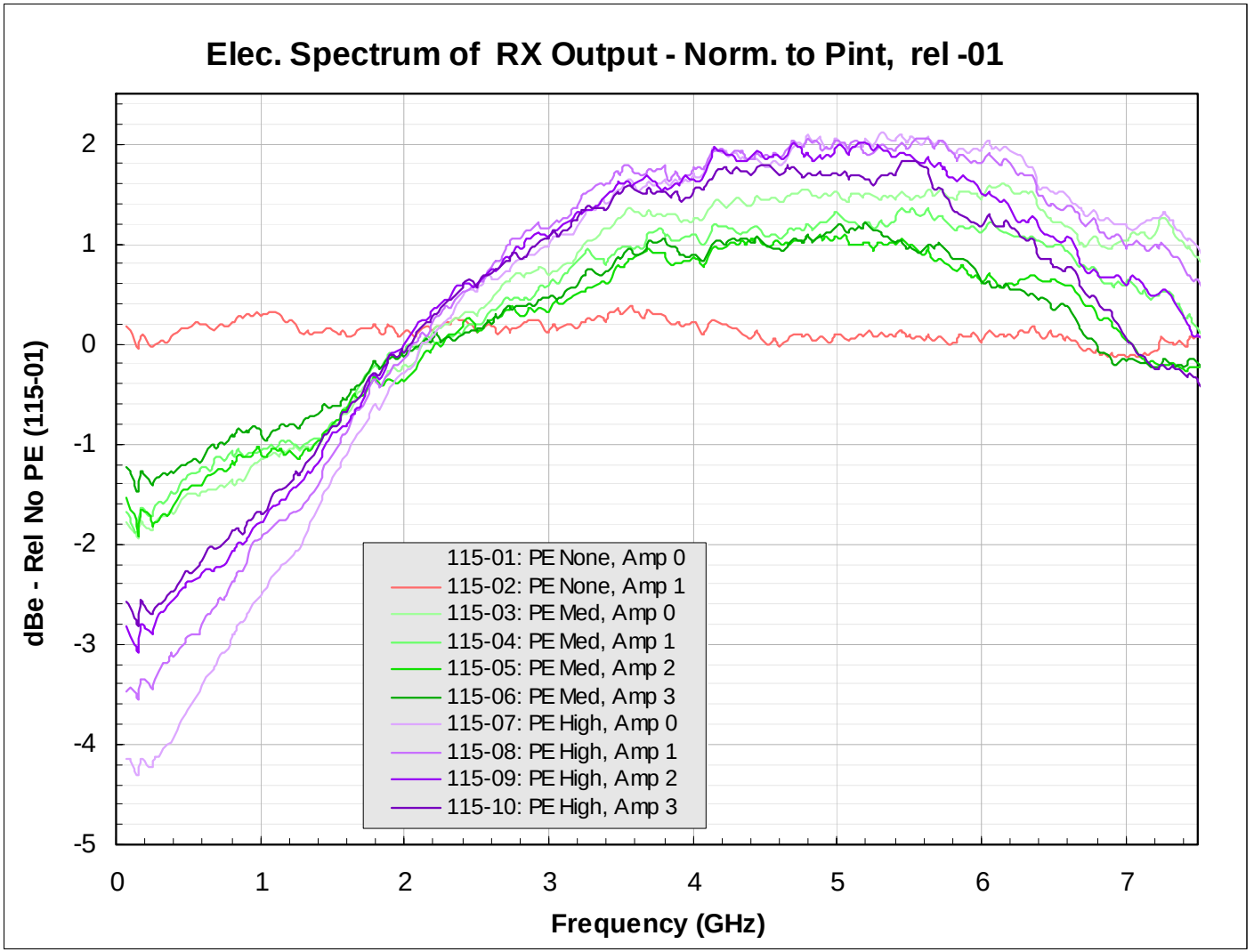
Power in Spectrum Out of PT10C RX:

-11.57 dBm

(Similar to no preemphasis case)

Summary of Frequency Content in Transmit Eyes

- **Comparison of the electrical spectra of various optical preemphasis cases generated (includes RX response)**
- **Normalized to same integrated RF power, plotted relative (point by point) to non preemphasized case (Case 1, not ploted)**



Summary of Results

- **Modeling shows Substantial Penalty Reductions (~ 1.8 dB) from Reasonable Preemphasis on Example Electrical Eyes**
- **TO BE COMPLETED: Measurement of Penalty Reduction using Reasonable Preemphasis on Real Optical Eyes**
  - **Eyes Far From Ideal, Much Better Probably Possible**
- **Even if One Argues that Preemphasis Only Has a Penalty Benefit Because of Extra Modulation power at Same OMA, That is Not the Issue:**
  - **Real Goal is Not Saving 1 dB of Optical Power**
  - **Real Goal is Making the EDC work on a Worse Fiber than it Could Without Preemphasis.**
  - **I.e. Whether Preemphasis Can Make a System Function Where the EDC is Incapable at ANY Reasonable Power (Error Floor) without Preemphasis**
- **Even 1 dB Penalty Reduction in the Required TWDP limit, achieved through Preemphasis, Will Lead to Important Coverage Increases with Given EDC Performance Limits**

Proposal for –LRM Standard

- **Propose We Allow for Some Preemphasis Even Though More Work to be Done. Later Could be Used to Simplify Launch**
- **How would it Work When and If We Do get Experimental and More Theoretical Data?**
- **No Need to Prescribe Preemphasis Details, Simply Require Smaller TWDP Penalty**
  - **Example: 1 dB improvement relative to the 47 ps 'nominal' transmit eye**
  - **TWDP = 4.0 dB max Would Allow ~ 5.0 dB max PIE-D Links w/ Lindsay's TWDP spec Proposal**
  - **TWDP = 4.6 dB max Would Allow ~ 5.6 dB max PIE-D Links Which Clearly Gives 99% Coverage**
- **Eliminate or Greatly Reduce Overshoot Limits on Eye Mask**
- **Relax Inner Eye Mask, or Consider Eliminating Eye Mask (need to consider TX jitter question)**
- **Retain OMA Definition Based on Long Square Wave (Use 8 – 10 bits vs Current 4 bits?)**
  - **Allows More Total Modulation Power in Preemphasized Eye**
- **Clearly Define ER Measurement on Long Square Wave as Well (same pattern as OMA)**
- **Assuming we are using the extra margin to reduce EDC PIE-D requirements for same coverage:**
  - **Choose TP3 Comprehensive Test IPRs to Correspond to Lower PIE-D (say 4.0 dBo)**
    - **Rigorous Method would recompute IPR and coverage curves with nominal preemphasized signals.**
    - **Simply reducing the PIE-D number for choosing the test impulses is probably very close.**
  - **Choose TWDP Channel Responses for Larger PIE-D (say 5.0 dBo) with Nominal Eye (no PE)**
    - **But keep IPR Shapes Similar to TP3 Impulse Response Choices**

Further Work

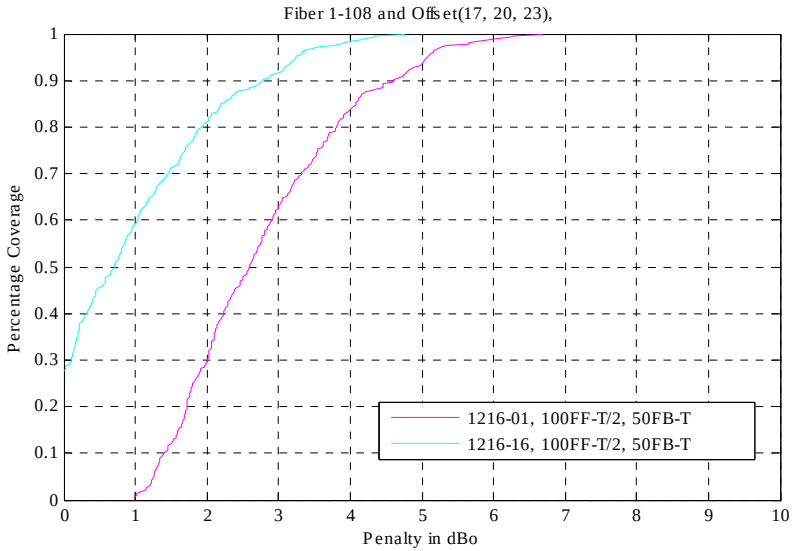
- **Extend TWDP Analysis to Latest Channel Models with Connectors to Confirm Generality**
  - **GEN54YY and Cambridge Models**
- **Perform TWDP analysis on Captured Optical Waveforms**
- **Conduct Extensive Link Experiments**
  - **Many Channel Responses**
  - **Different Optical Preemphasis Implementations and Performance**
  - **Different EDCs**

Backup Slide – Modeling with Short EDCs

- **Question, Do Modeling Results Apply to Finite, and in particular Short EDCs?**

Infinite (well, very long) EDC.

1.8 dB Advantage for Strong Preemphasis



Finite (10 T/2 FFE, 2 T DFE) EDC.

~1.5-1.6 dB Advantage for Strong Preemphasis