Gain and Equalization Adaptation to Optimize the Vertical Eye Opening in a Wireline Receiver

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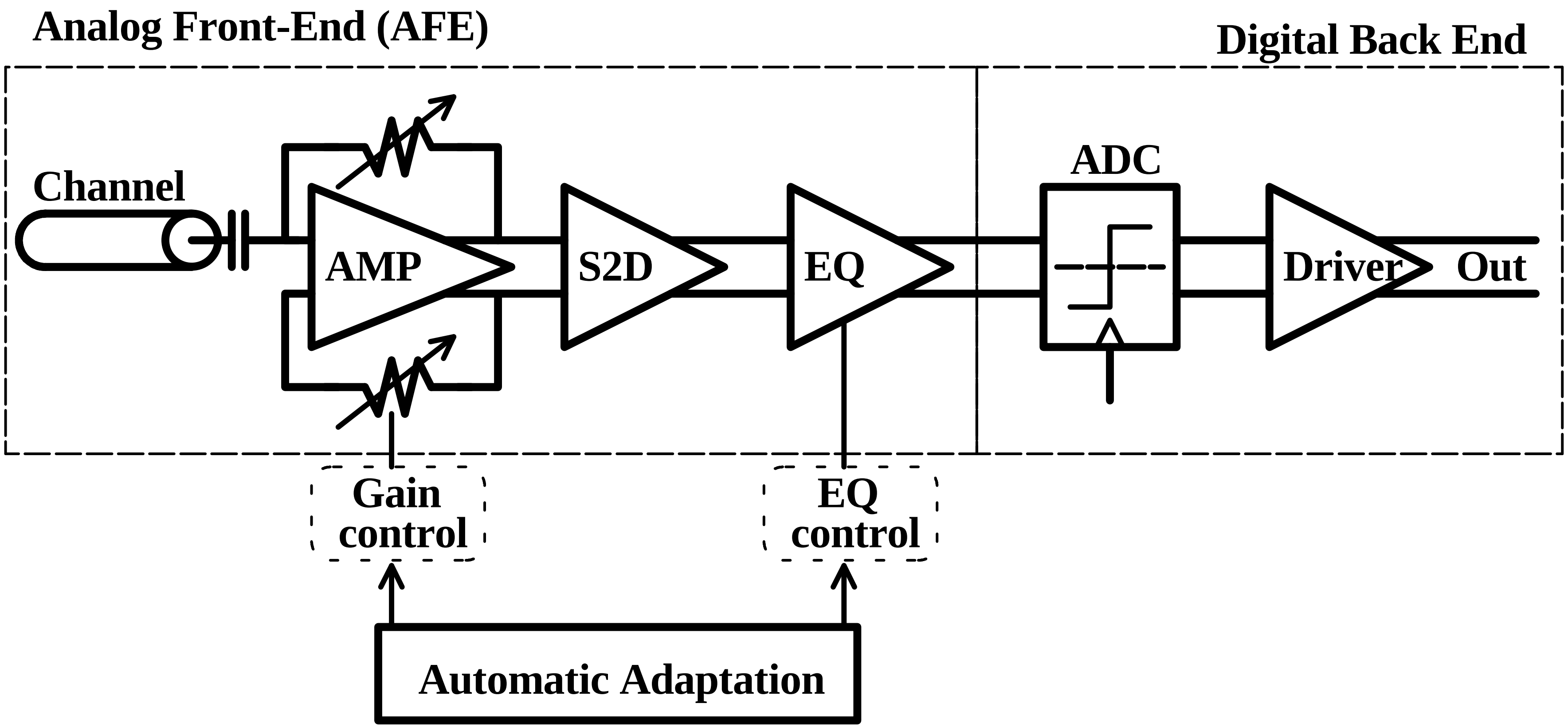
Analog Front End Adaptation



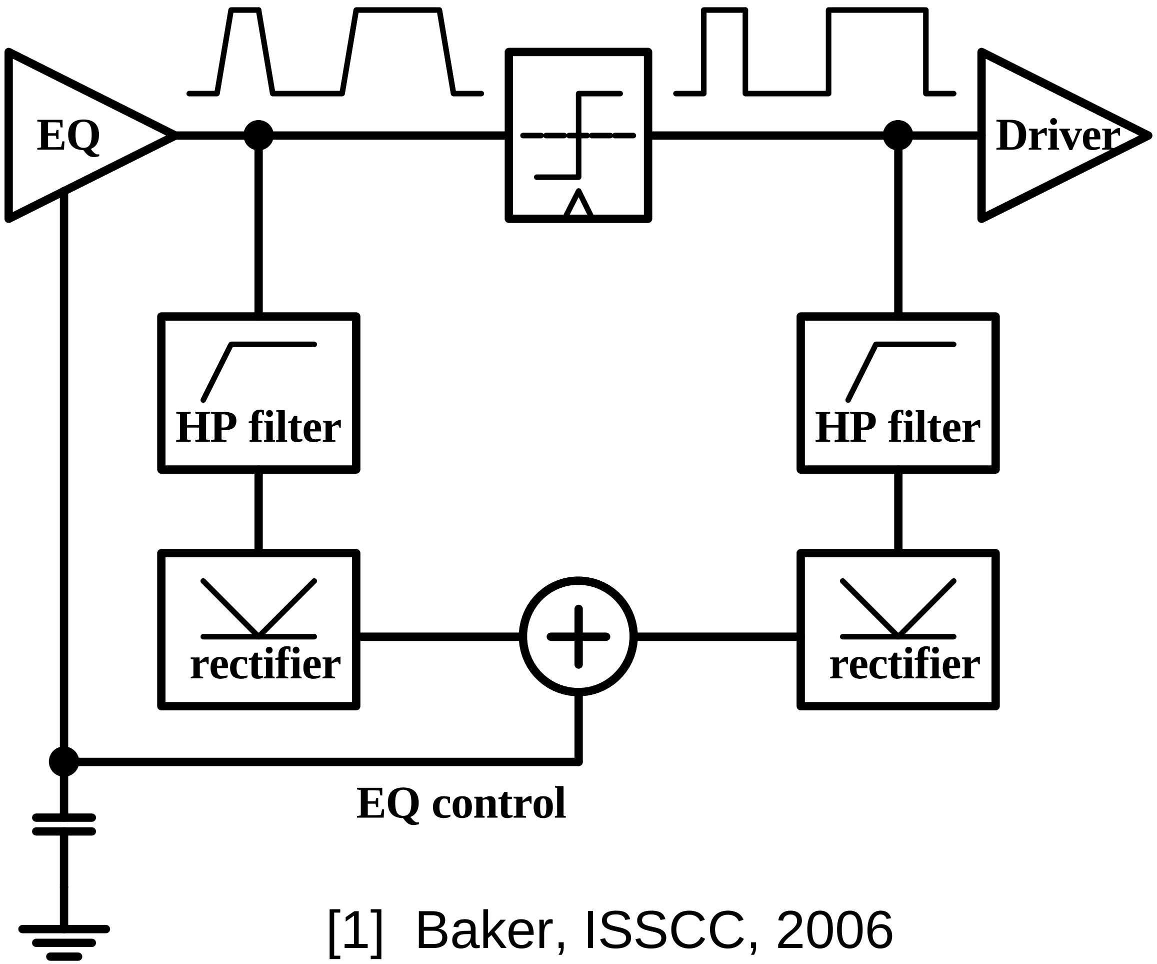
Control signals should be generated automatically and should be able to adapt to a variety of channel conditions

Outline

- **Adaptation: existing and proposed technique**
- **Theory and implementation**
- **Simulated and measured results demonstrate validity**

Analog Adaptation of EQ

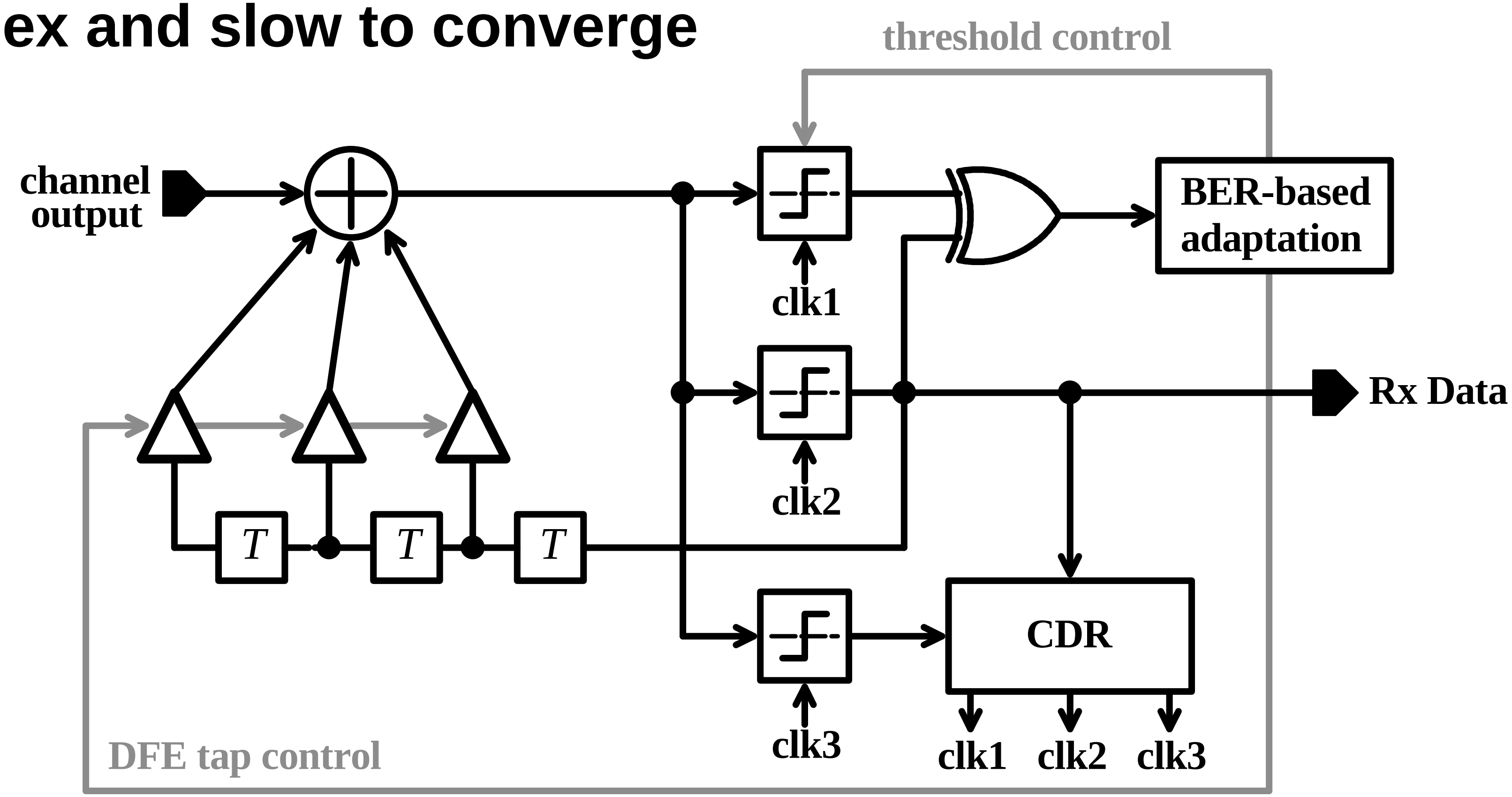
- **Filters consume large area**
- **Minimizing difference in high frequency content does not guarantee best equalization**



[1] Baker, ISSCC, 2006

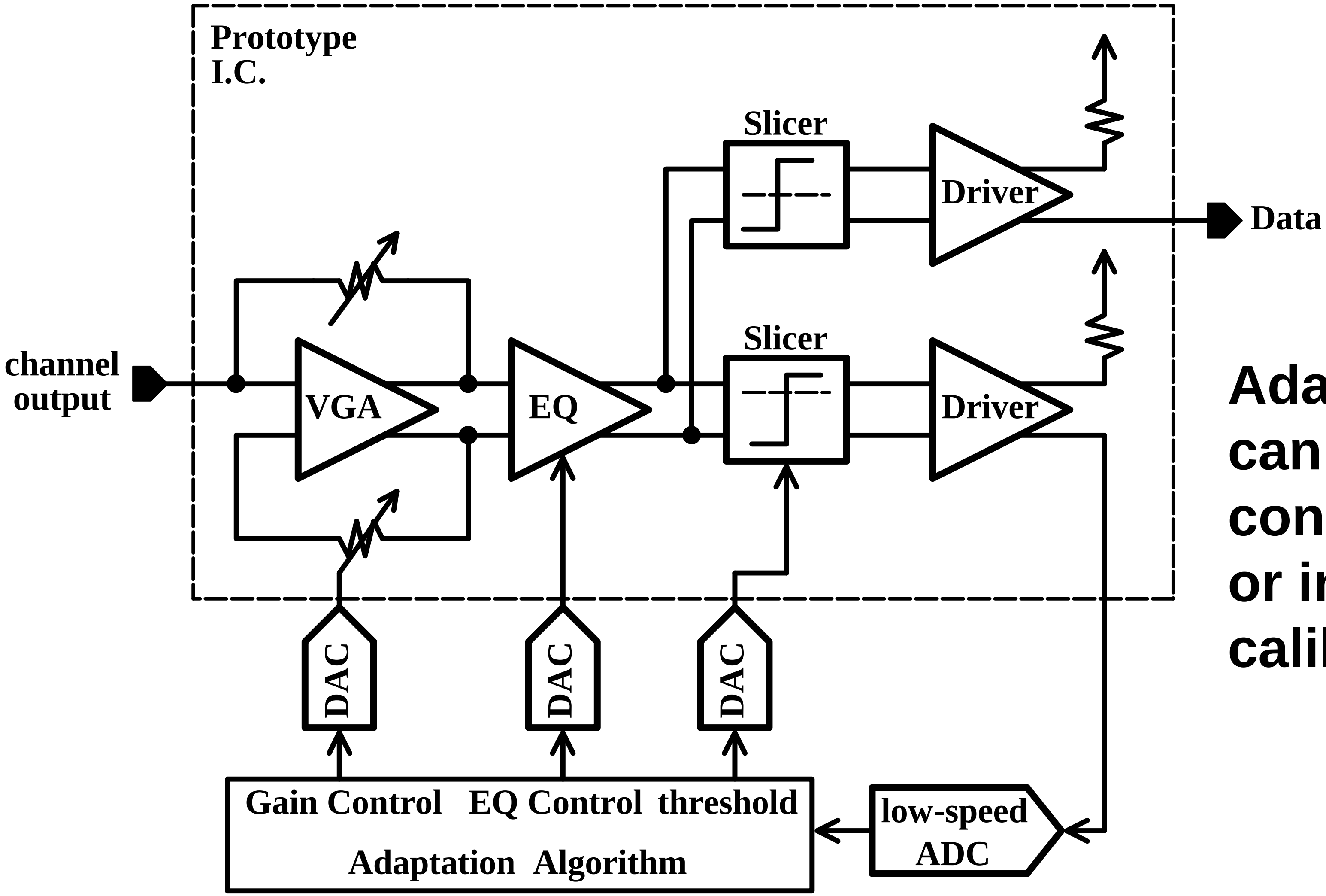
BER-Based Adaptation of EQ

Ensures optimal eye opening but very complex and slow to converge



[6] Chen, JSSC, 2008

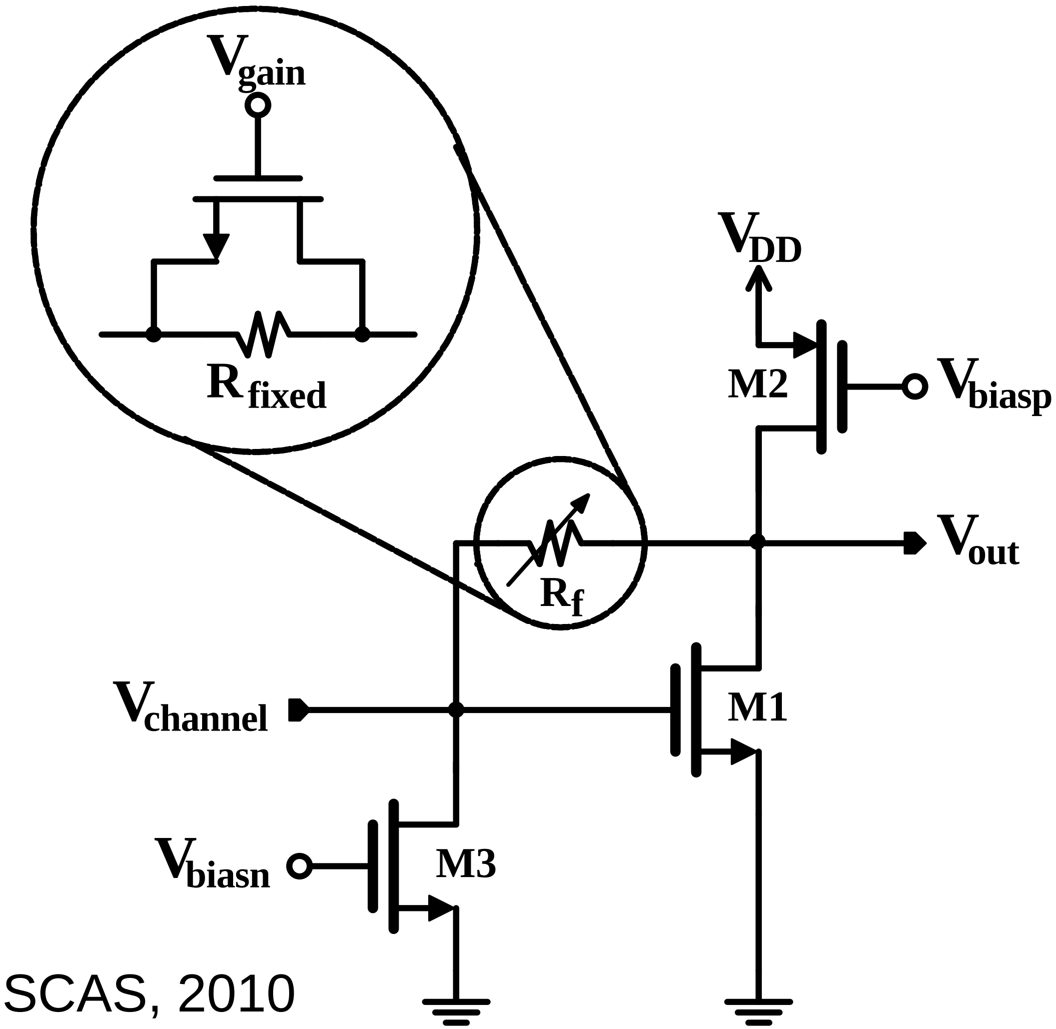
Proposed Architecture Test Setup



Adaptation can run continuously or in start-up calibration

Variable Gain Preamplifier

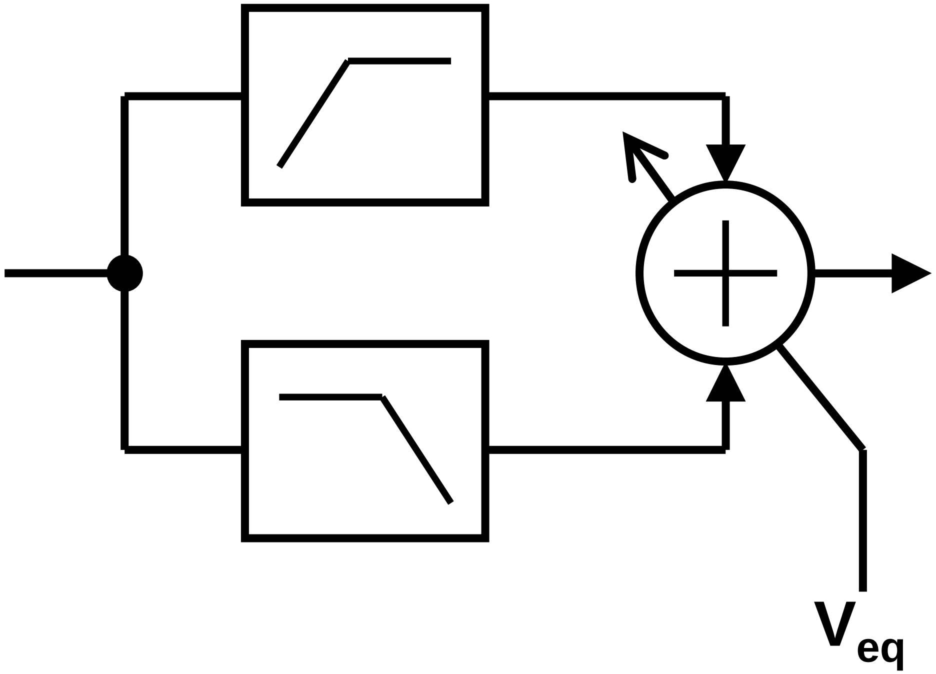
- Gain controlled by analog signal V_{gain}
- Increased V_{gain} results in decreased preamplifier gain



[11] Dunwell, ISCAS, 2010

Analog Split-Path Equalizer

- **High frequency peaking controlled by analog signal V_{eq}**
- **Increased V_{eq} results in decreased low frequency gain and increased high frequency peaking**



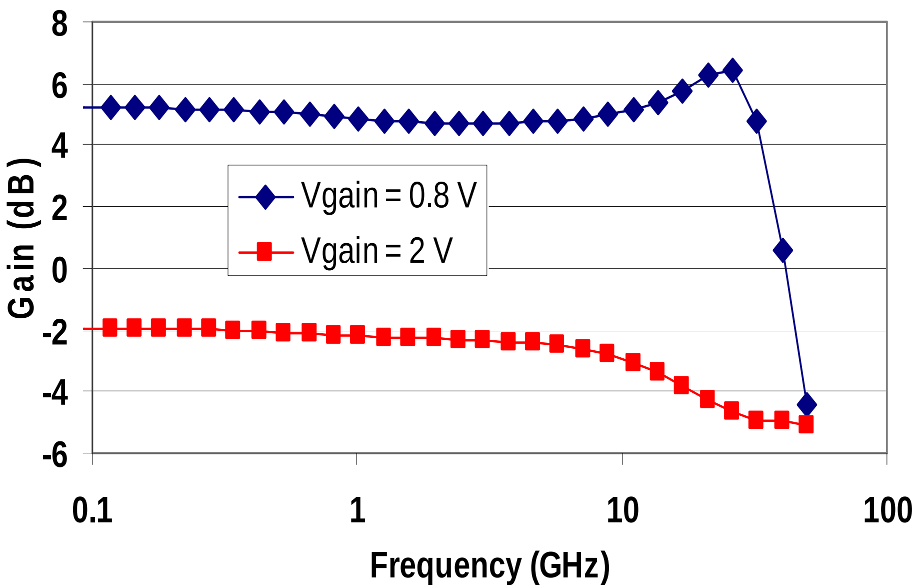
[10] Zhang, JSSC, 2005

EQ and VGA Simulation Results

Variable gain amplifier:

8 dB gain control

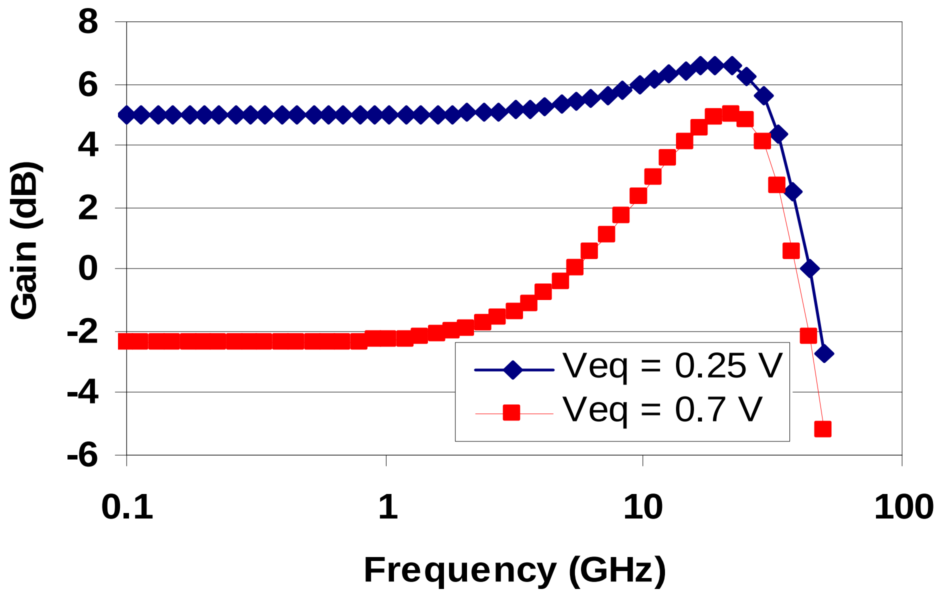
Flat BW from 0 to 10 GHz



Equalizer:

8 dB low freq gain control

high freq peaking



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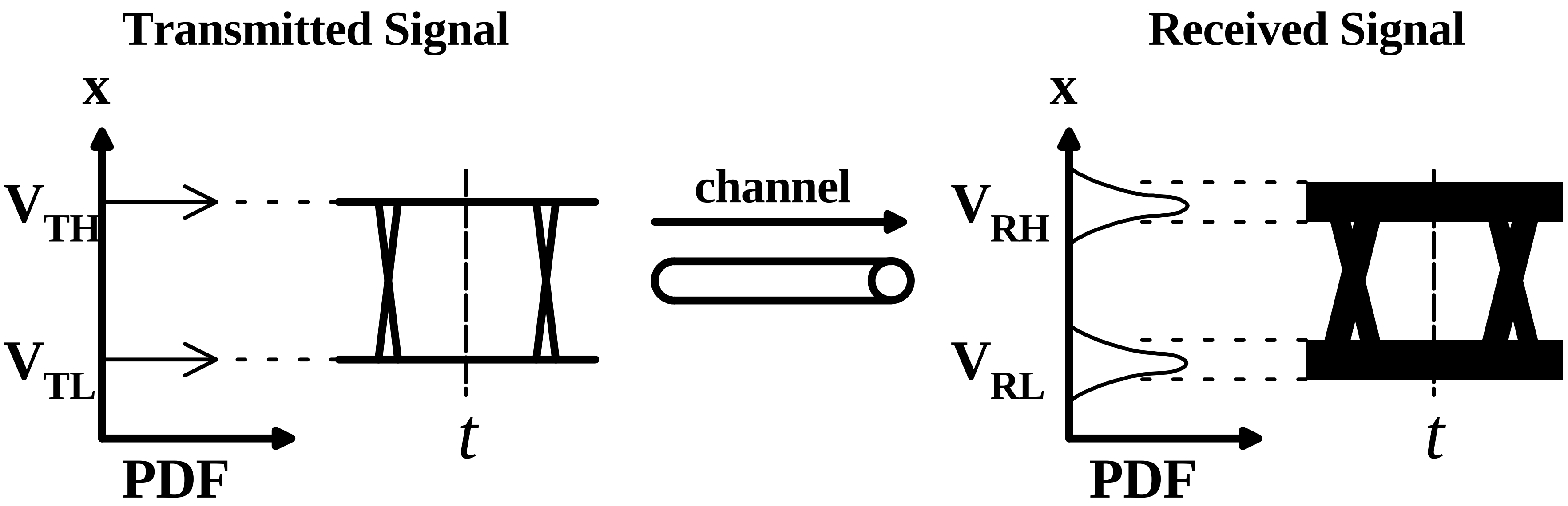
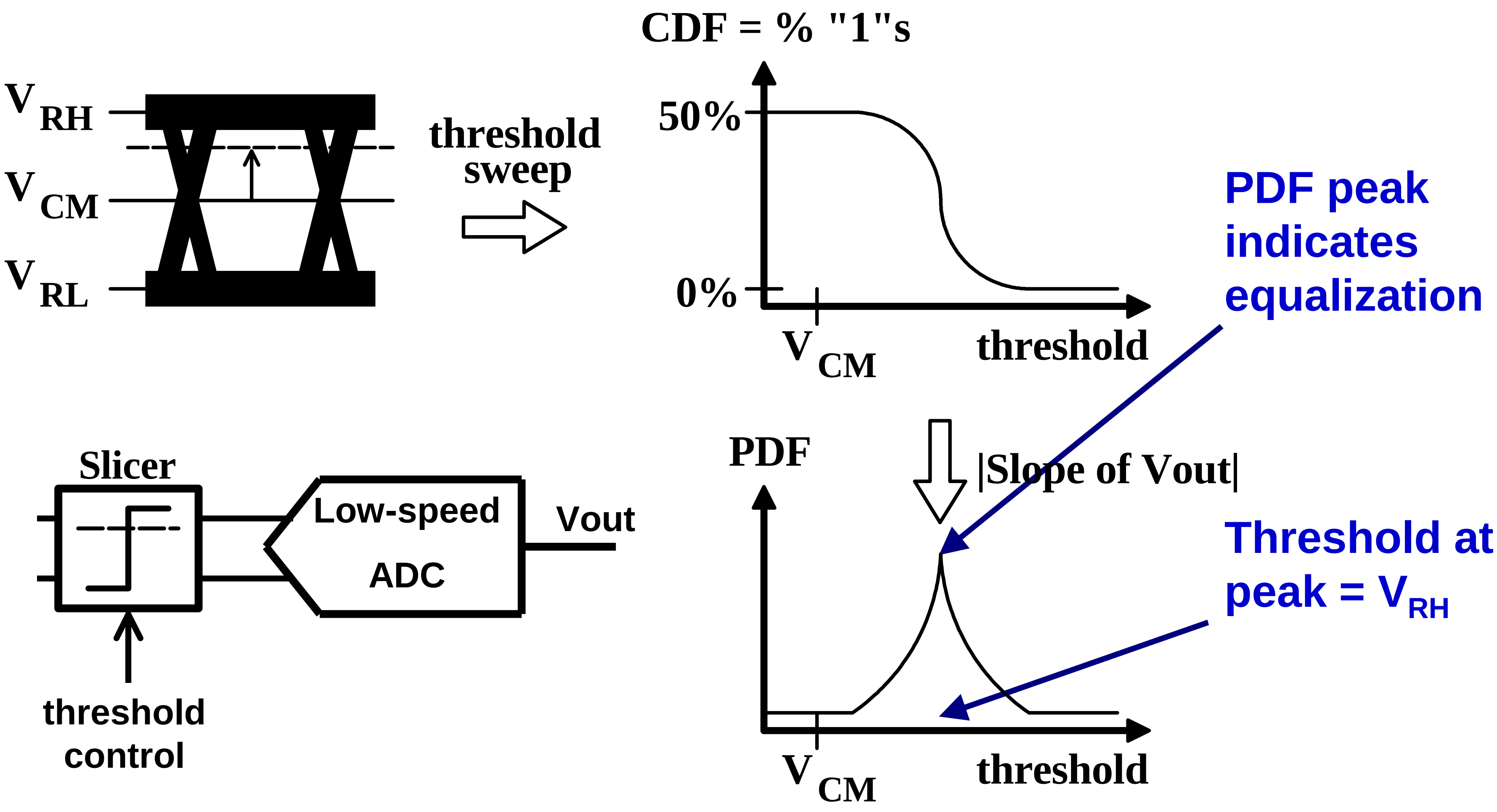
PDF Indicates Vertical Eye Quality



'x' is a random variable created by sampling the PRBS data at the midpoint of each bit

Threshold Sweep to Obtain PDF



Outline

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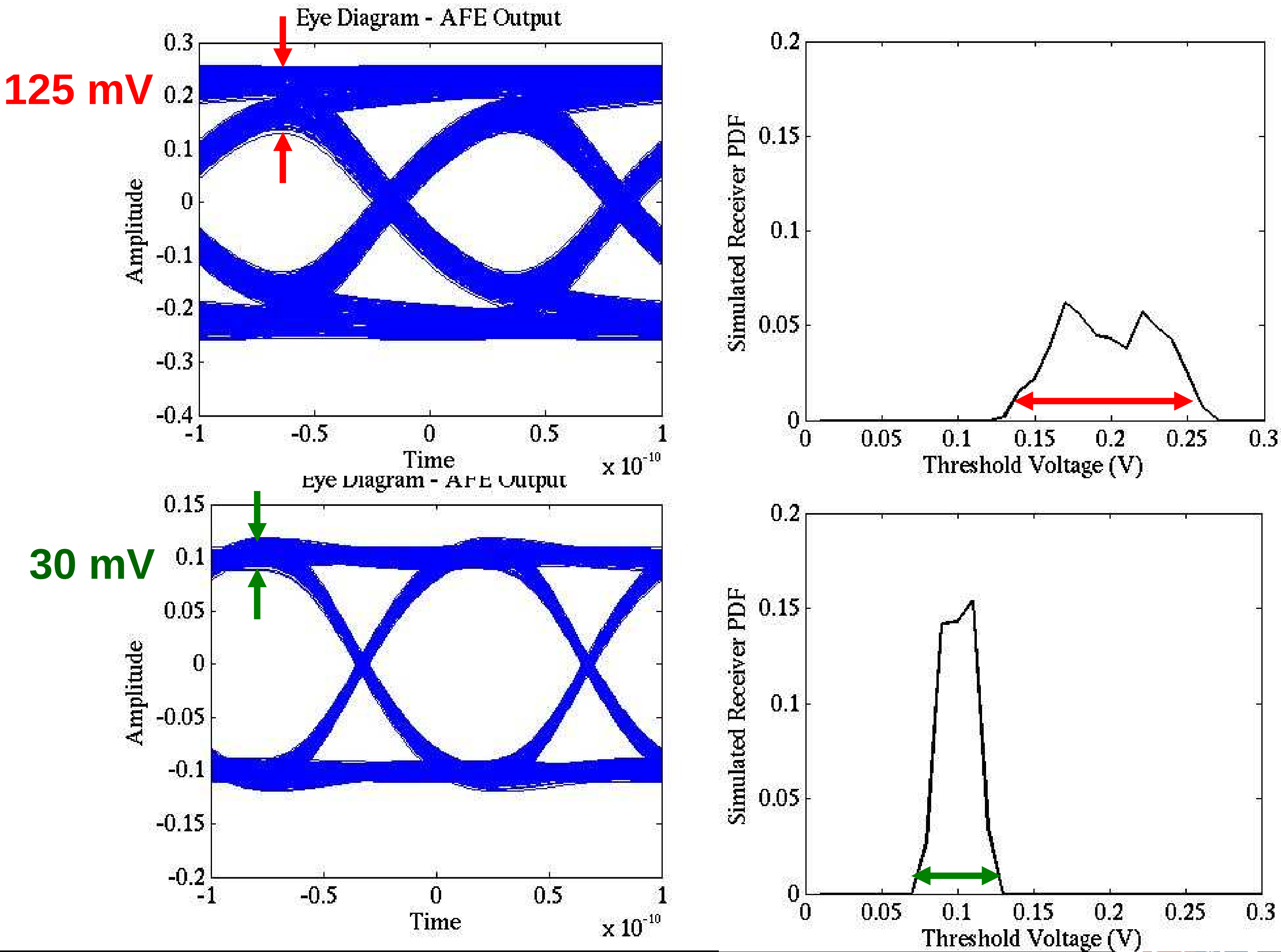
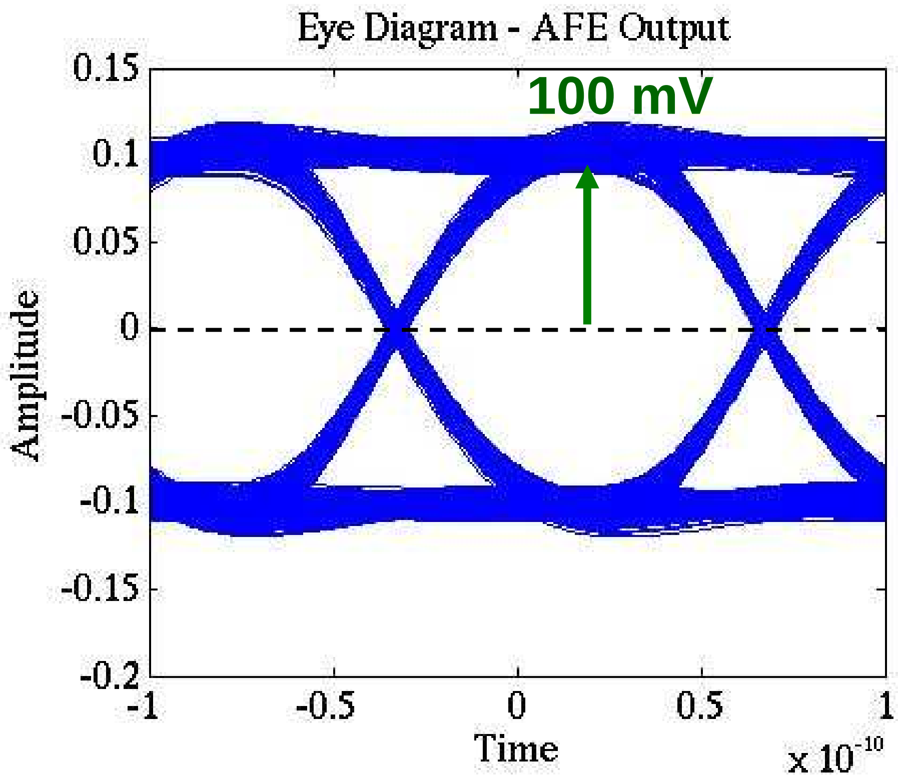
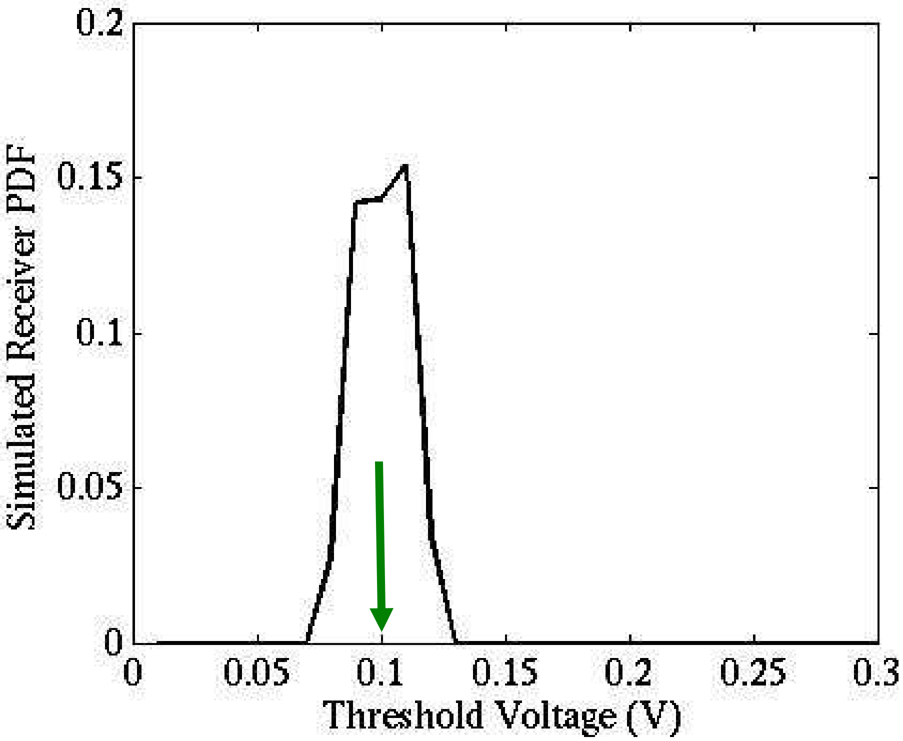
- **Simulated and measured results demonstrate validity**

Simulation Results – 10 m Cable



Simulation Results – Gain Setting

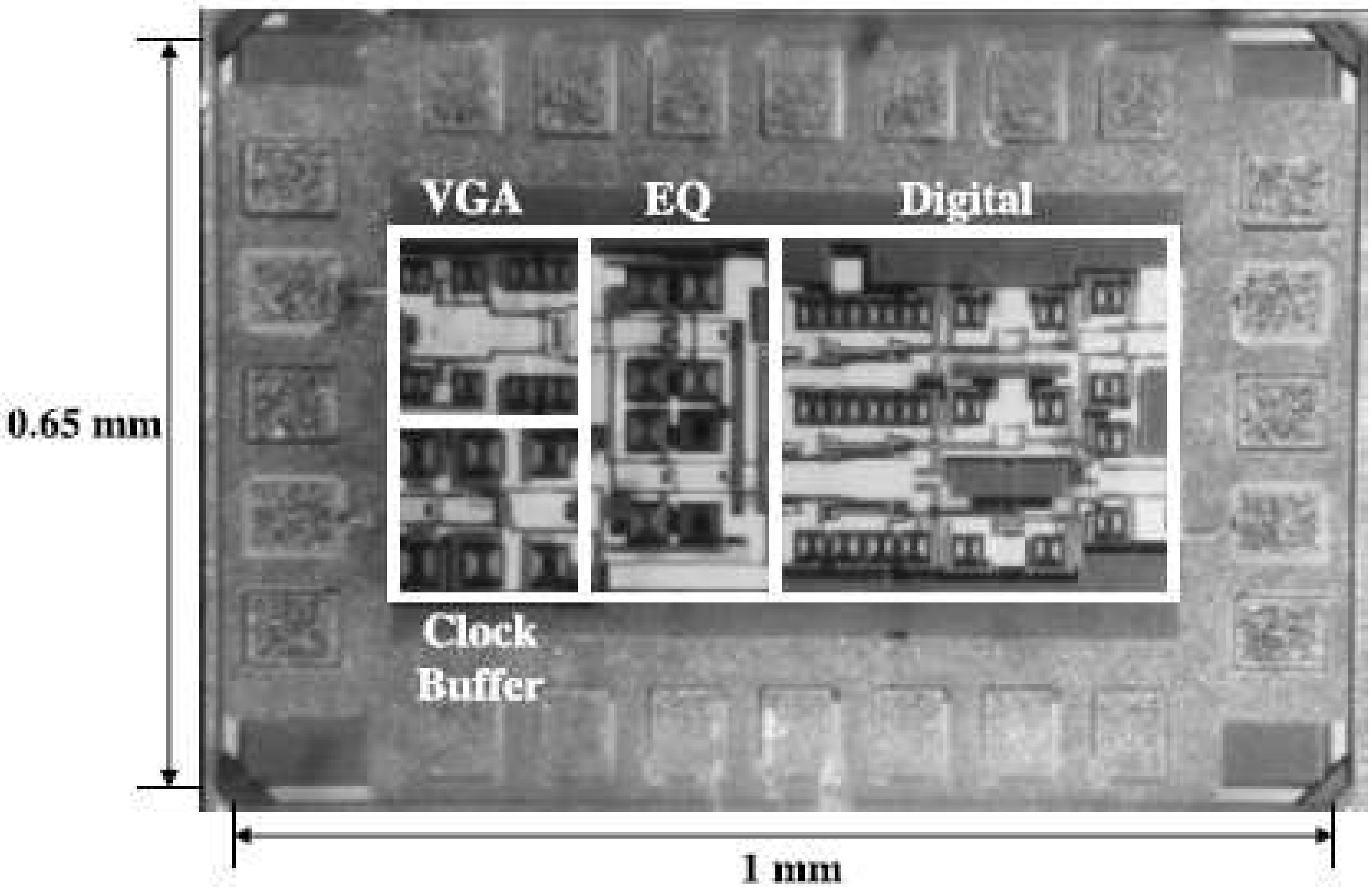




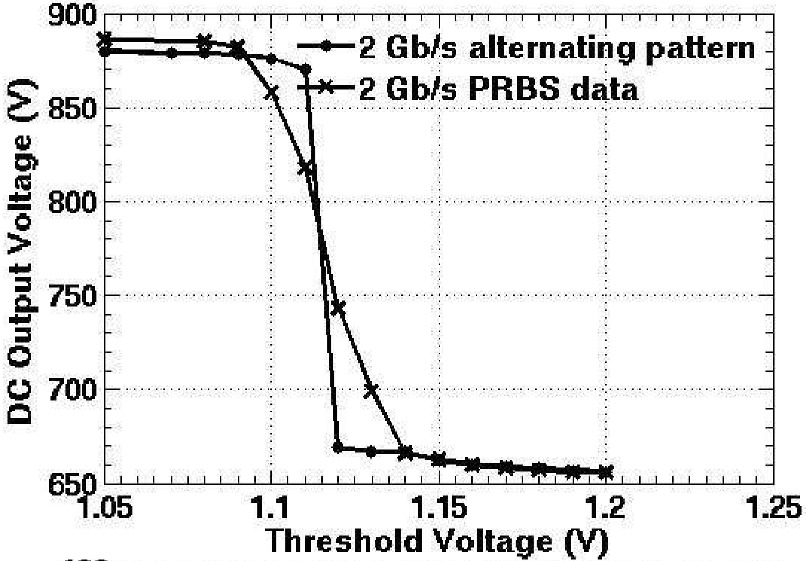
Prototype in 65-nm CMOS

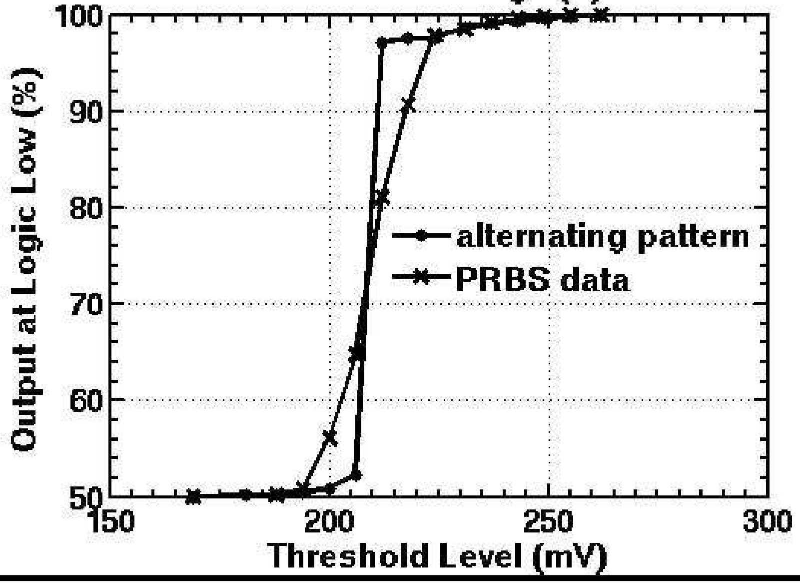
Vdd = 1.2 V

Adaptation performed off-chip with minimal additional hardware

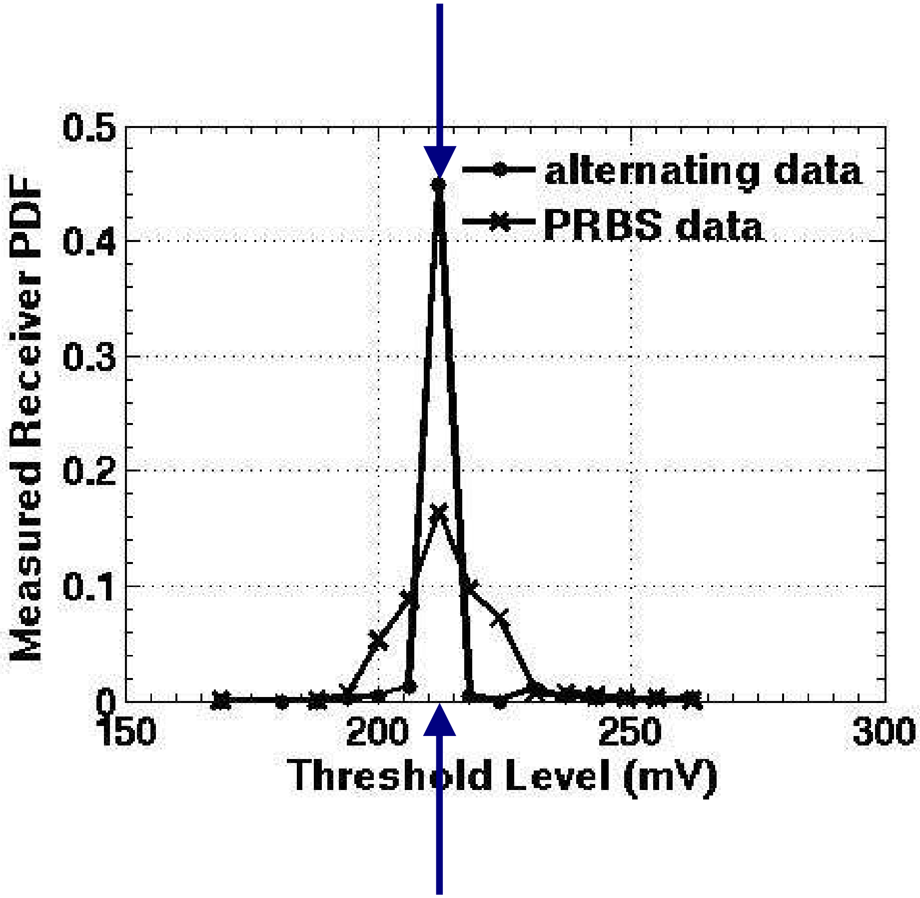


1010 Pattern vs PRBS Data (2 Gb/s)





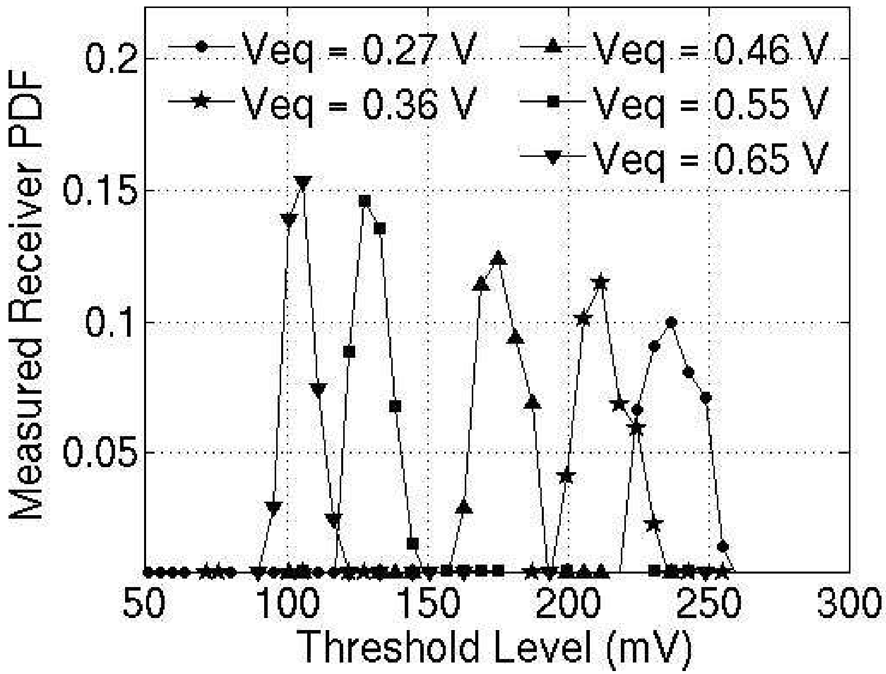
High peak = narrow PDF



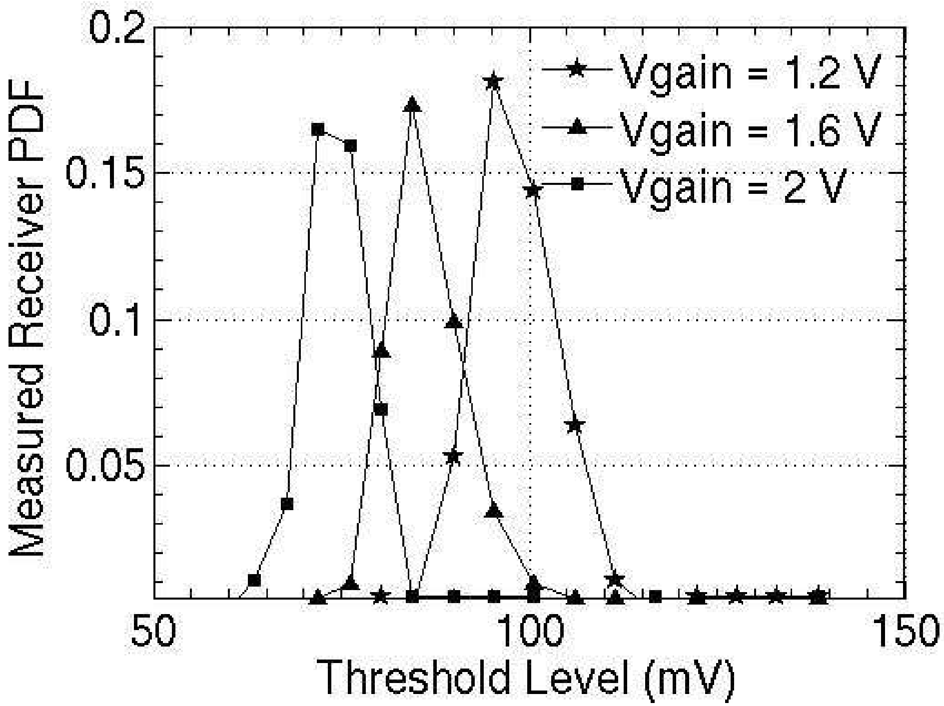
Threshold at peak = eye amplitude

Measured Results – 2Gb PRBS

Step 1: Sweep V_{eq} to find peak PDF



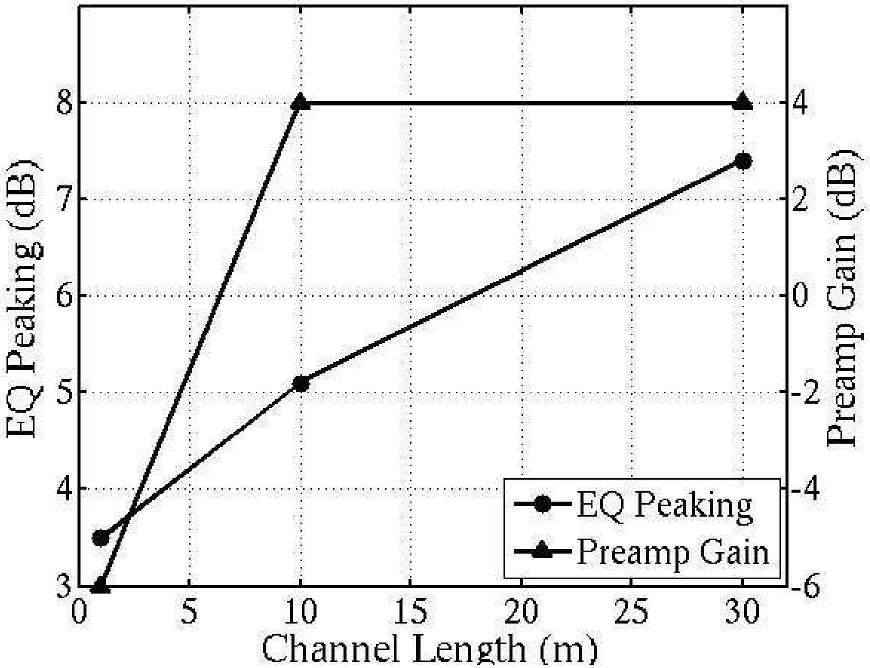
Step 2: Sweep V_{gain} to set amplitude



Varying Channel Conditions

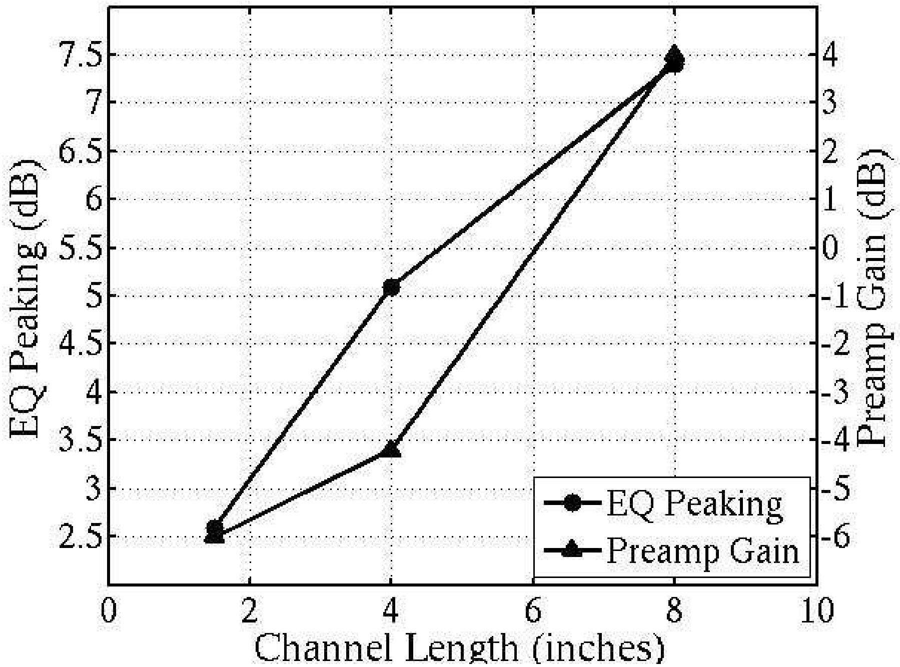
Coax Cable:

10 Gb/s (5 Gb/s for 30 m cable)



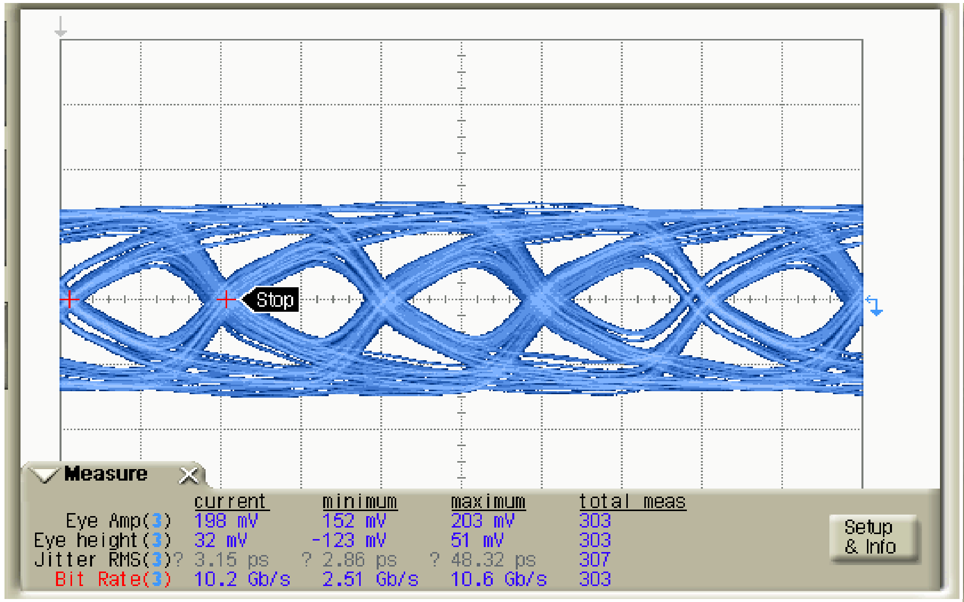
PCB Traces:

4 Gb/s for all lengths

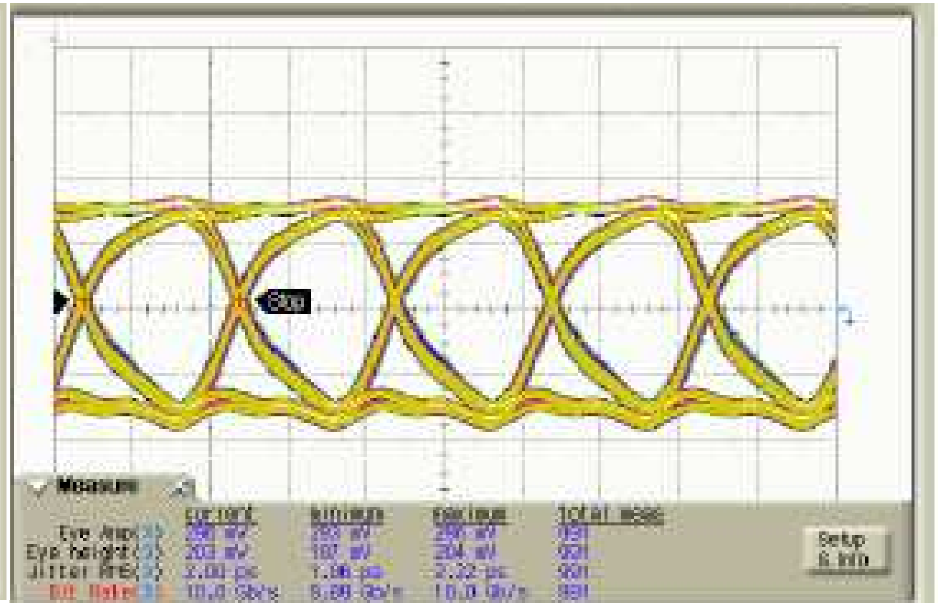


Eye Diagrams – 10 Gb/s

10 m coaxial cable channel output



Receiver output after adaptation



<u>Vertical:</u> 100 mV/div

<u>Horizontal:</u> 50 ps/div

Conclusions

- **Proposed adaptation technique :**
  - **Quickly optimizes vertical eye opening over a variety of channel types and lengths.**
  - **Optimizes equalizer peaking and preamplifier gain with a single set of data.**
  - **Can run continuously on parallel data line or at start up with minimal added circuitry.**

Thank You

Channel Loss