Equalizer Adaptation

- Many adaptive filtering algorithms
  - LMS, RLS, steepest descent, interior point method, ...
  - Each with different convergence properties

- Link channel changes relatively slow
  - Key is to minimize overhead from adaptation

- Simple adaptation schemes generally preferred
Simplified CTLE Adaptation

CTLE Adaptation Block Diagram
Adaptive FIR Filters: LMS

Practical Issues with LMS in Links

• How do you know what the error is relative to?
  • I.e., what is your reference?

• How precisely do you know the error?
  • I.e., how many bits of information does each sample of the error give you?
Finding the Error

- Error is relative to the “data level” (dLev):

- But, high resolution estimate of the error means high-resolution ADC…

Sign-Sign LMS
MMSE vs. ZFE

Finding dLev: Dual Loop
  • Stojanovic et al, JSSC 2005
**Eye Diagram Evolution**

![Eye Diagrams](image)

- Initial eye
- Mid-way equalized
- Equalized

**Dual Loop Convergence**

- Both loops are converge within wide range 0.1 – 10x of relative speeds
  - Hard to prove analytically
Practical Issues: Data Correlations

Spectrally Gated Adaptation

- Leibowitz et al, ISSCC 2007
Practical Issues: Dither/Resolution

- Can’t set tap values perfectly
  - Always have some residual quantization error

- Better include this error in link budget
  - Acts as quantization noise
  - Tap resolution must increase with # of taps
    - Noise accumulates

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Practical Issues: DFE Loop Unrolling