IEEE 802.3ap

Adaptive Tx Equalization

IEEE 802.3ap Task Force

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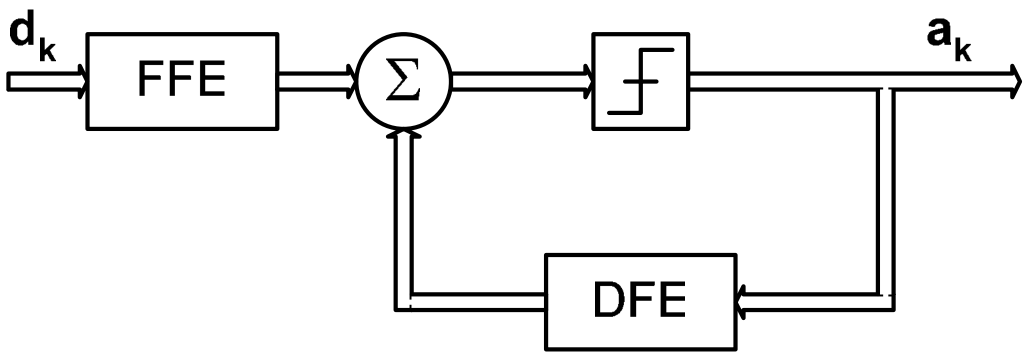
Channel Equalization

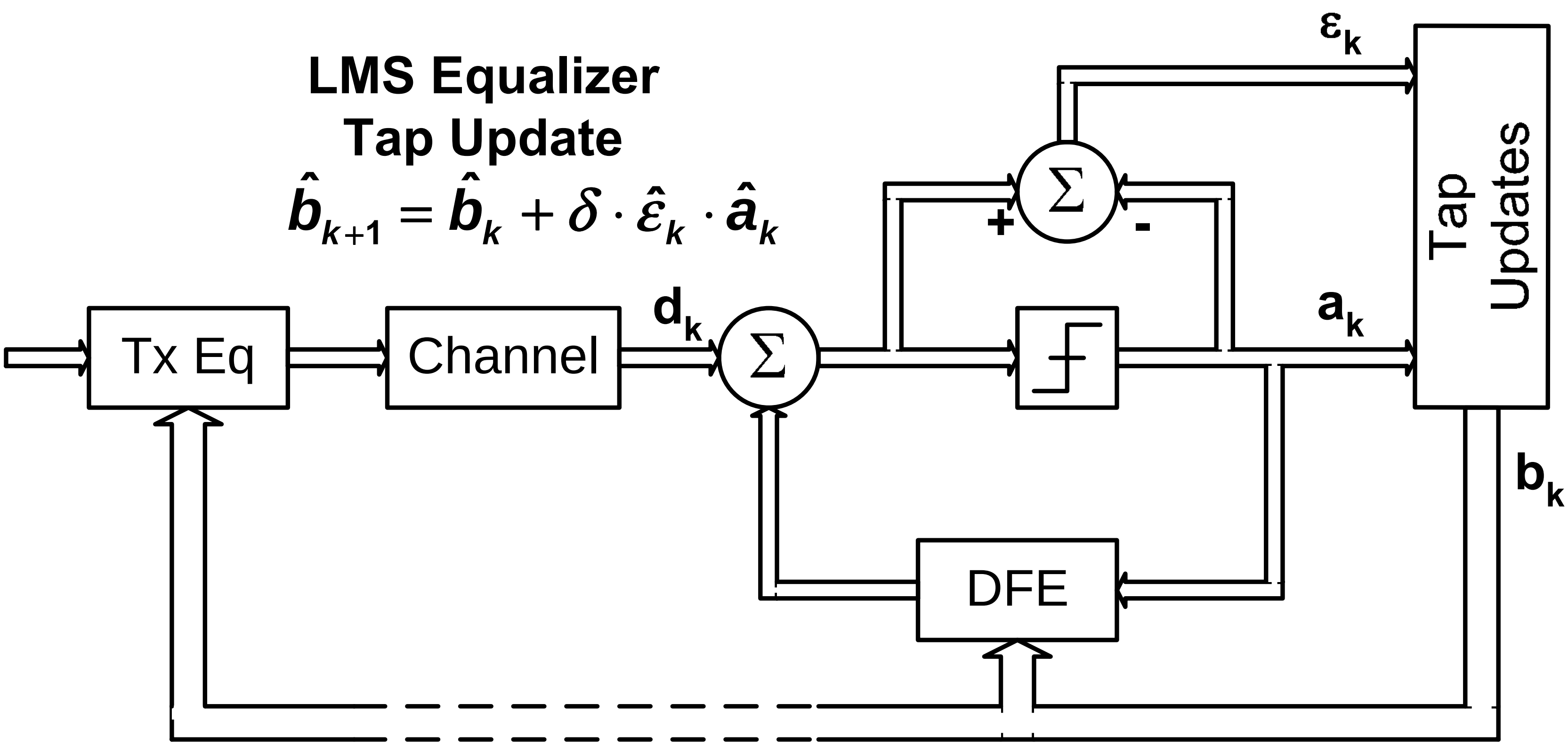
- Consider a general case Rx equalizer with FFE and DFE
  - Might also include linear equalization



- Structurally, an FFE requires multipliers & samplers
  - Variable gain amplifiers, linear samplers
  - DSP-based multipliers and A/Ds
- For some measures, optimal FFE placement is in Tx
  - lowest power, complexity, area
  - Best performance, not Φ-limited

Tx/Rx Equalization Block Diagram

- Combined equalization with FFE in Tx
- Assumed feedback path (back-channel) to Tx for adaption loop
- Rx controls all the updates



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Tx Equalizer Control Alternatives

- Tx Equalizer control can be either: fixed, adaptive, or a hybrid
- Fixed Tx equalizer
  - No back-channel needed
  - Limits channel application space
  - Increases equalization load on Rx
- Adaptive Tx Equalizer
  - Continuous adaption tracks environmental changes
  - Requires channel knowledge to set optimal equalization
  - Historically, MMSE or zero-forcing LMS adaption loops are used
  - Most adaptation loops are dependent upon a step-size (or loop gain) parameter (δ) for stability and adaption time trade-off
  - Loop stability can be delay-sensitive.
    - In BP apps, this is both routing- and slot-dependent, which are known a priori
  - 2nd order stability problems are possible – … Tx Eq change alters NEXT … causes next lane Tx Eq change … which alters NEXT, which …
- Hybrid Tx Equalizer
  - Change Tx Equalizer in slower blocks, alternating with Rx updates
    - Opens the control loop between Tx updates to reduce chance of noise-related interactions
  - Set Tx Equalizer during initial training only
    - Rx Eq must track environmental changes until next link reset
  - User programmability based on slot position

Adaptive Tx Equalizer Control

- Tx equalizer control & structure affects interoperability
  - Launch signal must be part of the PHY spec
  - Rx can only control what it knows exists
- This is independent of line code selection
  - Affects all coding schemes equally
- A multi-tap adaptive FFE complicates the Tx spec
  - What do we measure? Eye height? T_{RF}? Programmability? INL/DNL?
- What does the Rx need to know about the Tx?
  - Equalizer structure – linear vs. sampled

  Assuming sampled …
  - Number of pre- and post-cursor taps (i.e. main tap position)
  - Range of each tap value relative to the main tap - ex. ±80% or -20~+40%
  - Nominal tap accuracy (each tap)– ex. 6 bits
  - Settling time for tap changes
- What does the Rx need to know about the channel?
  - Gross delay
    - Loop stability
    - Possibly adapt thresholds after tap adjustment – peak power optimization
- What does the Tx Eq need to know?
  - Initial condition
  - Is an Rx device present to control it?

Summary

- Control requirements for channel equalizer are not clear
- May have far-ranging system issues
  - Tx compliance testing
  - Startup conditions
  - Adaption algorithm may need to be considered as part of signaling
  - Standardized Tx details may need to be communicated to Rx
- If adaptive Tx equalization control is required, we need to define access to a back-channel
  - Out of band signaling - MDIO, I2C, unused lane, etc.
  - In-band signaling - FLPs, k-codes, etc.
- If adaptive Tx equalizer control is not possible, then bounding cases become even more important to prove operation