Thoughts about adaptive transmitter FFE for 802.3ck Chip-to-Module

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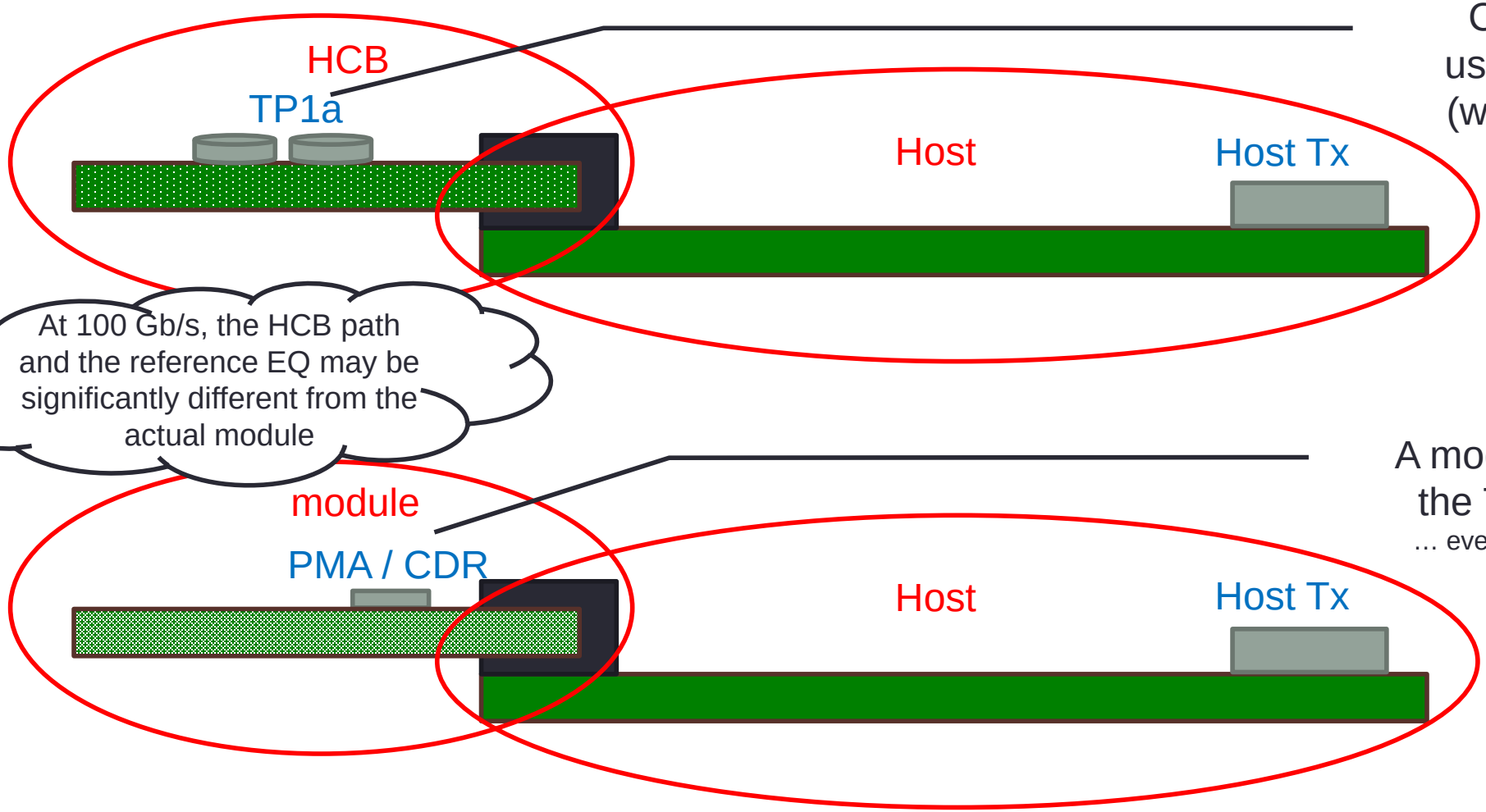
Introduction

- Using a long transmitter FFE has been suggested as a way to reduce module SERDES complexity
  - See sun_100GEL_01b_0118, sun_3ck_01a_0518, healey_3ck_01b_0718
- The performance of a long transmitter FFE is comparable to that of a similar FFE in the receiver.
  - The differences will not be analyzed in this presentation.
- The power/area costs of a long transmitter FFE are lower than that of a similar FFE in the receiver.
  - This will not be analyzed in this presentation.
- We assume that a pluggable, interoperable interface must have adaptive equalization. Adaptation can only be controlled by the receiver.
  - If the equalizer is located in the transmitter, and is adapted by the receiver, some concepts have to be changed.
  - This aspect is the focus of the presentation.

Existing C2M host output paradigm



Compliance is measured using “eye” metrics at TP1a (with a reference equalizer)

A module is expected to work with the TP1a-compliant host output

… even though the actual end-to-end channel is different

The module can’t control the Tx equalization

Adaptive Tx equalization - paradigm change

- The “open eye” should be at the module CDR decision point
  - The module can tune the Tx equalization to a setting that achieves that
- With the chosen setting, at a specific HCB test point, the “eye” will not be optimized (and may not be open at all)
  - So we should not measure compliance this way
- What else can we do?

Adaptive Tx equalization - paradigm change

- Alternative specification methods exist in the “CR” PMD family
  - Linear fit pulse for qualifying linear parameters (bandwidth, equalization…)
  - Noise, linearity
  - Jitter measured on specific edges (to exclude DDJ)
- CR electrical specs are measured at TP2 (equivalent of TP1a in HCB)
- Measurable with any equalization setting
  - Actual equalization range and step sizes are also specified and may be tested
  - The burden of verifying this increases with the number of taps and resolution of the coefficients

Host Tx adaptation – what would it take?

- The module is responsible for getting the Tx to an adequate setting to meet its BER target
- We need a control channel
  - Initial training pattern+protocol as in KR/CR?
  - Management controlled using registers as in existing AUI-C2C?
  - … maybe some blend of these two or something else
- The module has to generate the requests and handle the responses
  - Some state diagrams (or equivalent descriptions) should be specified
- The module has to indicate that it is ready to receive real data from the host
  - Link up delay
- If we assume the Rx has CTLE-only equalization capability, the Tx FFE has to be longer and with fine steps
  - The required FFE resolution will likely be finer than 2.5% steps (maximum step size for c(-2) in clause 136)
  - Training a longer FFE is likely to have a timeout longer than 3 seconds (allocated for 4-tap FFE training in clause 136)

FFE adaptation

- Equalizer adaptation, especially for a long FFE, requires non-trivial design for setting the individual taps based on the signal seen by the Rx
- Moving the equalizer from the Rx to the Tx does not reduce the complexity required to for adaptation
- Extra burden is added for communicating requests and responses between Rx and Tx, instead of applying changes internally in the Rx
- We should consider continuous adaptation (after link start-up) which was not assumed in the past for Tx equalizers.
  - Some continuous Tx FFE adaptation may be needed for other architectures as well.

How to test a module?

- With the current paradigm, the module is tested with a signal that has specified “eye” parameters.
- This doesn’t work anymore if the module is responsible for setting the Tx equalization.
- The test pattern generator has to have the equalization capabilities required from a host Tx
  - And a control method that the module can use.
- Again, similar methods exist in the existing CR/KR specs.
- Test equipment availability may be a concern we need to address.
  - Note that testing a module assuming only Rx equalization has other complexities; for example, the reference receiver has to be implemented in the scope.

Interoperability and system implications

- If a startup protocol is used, both sides need to implement training patterns and logic as in the KR/CR world.
  - Link can then be established with minimal management intervention.
  - Only works at link up time. What if changes are required later?
- Alternatively – management registers approach
  - Every coefficient update has to go through management registers reads and writes (see example in **83D.5**)
  - With long and fine-grained FFE, expect lots of steps at link-up…
  - But this can also work after a link is established.
- A new arena for interoperability challenges and testing…

Summary

- Assuming accurate equalization is performed by the host Tx (and module Rx has only a CTLE) enables some power saving in the module, but requires several changes from past assumptions.
  - Host Tx specs based on CR methods instead of eye measurement.
  - The module Rx controls the equalization through a control channel, and is responsible for finding a sufficiently good setting.
  - Module Rx testing will require a more capable pattern generator and a different test procedure.
  - Increased management activity may be needed for link-up.
  - New interoperability challenges.
- All these changes have to be supported by definitions and requirements in the standard.
- Note: assuming long FFE in the Rx would also require some changes from past assumptions.