Thoughts on TQM Definition and Characterization Requirements for Coherent Short Reach Links

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7/8/2024

Agenda

- We discuss our perspective on:
  - Transmitter Quality Metric (TQM) definition
  - A possible approach for TQM spec derivation
  - Requirements imposed on reference receiver
  - Requirements imposed on characterization setup

Transmitter Quality Metric (TQM): Definition

- TQM is required to achieve two main goals for interoperability
  - evaluate and compare the quality of transmitters
  - as a transmitter spec to qualify a given transmitter
- Transmitter Quality Metric can be defined as
  - $TQM = 10 * \log_{10}\left(\frac{RSNR_{ideal}}{EquivalentSNR_{Tx}}\right)$, to achieve a given RSNR penalty at the de-mapper due to non-ideal transmitter at a certain Pre-FEC BER (preferably at FEC limit) assuming interleaver fully Guassianizes the noise seen by the FEC.
- TQM should consider end-of-life performance guarantee
  - Thus, the measurement with reference receiver and characterization setup at the beginning-of-life should have adequate margin to specification, to guarantee end-of-life performance with acceptable FIT (failure in time) rate

Transmitter Quality Metric (TQM): Approach to Spec Derivation

- Approach to spec derivation with example
  - Let's say we would like 80% of noise/impairment contribution to come from channel, this translates to ~1 dB penalty compared to ideal RSNR
  - This means 20% of noise can come from Tx/Rx non-idealities, this translates for e.g. to 20 dB modem SNR to achieve RSNR let's say of 13 dB for DP-16QAM
  - Assuming equal contribution, 0.5 dB penalty (10%) comes from Tx and 0.5 dB penalty (10%) from Rx non-idealities
    - » Any other Tx to Rx contribution ratio can also be considered, without implication on idea
  - TQM spec in this case can be defined as max -10 dB ($\frac{RSNR_{Ideal}}{EquivalentSNR_{Tx}}$ or $\frac{\sigma_{Tx}^2}{\sigma_{Ideal}^2}$), given a Rx with spec level impairments like linewidth, jitter etc.
    - » This includes margin for all penalties due to non-ideal transmitter,
    - » Transmitter designer can this way, trade off Tx characteristics like noise, linewidth, non-linearities, jitter to ensure TQM does not exceed this spec.
    - » TQM can also be represented as RSNR penalty margined for Tx non-idealities $\frac{\sigma_{Ideal}^2-\sigma_{Tx}^2}{\sigma_{Ideal}^2}$, both are equivalent representations
  - 1 dB RSNR penalty assumed so far translating to 20 dB modem SNR would be an aggressive target (not limited to low cost & short reach application)
    - » 3 dB reduction in modem SNR target of 17 dB modem target (i.e. 40% of noise coming from Tx/Rx non-idealities) or -7 dB TQM metric looks more reasonable to meet expected receiver sensitivity specs

Reference Receiver Requirements

- System/DSP penalties for LW, jitter increase non-linearly with effective impairments from Tx and Rx
  - For e.g., if Tx has y MHz linewidth, the penalty is let's say x dB, but if we have a receiver also with y MHz of linewidth, the penalty is > 2x dB, this penalty delta from additive penalty approximation (2x in this case) increase with combined impairment for Tx and Rx
- Reliable TQM measurement impose a requirement on the reference receiver to have spec level impairments to ensure NO artificial gain in TQM is measured/reported which would potentially be lost when pairing with spec level receiver due to penalties scaling because of combined impairments
- Receiver impairments, like jitter & linewidth can be emulated on the digital reference receiver with a prescribed mask defined by MSA requirements with high-quality analog front end.

Characterization Setup Requirements

- Ideally, TQM should be measured with spec level channel impairments like SOP, DGD, PDL etc. to guarantee TQM is not optimistic in considering penalties from linear impairments coming from Tx side
  - System penalties for linear impairments also increase non-linearly with total received linear impairments (from Tx and Channel) like linewidth and jitter penalties discussed in previous slide.
  - CD, SOP, DGD can be emulated digitally, but emulating PDL digitally has draw backs
    - PDL in passive links corresponds to worst case PDL scenario as the noise seen by PDL affected signal is basically receiver front end noise
    - Therefore, digitally emulated PDL would see only digitally added noise and not the actual front-end noise and this can cause potential error in TQM estimates depending on reference receiver front end noise magnitude compared to digitally added noise.
- This can be achieved by considering a setup with SOP, DGD and PDL emulators to add spec level impairments
- Alternatively, simplification, like implications of using back-to-back TQM evaluation can be evaluated (requires further consideration & analysis on budgeting)

Thank You!