Another look at COM termination parameters and Tx/Rx return loss specifications

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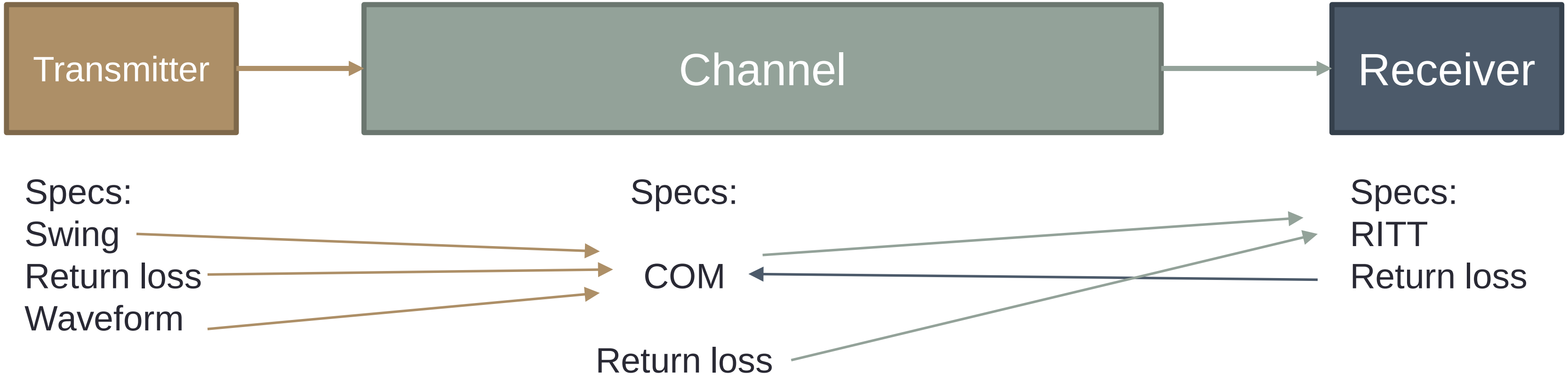
Scope

- This presentation results from several comments and presentations around COM and return loss.
- I’m trying to think out of the box ➔ possibly big changes
- We are converging in WG ballot, so may not want big changes at this point
- There is no new data in this presentation – only ideas
- This may just be an opening of a discussion, without changing anything now
  - Although there is comment #18 in case we agree on something…
  - I would welcome follow-up by other people

background

1



2

Maximum power transfer theorem (Jacobi's law)

"to obtain maximum external power from a source with a finite internal resistance, the resistance of the load must equal the resistance of the source" (source: Wikipedia)

But there are other criteria…

Reflection-free matching: $Z_{load} = Z_{source}$

Maximum power transfer matching with reactive circuits: $Z_{load} = Z^{*}_{source}$

Maximum voltage drop on the load: $|Z_{load}| \gg |Z_{source}|$

Channel perspective

- Our reference differential impedance is 100 Ω
  - (“shall” in 136.11.1, also COM parameter R_0 is 50 Ω, and all precedence)
- We specify the channel using COM which assumes specific terminations of the transmitter and the receiver.
- Is 100 Ω always the best impedance?
  - A channel which is very close to 100 Ω may cause reflections and degrade system BER with Tx/Rx that are not 100 Ω (this can sometimes be seen in COM).
  - A channel that matches the actual impedance of the non-100 Ω Tx and Rx may have bad return loss, but improved system BER (this can be seen in COM too).
- Practical systems sometimes use other impedances
  - Intel “recommends” 85 Ω ±15% for PCIe/HDMI/DVI/DP; USB type C is specified as 85 Ω ±10%
  - Lower impedance reduces insertion loss and may improve matching with some connectors…

Transmitter perspective

- Reference differential impedance is 100 Ω (120D.3.1.1, and all precedence)
- A transmitter that deviates from 100 Ω may show bad return loss.
  - It may also have degraded pulse shape results when measured with a 50 Ω scope termination.
- A transmitter which is very close to 100 Ω may cause reflections with a channel that is not 100 Ω, which may degrading system BER.
- A transmitter that matches the actual impedance of the channel may have bad return loss, but actually lower reflections, and improve system BER.
- Transmitter termination may be configurable!
  - This may also affect voltage swing on a given load (depending on transmitter design)
  - There may be a tradeoff between signal amplitude, crosstalk, and reflections
  - There are practical cases where one setting is used for meeting RL specs, and another setting is used for optimizing BER on a given channel
  - We ignore that in all our standards – both Tx specs and channel specs.

Receiver perspective

- Return loss specs for Rx are a matter of continuous debate
  - BER is the objective; it is measured in RITT; why should we care about RL?
  - … because the channels are specified with some assumptions on the Rx.
  - If a system (combination of Tx+channel+Rx) works as expected, we shouldn't care about RL; but if a system fails, the Rx RL might be the culprit.
- Rx matched to the channel would reduce reflections
  - But the Rx typically includes active circuits – it does not use only the power delivered from the channel
  - This is quite different from optical or RF systems where power really matters
- Impedance matched Rx may or may not be the best thing
  - Higher Rx termination may provide higher input voltage
  - Tradeoffs with reflections are possible here too
  - Rx termination may be configurable too
  - We ignore that too…

…and other assorted problems

- RL is specified as a per-frequency mask; failing the mask at some frequencies may be insignificant
- RL is specified in the frequency domain by magnitude only; but we use baseband signaling and phase *is* significant
- Some reflection effects can be mitigated by equalization, like the kind we assume (CTLE and short DFE)
- So should we care at all?

Can we stop specifying (or relax) RL?

- This author's opinion is: no
  - For compliance, there should be one reference and limits to how much you can deviate – otherwise, there is no interoperability
  - The methods may change from what we have today (e.g. we may adopt ERL)
- But we may acknowledge that actual systems may deviate from 100 Ω
  - Copper cable is part of a pluggable/interoperable ecosystem; moving it to another impedance is a longshot
  - But backplanes and AUI-C2C are engineered interconnects
- We may explicitly allow a device that is compliant at 100 Ω to be configured to another impedance if it improves BER in a certain system
  - E.g. using MDIO registers
  - Compliance at another impedance setting can be checked using renormalization
  - This may improve design flexibility

Proposals for the near term

- For backplane (and possibly AUI-C2C)
  - Specify COM with nominal Rd=50Ω (or another single value if there is consensus)
    - This may improve results
  - Quantify the possible COM degradation with combinations of other Rd values that still enable meeting the Tx/Rx RL specs (whichever way they are expressed)
    - My estimate based on prior presentations: 0.5 dB. More analysis may be done with increased coverage.
  - Increase min COM from 3 dB by the degradation we find, to account for allowed mismatches.
  - Add an informative note that engineered systems may be designed with differential impedance different than 100 Ω; in such systems, COM termination parameters should be modified and RL measurements should be renormalized.
- For cable assembly
  - Specify COM with nominal Rd=50Ω and Zc=100Ω for the host PCBs (or another single value for each, if there is consensus)
  - Use similar quantification of degradation (default: 1 dB) and increase minimum COM accordingly
  - No informative note here

Future ideas

- Standardize configurable terminations for performance optimization
  - MDIO registers, set during training, compliance methods

QUESTIONS/COMMENTS?

Thank you