Return Loss Simulation and Evaluation

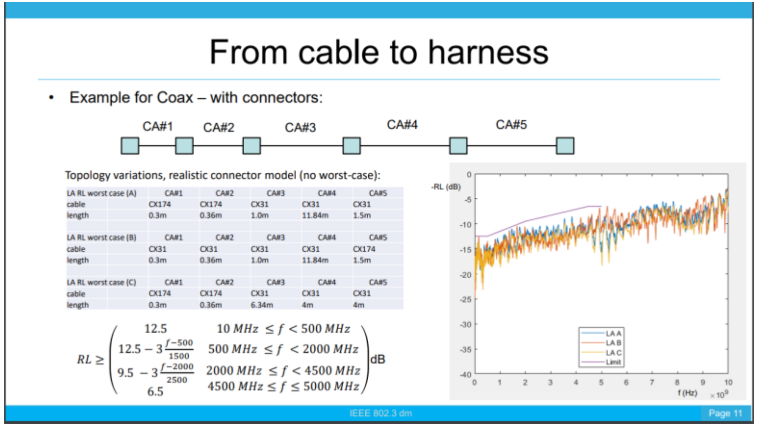
Contribution to 802.3dm Task Force channel ad hoc

August 28, 2024

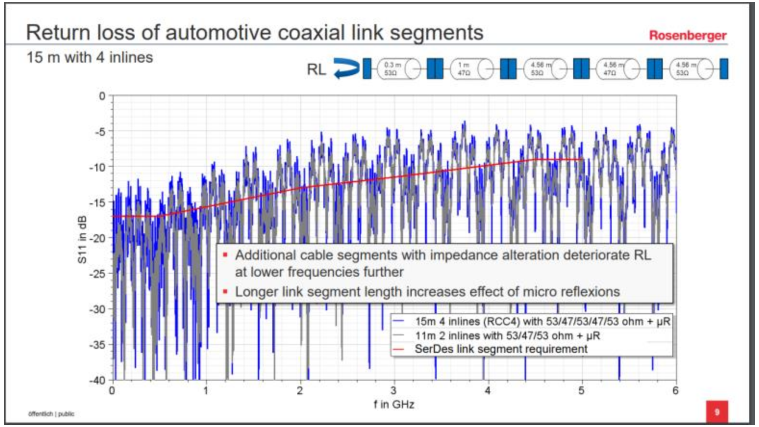
Ragnar Jonsson - Marvell

Introduction

- In the 802.3dm meeting in Montreal in July 2024 there were two presentations suggesting that the return loss on coax cables will be significantly higher than previously thought
- In this presentation we look at the implications of accepting this high echo, with emphasis on secondary reflections and equalizer design
- The presentation will also look at what may cause such high echo levels



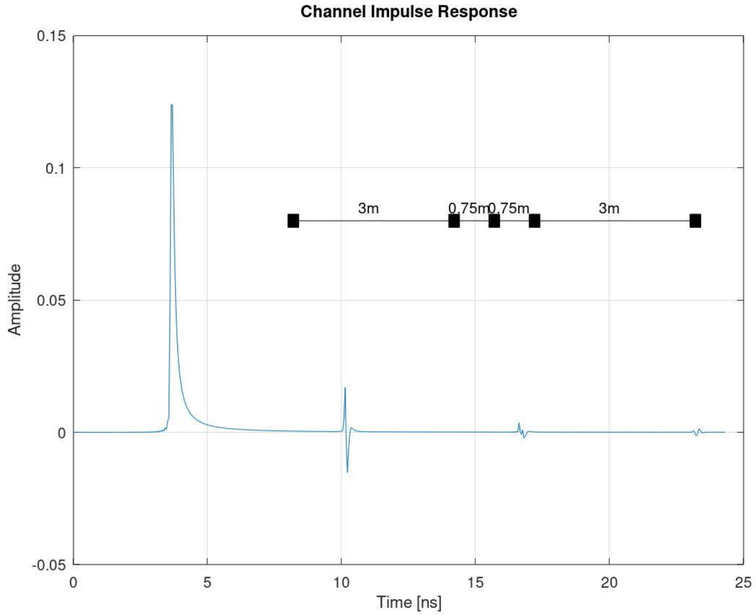
From https://www.ieee802.org/3/dm/public/0724/Zerna_802.3dm_01b_240717_IL_RL_Limits.pdf



From https://www.ieee802.org/3/dm/public/0724/mueller_3dm_01a_07_01_24.pdf

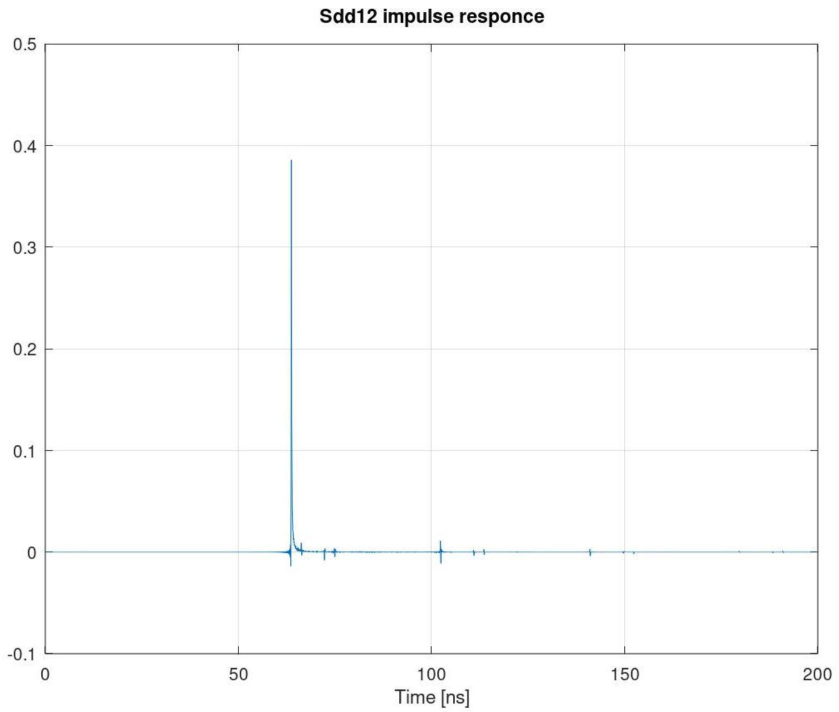
Reflections in the Transmit Path

- The plot to the right shows the impulse response for the channel Insertion Loss
- Because of impedance mismatch at the inline connectors there will be reflections that will go back and forth (secondary reflections)
- These reflections can show up as smaller delayed pulses in the channel impulse response and make it harder to equalize the received signal



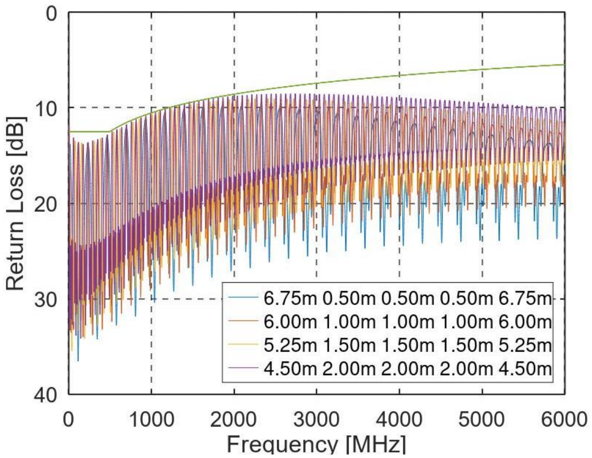
Secondary Reflections

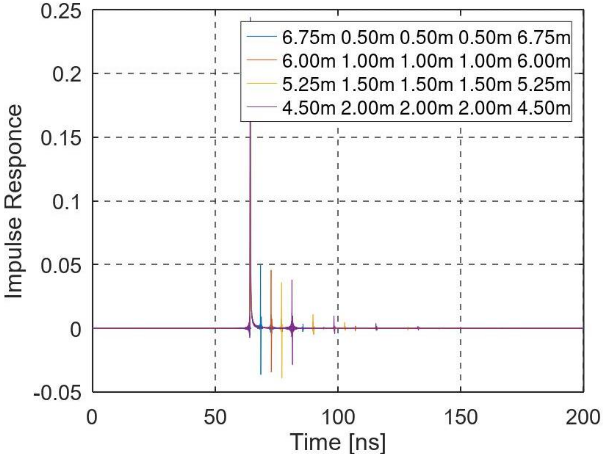
- The presentation by Thomas Müller, Stephan Kunz and Philipp Grimm in the July 2024 meeting mueller_3dm_01a_07_01_24.pdf had very high echo levels
- The plot on the right shows the impulse response for a channel that is very similar to the 15m channel that was shown in that presentation
- The secondary reflections are clearly visible in the plot
- These reflections will degrade receiver performance, especially at high data rates



Secondary Reflections

- The plots on the right show the simulated return loss and channel impulse response for some channels with secondary reflections
- The return loss plot also shows the limit from mueller_3dm_01a_07_01_24.pdf
- The simulation assumed very bad connectors, but such connectors would be allowed if the return loss limit is too loose
- Notice how significant the secondary reflections are and that they change with channel topology





Secondary reflections can be significant and will depend on cable topology

Unpredictability of Secondary Reflections

- PHY designers must make the PHYs sufficiently robust to handle any channel conditions that are within the required specifications of the channel
- This means that any robust PHY design will consider multitude of possible corner cases, out of all the possible channel responses
- The insertion loss and the return loss play a key role in limiting the variability in the channel conditions
- If the return loss limit is relaxed too much, the secondary reflections will be much more varied and harder to predict
- This will result in either increased complexity of the PHY design, or less robust performance

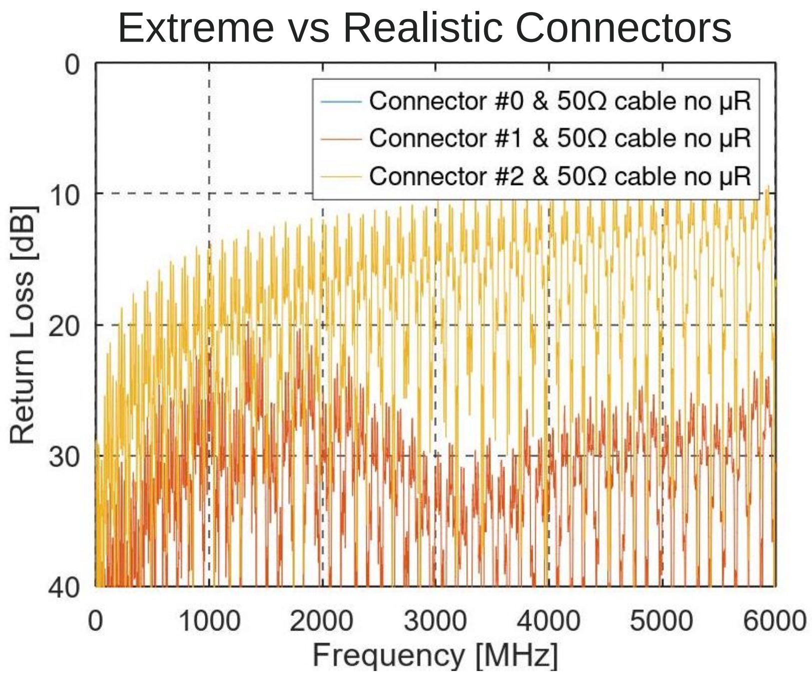
Return loss limits that are too relaxed may drive up relative cost of 802.3dm PHYs

Where Does Echo Come From?

- There are four primary sources of echo on the channel:
  - Reflections from inline connectors, due to impedance mismatch
  - Reflections from mismatched impedance on the cable
  - Reflections from the MDI interfaces, due to impedance mismatch
  - Micro-Reflections from minor impedance mismatches along the length of the cable
- The first two are usually the biggest sources of secondary reflections, but reflections from the MDI can be considerable factor on short cables

Good vs Bad Connectors

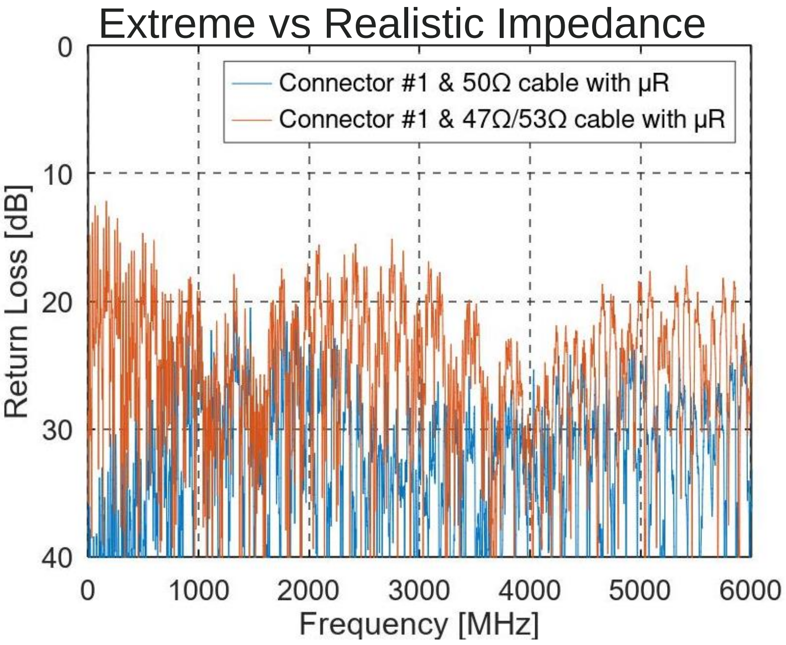
- The analysis in mueller_3dm_01a_07_01_24.pdf focused on very bad connectors that almost violated the worst-case return loss specified in USCAR49
- Real connectors from quality manufacturers are typically much better than the worst-case return loss allowed by USCAR49
- The plot on the right compares the return loss for a 15m cable with four inline connectors, when the connectors are of different quality
  - Connector #0 is ideal connector
  - Connector #1 is real connector
  - Connector #2 is worst case connector emulating the return loss limit from 2022-05 version of USCAR49
- The cable construction is the same as the 15m cable in mueller_3dm_01a_07_01_24.pdf, except that all the cables are 50Ohm in this simulation



There is a big difference in the RL of the real connector and the simulated worst case

Cable Impedance Mismatch

- The analysis in mueller_3dm_01a_07_01_24.pdf assumed maximum cable impedance mismatch in some of the simulations
- The cable impedance would alternate between 47Ohm and 53Ohm, from one cable segment to the next, which is the absolute maximum allowed impedance variation
- The plot on the right shows the impact of these extreme impedance fluctuations, compared to constant 50Ohm impedance across all cables
- The plot shows that the extreme fluctuations will increase the echo by few dB
- At lower frequencies the echo increases even more

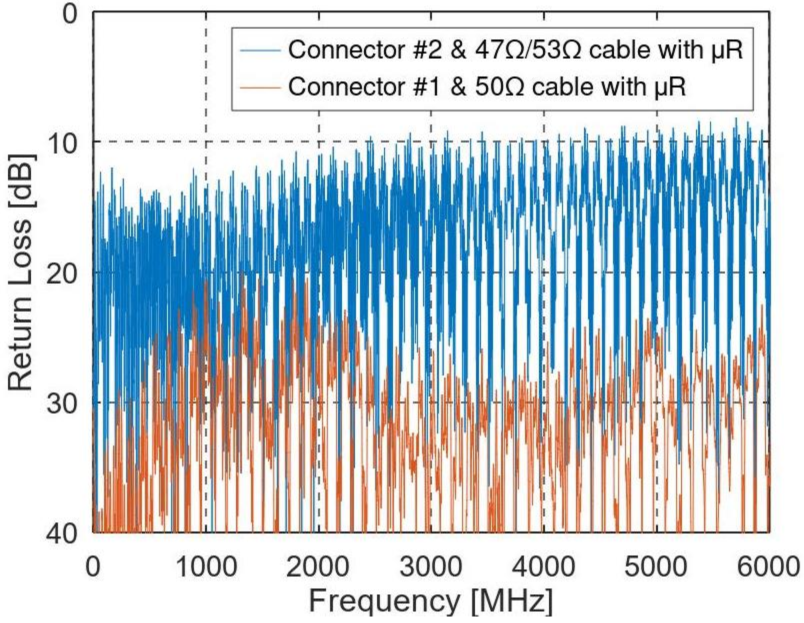


The extreme cable impedance mismatch will increase the echo by few dB

Extreme Echo vs Reality

- The analysis in [mueller_3dm_01a_07_01_24.pdf] assumed worst case connectors and maximum cable impedance mismatch, resulting in unexpectedly high echo
- In reality, not every one of the four inline connector will be the absolutely worst allowed connector
- In reality, real connectors are much better than the worst-case connectors
- In reality, cables will rarely be assembled from alternating segments with extreme impedance mismatches
- In reality, cables have much better impedance tolerances than the extreme limits

Extreme vs Realistic Return Loss



The cable limits should be based on realistic assumptions with reasonable margins

Summary

- The worst-case return loss discussed in two presentations in the July meeting are too pessimistic
- Too relaxed return loss limit can result in secondary reflections in the channel insertion loss impulse response
- Too relaxed return loss limit will make it harder to optimize the equalizer design, and may drive up the relative cost of the PHY
- Too relaxed or too tight limits on cables can undermine the competitiveness of 802.3dm PHYs in the market
- The insertion loss and return loss limits should be based on realistic assumptions with reasonable margins

The cable limits should be based on realistic assumptions with reasonable margins

MARVELL™

Essential technology, done right™