Analysis of Return Loss Limits

Contribution to 802.3dm Task Force

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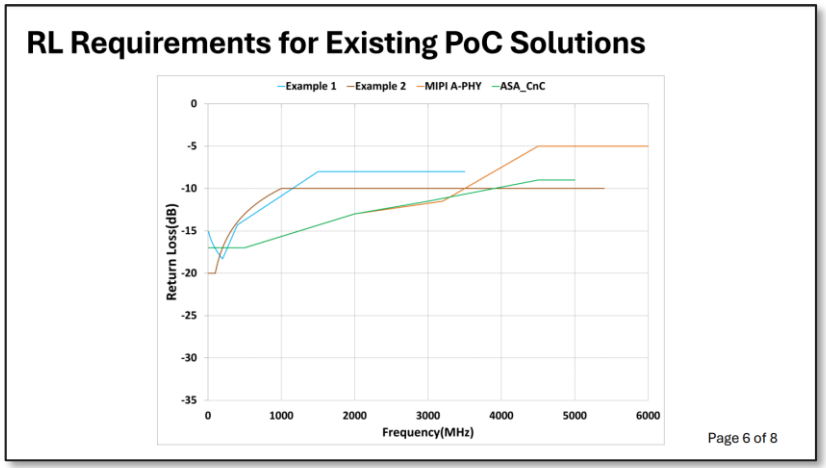
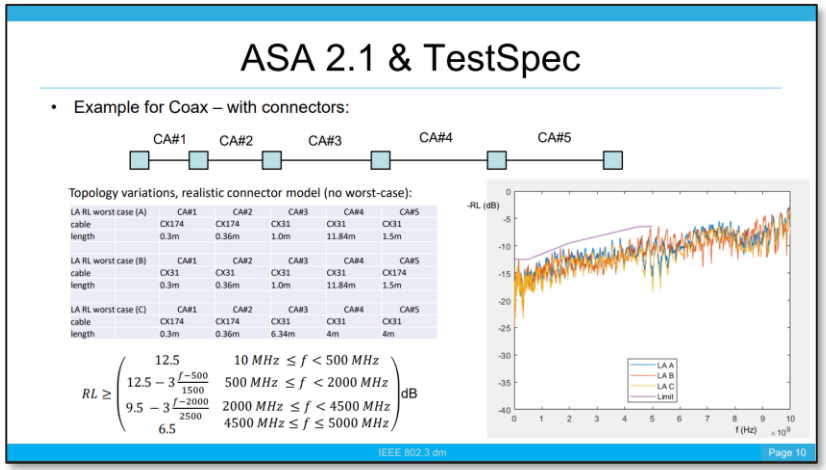
Introduction

- It has been communicated to the 802.3dm Task Force that ASA 2.1 will have a new return loss (RL) limit, that might be suitable for adoption for 802.3dm
- The new ASA 2.1 limit allows for much **higher echo at low frequencies** (see bottom right), compared to what exists in the industry today (see top right)
- This presentation evaluates the new ASA 2.1 RL limit
- It is strongly recommended **not to adopt** this limit for 802.3dm



From https://www.ieee802.org/3/dm/public/adhoc/101024/boyer_sharma_3dm_xx_10_10_24.pdf



From https://www.ieee802.org/3/dm/public/0125/Zerna_802.3dm_01_250122_IL_RL.pdf

Probability of ASA 2.1 Reference Configuration

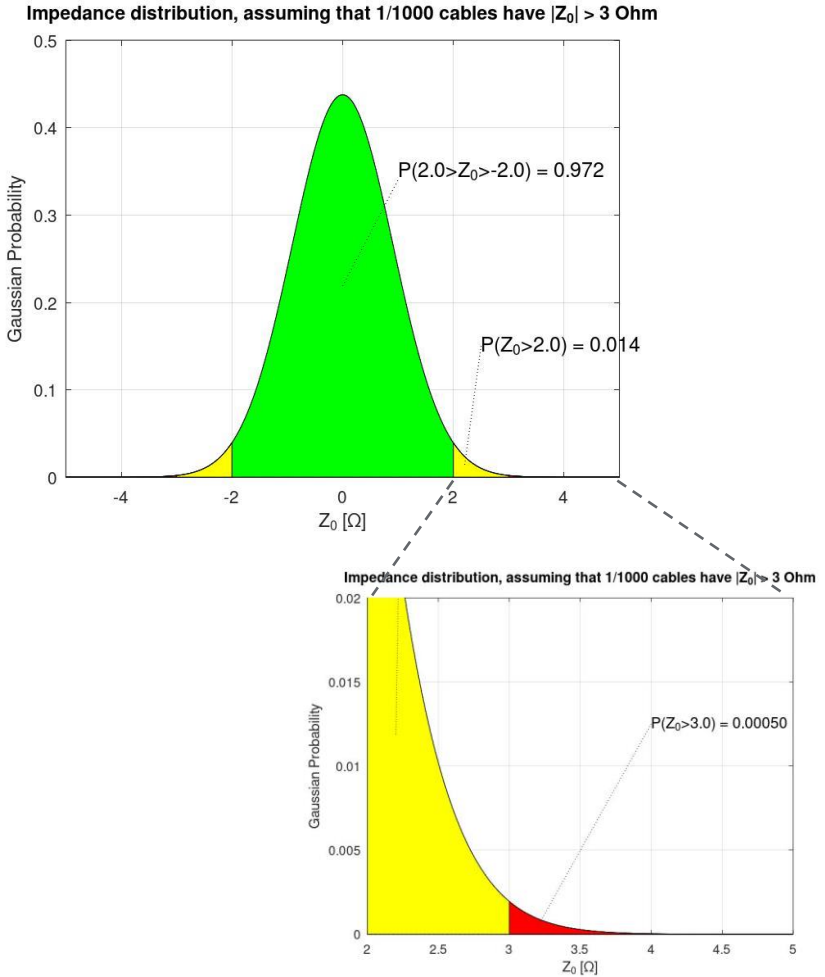
- According to Zerna et. al.[1], the fundamental assumption behind the new ASA 2.1return loss limit is that cable impedance from one segment to the next will alternate between 47Ω and 53Ω
- According to Statista [2] there are approximately 75 million cars sold worldwide each year.
- If we assume that there are on average 10 camera links using 802.3dm in each car in the future (this is optimistic), this means that there would be about 750 million 802.3dm camera links deployed each year
- As an example, if 1% of cable segments violate the +/-3Ω limit in ISO 19642-11, then there would be about 427 years between the occurrence of the ASA worst-case RL cables

Return loss limits used in the industry today are more realistic than the new ASA 2.1 limit

[1] https://www.ieee802.org/3/dm/public/0125/Zerna_802.3dm_01_250122_IL_RL.pdf
[2] https://www.statista.com/statistics/200002/international-car-sales-since-1990/

Probability of Impedance Mismatch

- According to ISO 19642-11 the coax cables of interest for 802.3dm must have less than 3Ω impedance mismatch (|Z0| < 3Ω)
- The plot on the right shows the probability distribution function (PDF) for cable impedance, assuming that the distribution is Gaussian and that one in 1000 cables violates the 3Ω limit
- For this case the probability of having impedance variation above 2Ω would be 1.4% (see top plot on the right)



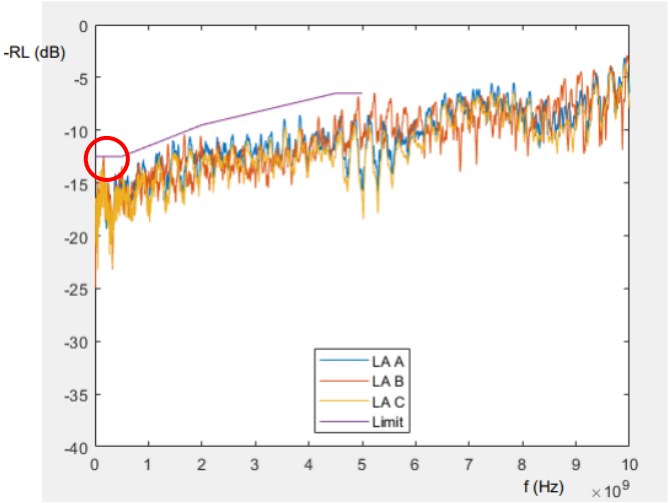
Probability of Bad Cable Combination

Portion of non-compliant cables	Standard Deviation [Ohm]	P(Z0>3)	P(Z0>2)	P(Z0>3)^5	P(Z0>2)^5	Average number of years between +/-3 Ohm cables	Average number of years between +/-2 Ohm cables
1/100	1.165	0.005	0.0430	3.13E-12	1.46E-07	4.27E+02	0.01
1/1000	0.912	0.0005	0.0141	0.0000	5.63E-10	4.27E+07	2.37
1/10000	0.771	0.00005	0.0047	0.0000	2.41E-12	4.27E+12	553.10
1/100000	0.679	0.000005	0.0016	0.0000	1.10E-14	4.27E+17	121,018.82

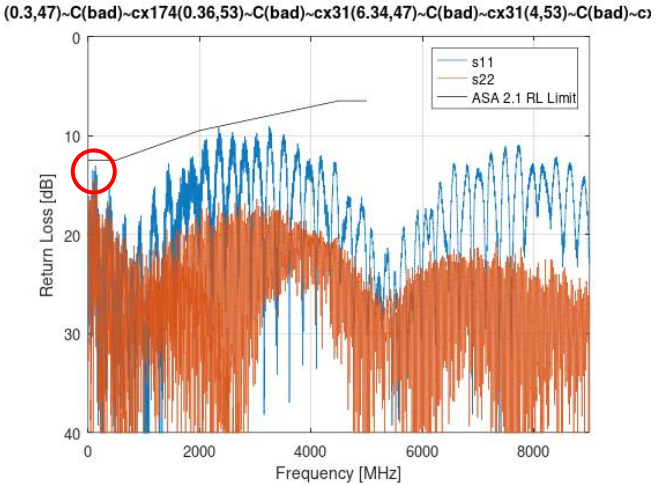
- The table above shows the probability of constructing worst case cables, consisting of five sections alternating between +/-2Ω or +/-3Ω
  - The table assumes that there will be 750 million 802.3dm links deployed each year (this may be optimistic), with all of them having four inline connectors (this is pessimistic)
- For example, if 1/100 of cable segments violate the +/-3Ω limit in ISO 19642-11, then there would be about 427 years between the occurrence of the ASA worst-case RL cables with 3Ω impedance mismatch
- Another example, if 1/1000 of cable segments violate the +/-3Ω limit in ISO 19642-11, then there would be about 2.4 years between the occurrence of the ASA worst-case RL cables with 2Ω impedance mismatch

Recreating ASA Simulation Results

- The simulation results for ASA 2.1 RL limit have been shared with 802.3dm (see top right)
- The plot on the bottom right shows the corresponding return loss generated in my simulation
- The difference between the plots is primarily due to the different connector models used
- Notice that both simulations show the high peak at low frequency (in red circles), which is due to alternating impedance values

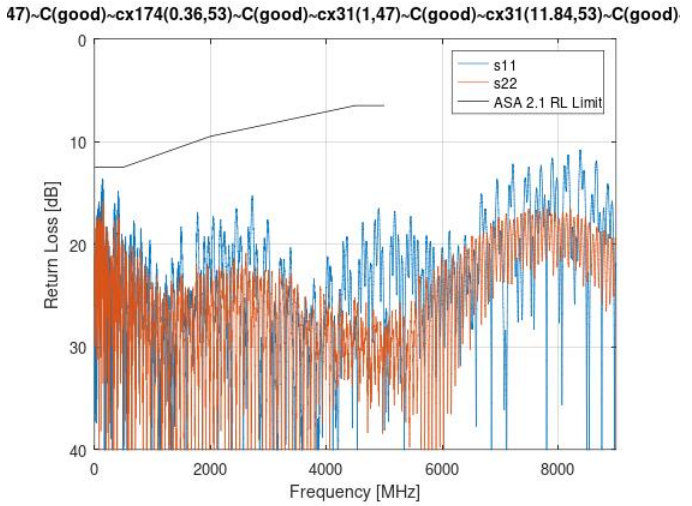


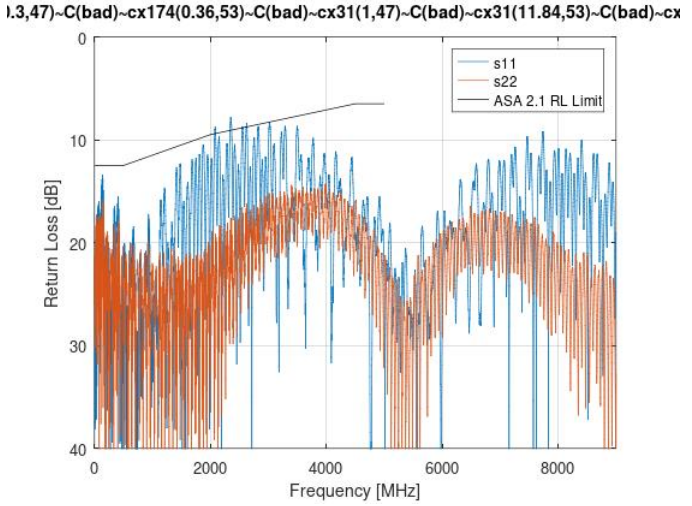
From https://ieee802.org/3/dm/public/0724/Zerna_802.3dm_01b_240717_IL_RL_Limits.pdf



Good vs Bad Connectors

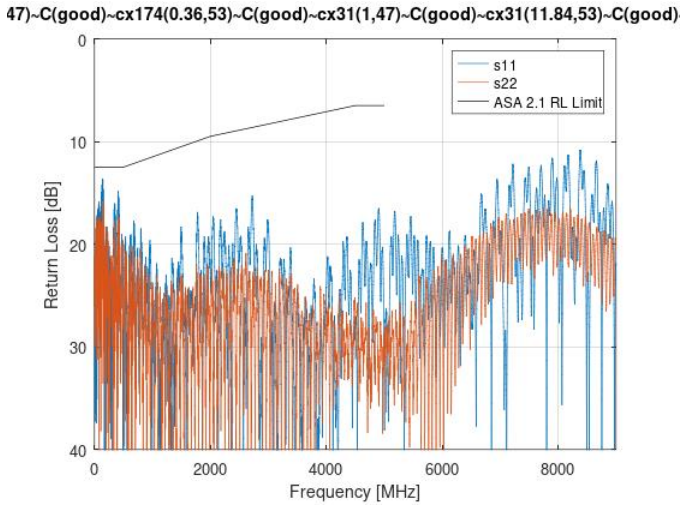
- The plots on the right show the difference in echo (return loss) for identical cables, except one of them has good connectors while the other one has bad connectors
- The bad connector has return loss that is touching the USCAR49 return loss limit
- Observe that the return loss for the cable with bad connectors is violating the ASA return loss limit

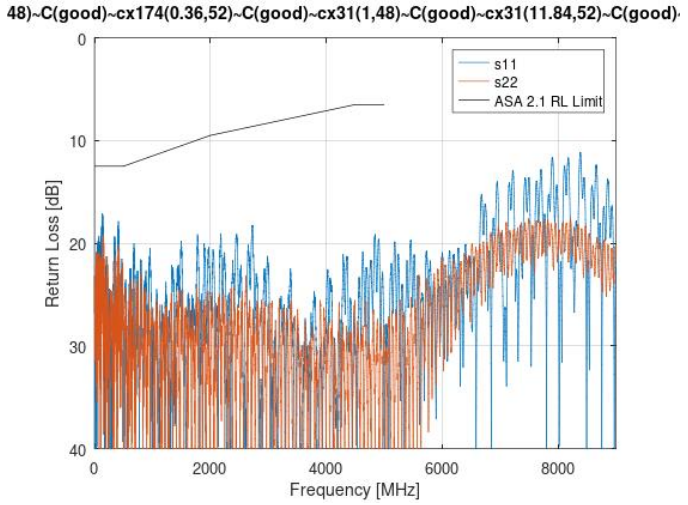




Extreme vs Bad Cable Impedance Variations

- The figure on the top right shows the return loss for extreme cable impedance variations of +/-3 Ohm
- The figure on the bottom right shows the return loss for bad cable impedance variations of +/-2 Ohm
- There is significant difference in the low frequency echo for the two cases
- The probability of encountering the extreme impedance variations shown on the top right are extremely small





Impact on PHY Power and Relative Cost

- The worst-case echo used to derive the ASA 2.1 return loss (RL) limit is too pessimistic at low frequencies and could lead to sub-optimal designs for 802.3dm PHYs
- While both the ACT and TDD solutions can handle the echo levels corresponding to actual cables that satisfy the ASA 2.1 return loss limit, the presence of the limits can lead to wasteful overdesign in the PHY
- PHY designers are usually cautious and use pessimistic assumptions in their design
  - See example of this in comments on Slide 7 of [3] and on Slide 7 of [4] talking about using pessimistic assumptions for the echo, on top of the pessimistic ASA 2.1 RL limit
- It is better to use the limited power and relative cost budget for the PHY to improve performance on longer links in the presence of noise, rather than spend this budget on non-existing echo

[3] https://www.ieee802.org/3/dm/public/0125/ahuja_8023dm_01a_011325_on_upstream_receiver_design_and_performance_ACT.pdf
[4] https://www.ieee802.org/3/dm/public/0125/sedarat_3dm_202501.pdf

Summary

- The assumptions about extreme cable impedance mismatch, used in the derivation of ASA 2.1 return loss limit, are very unlikely to ever be observed for real cables
- Relaxing the ASA 2.1 assumptions to assume that the worst-case cable combination is alternating +/-2 Ohm will significantly reduce the echo at low frequencies
- The ASA 2.1 return loss limit does not sufficiently account for connector variations, and may be too low at higher frequencies
- Existing return loss limits used in the industry today are much more realistic than the new ASA 2.1 return loss limit

Return loss limits used in the industry today are more realistic than the new ASA 2.1 limit

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