Coaxial Unbalanced Media for Automotive Applications Link Segment IL & RL

Contribution to IEEE 802.3dm, September 2024

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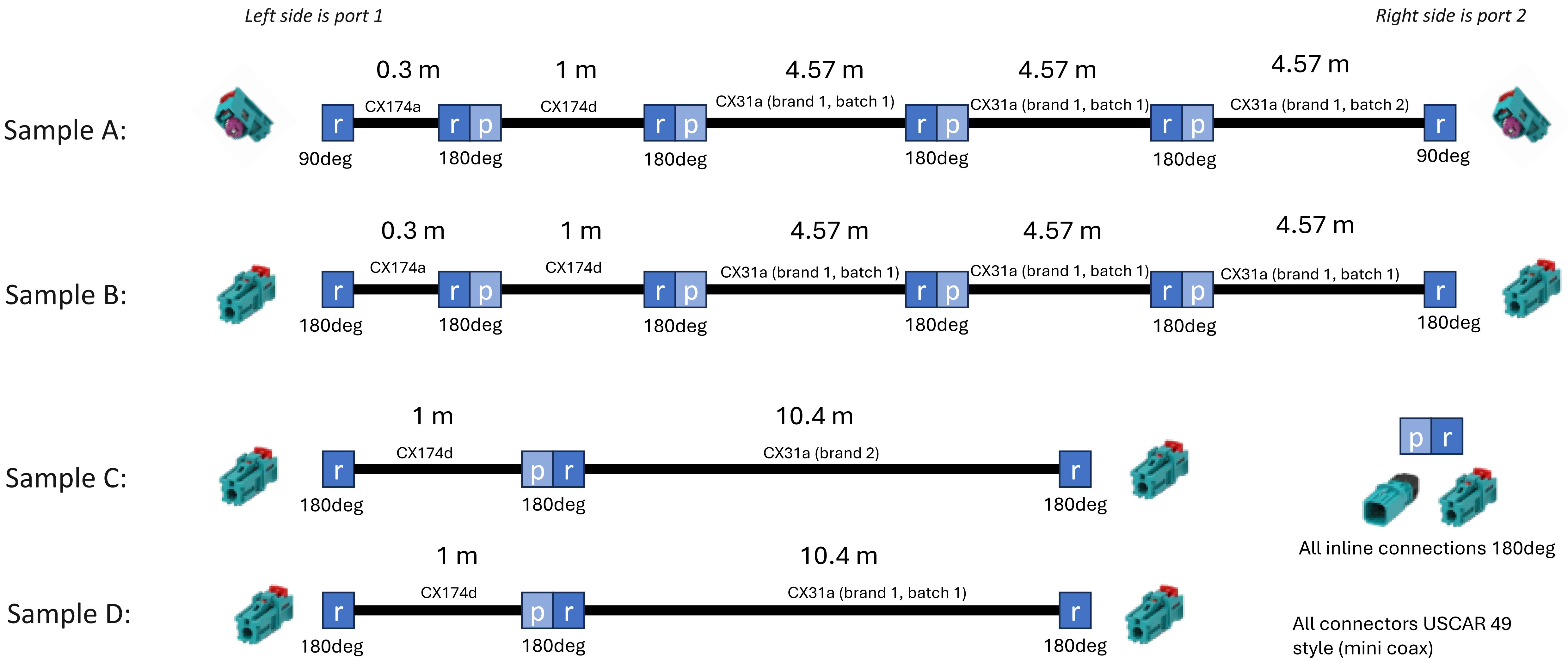
Scope

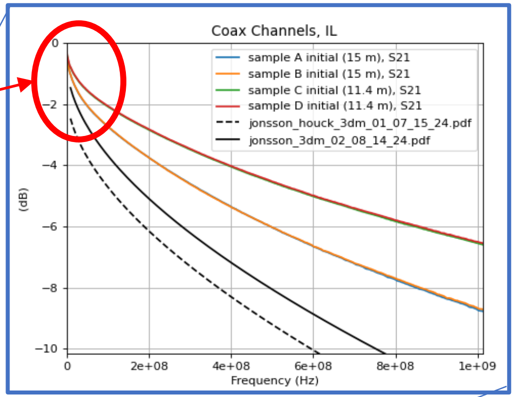
- The contribution discusses link segment performance (IL, RL) for coaxial cabling.
- Measurement results for different link segments and at different temperatures are presented
- Simulation results are presented to discuss reasonable assumptions for a limit calculation

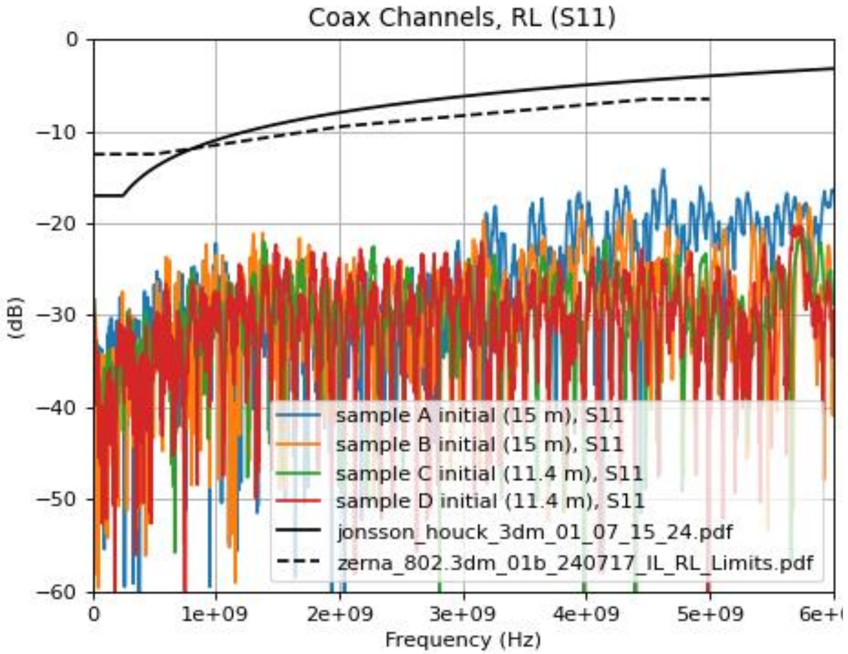
Sample Description

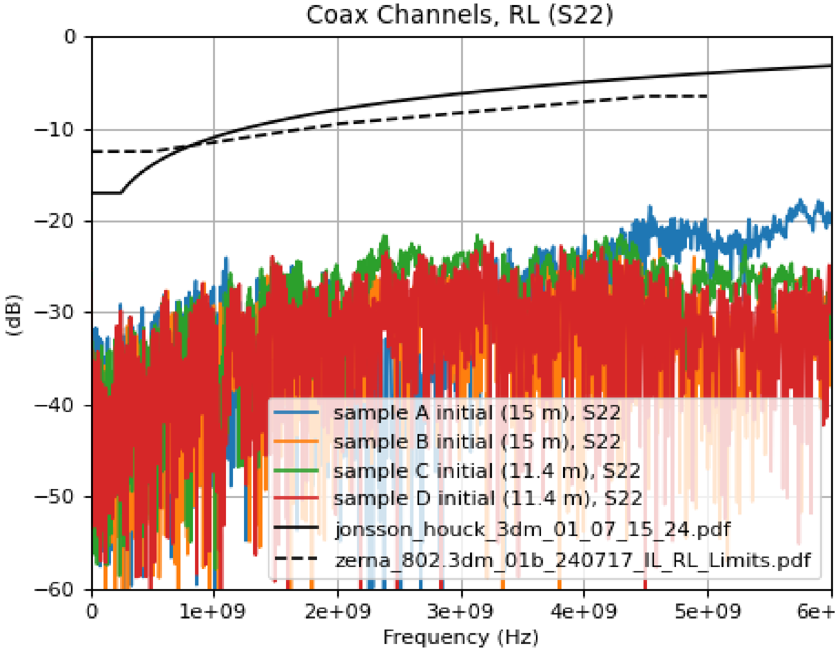


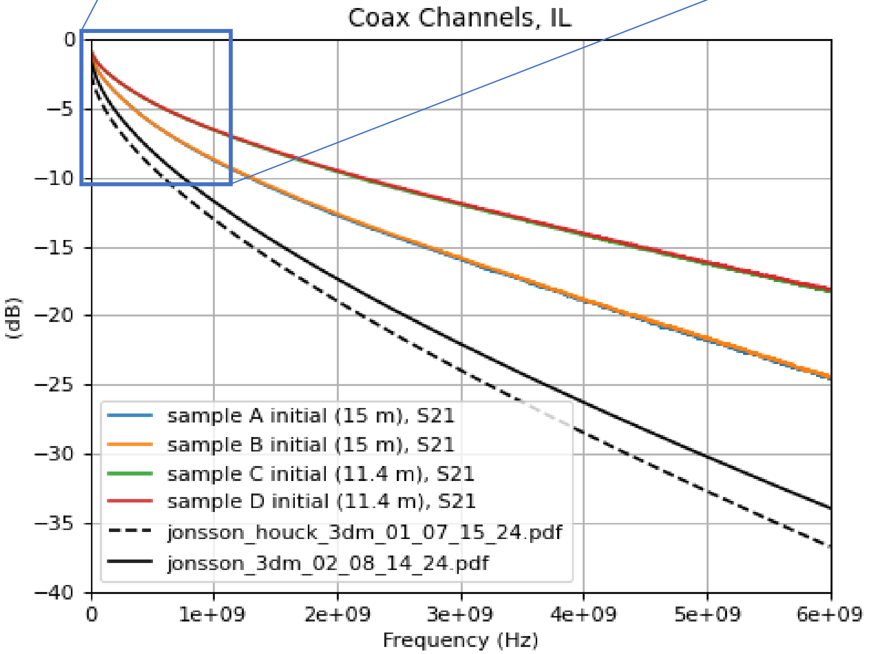
Initial Measurements

Solid line limit proposal close at 10MHz





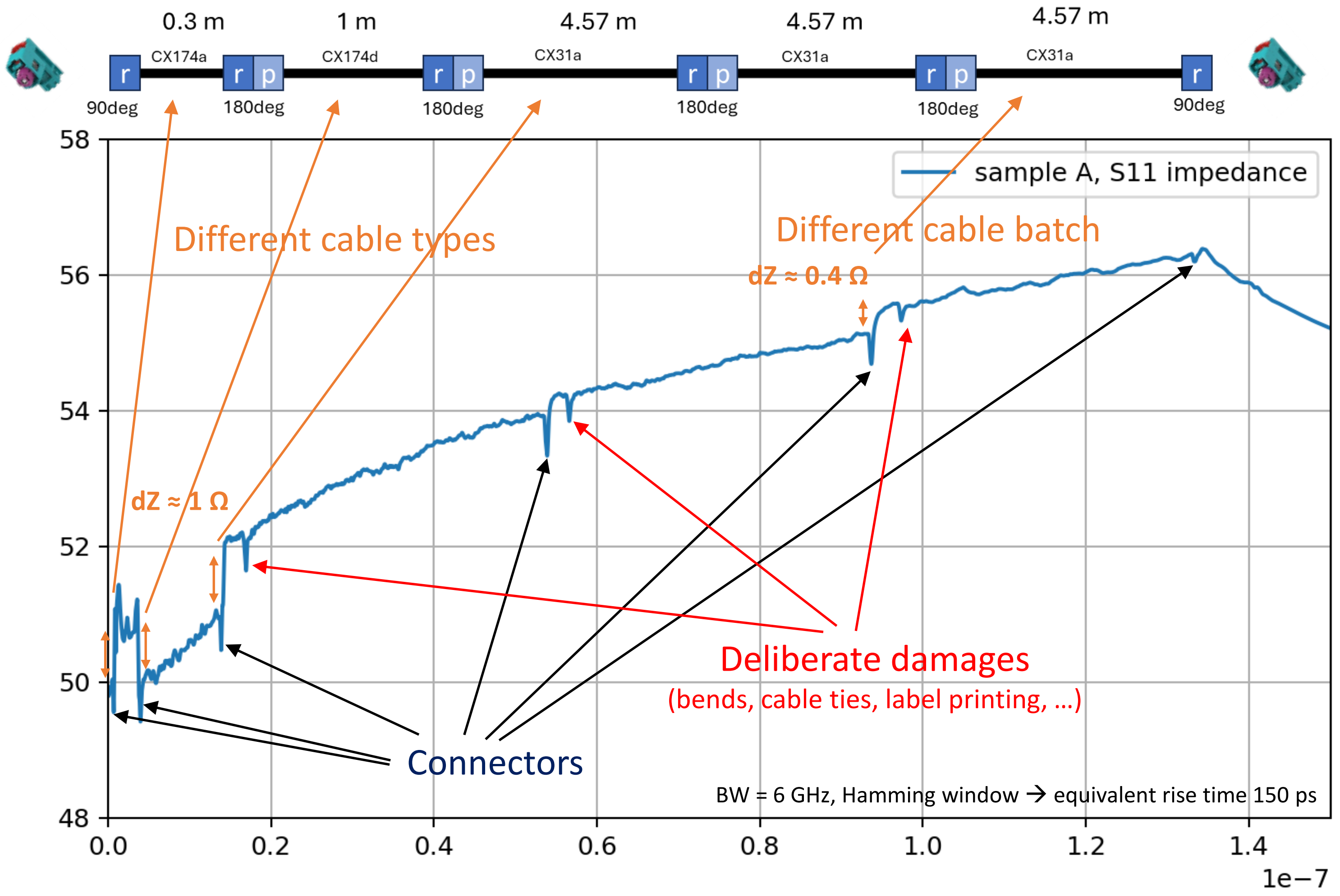




- Return loss: Comfortable margin to all limits
- Return loss: 90 deg. angled end connectors show significant lower RL at high frequencies
- IL: jonsson_3dm_02_08_14_24 proposal close to 15m channels at low frequencies

Initial Measurements – Time Domain

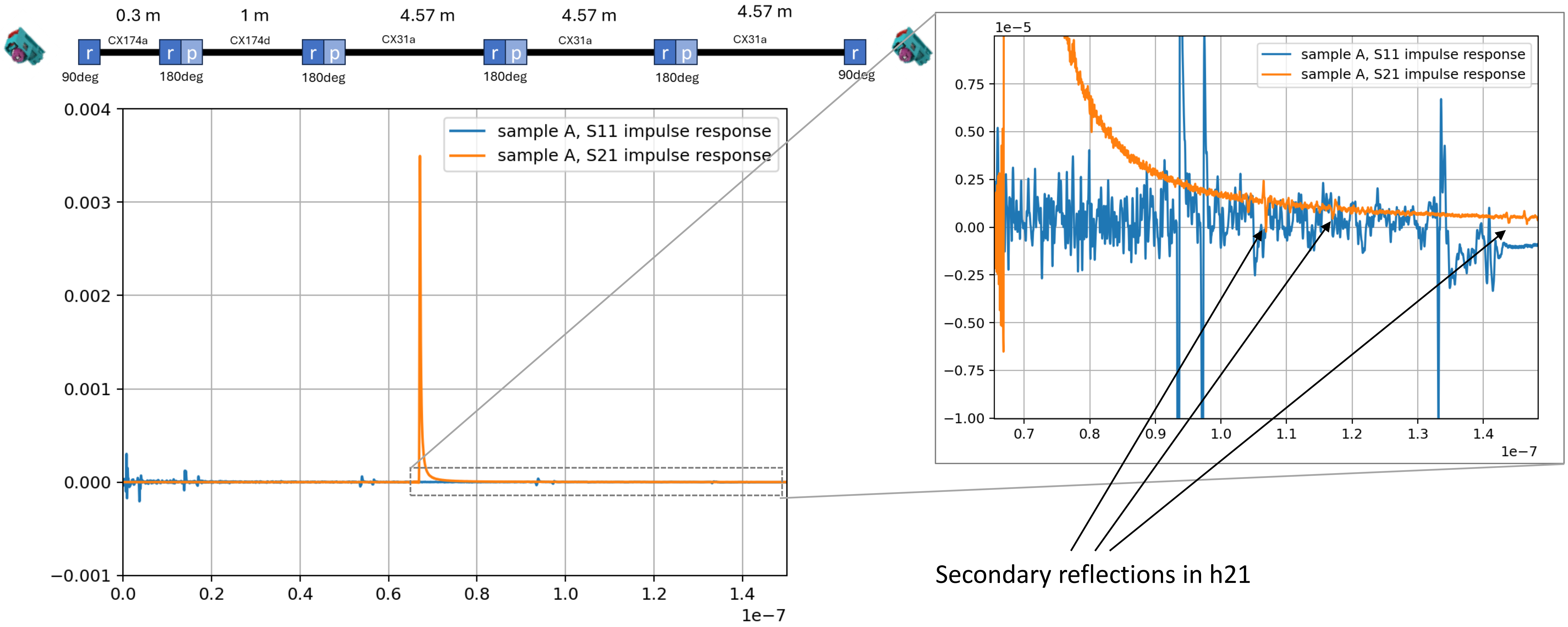
“realistic” channel, even with deliberate damage



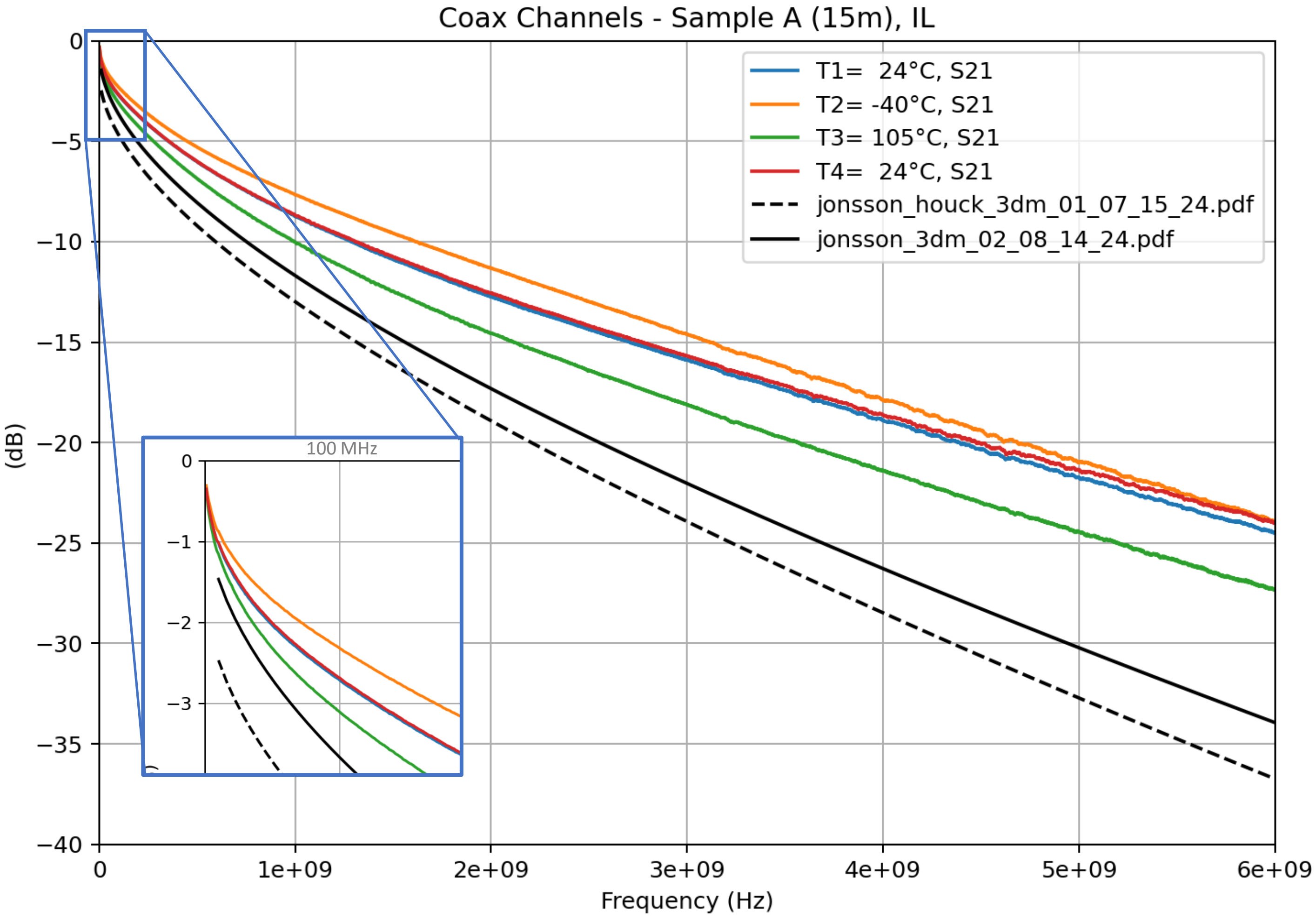
- Observed cable-to-cable impedance variation dZ ≈ 1 Ω
- Impedance variation even for same cable type on different batch
- Damages can easily have similar effect as connectors

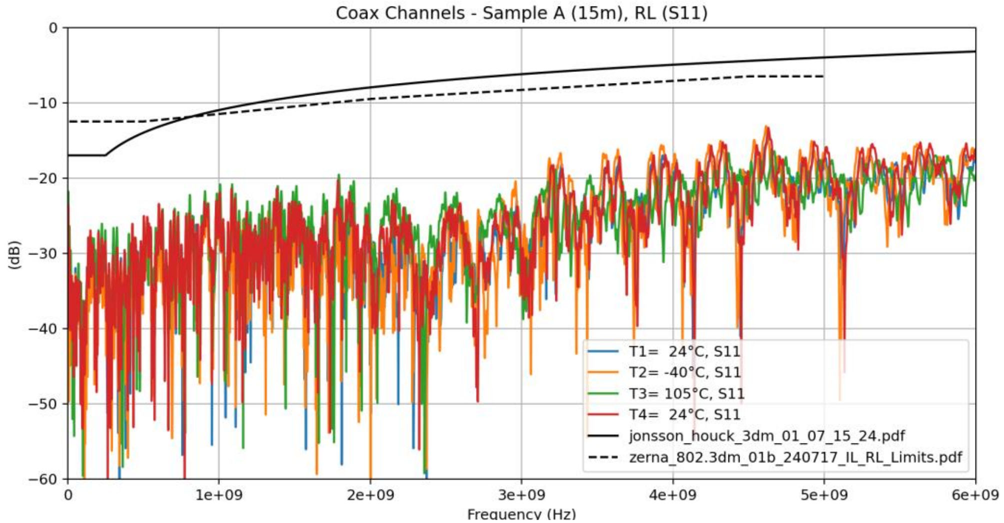
Initial Measurements – Time Domain

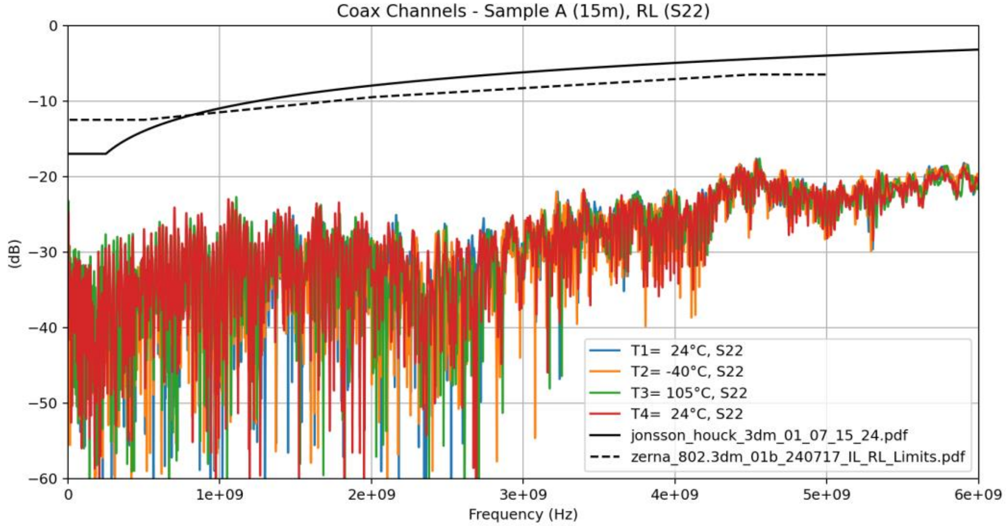
"realistic" channel, even with deliberate damage



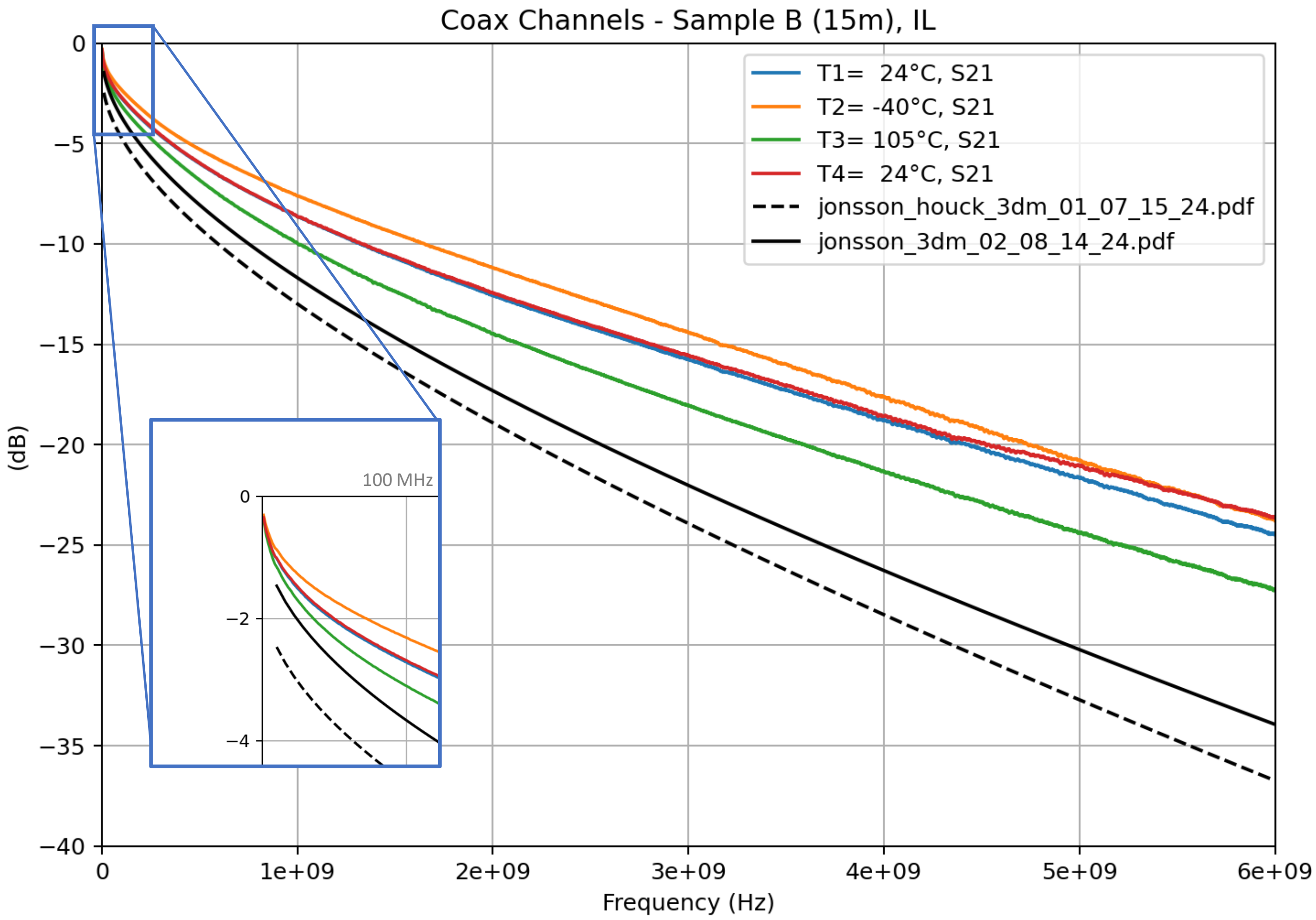
Measurements vs. Temperature, Sample A (15m)

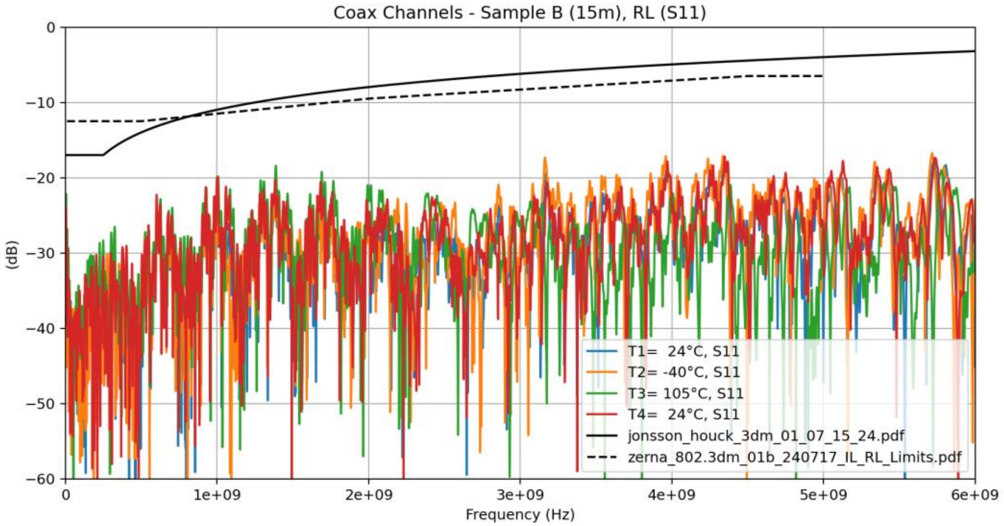


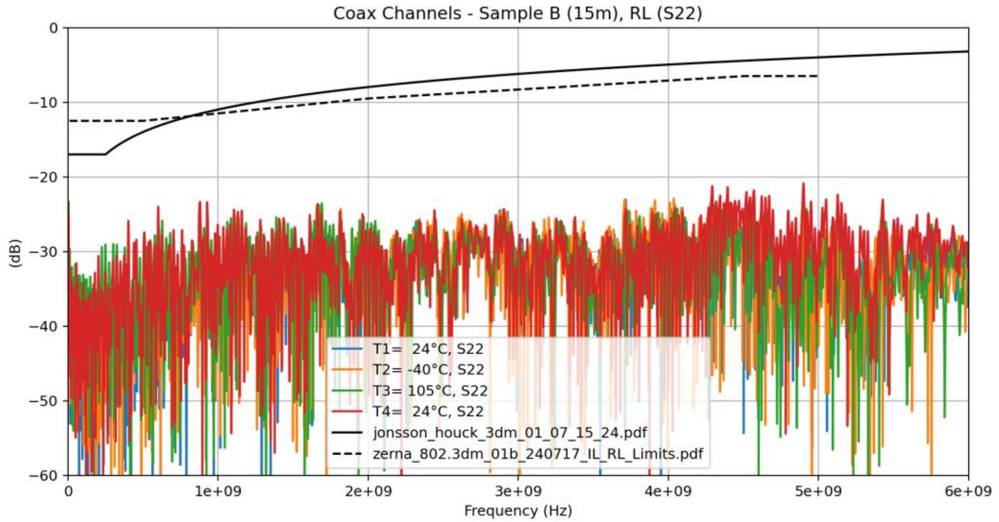




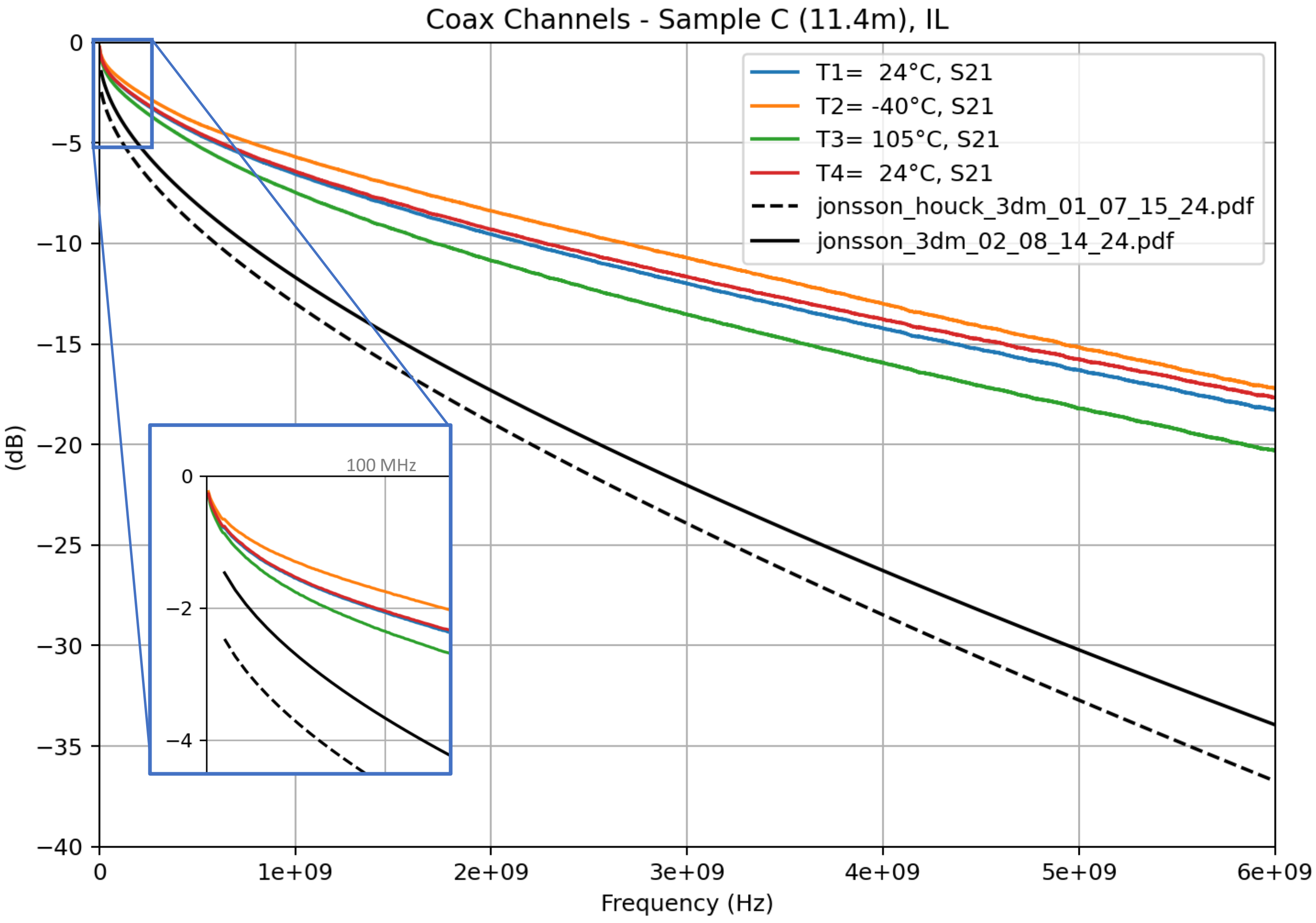
Measurements vs. Temperature, Sample B (15 m)

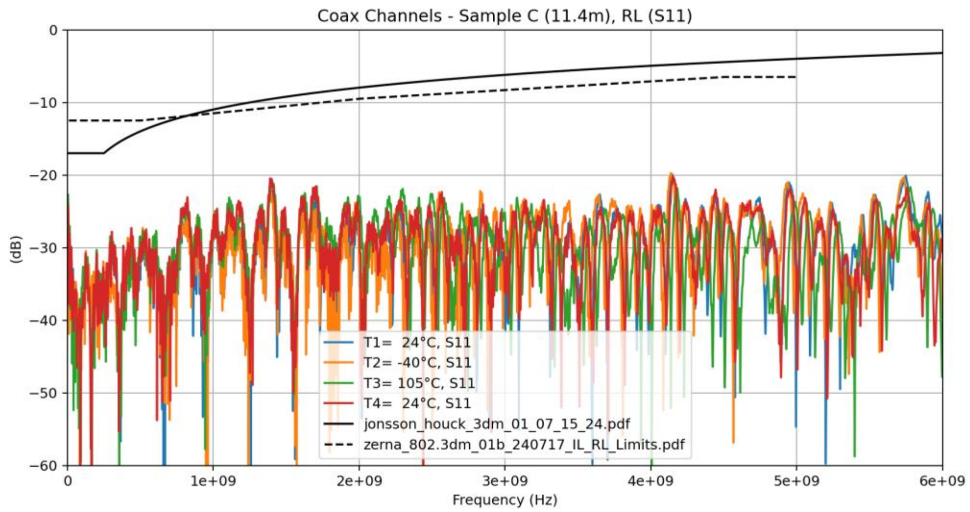


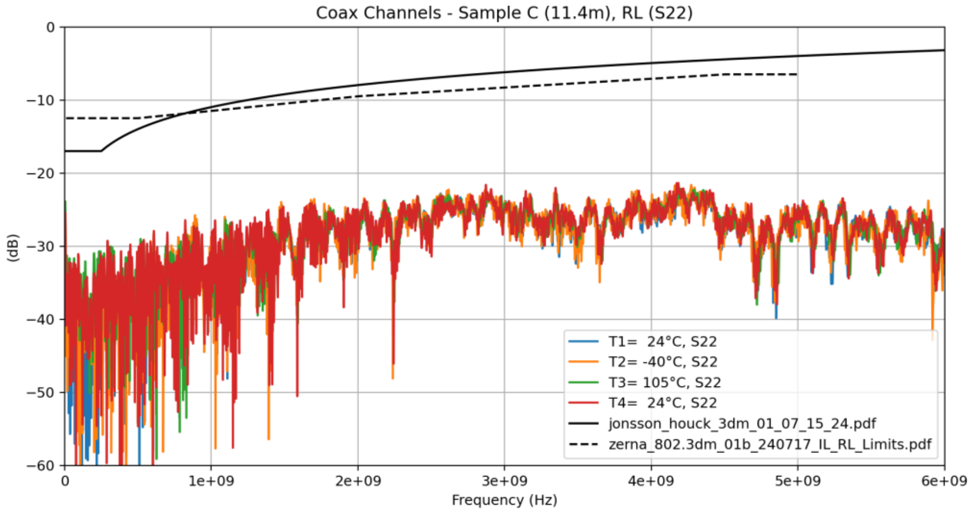




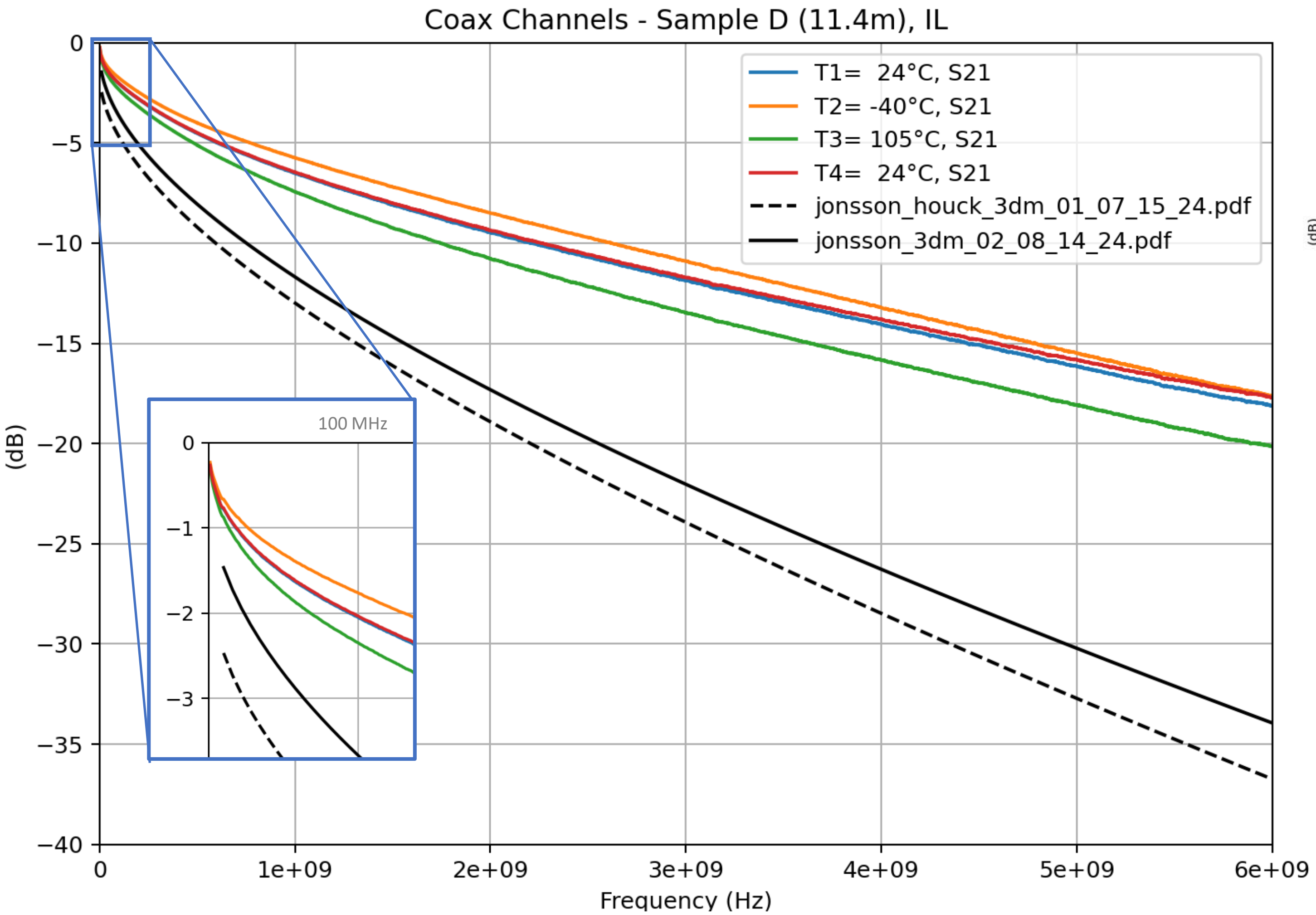
Measurements vs. Temperature, Sample C (11.4 m)

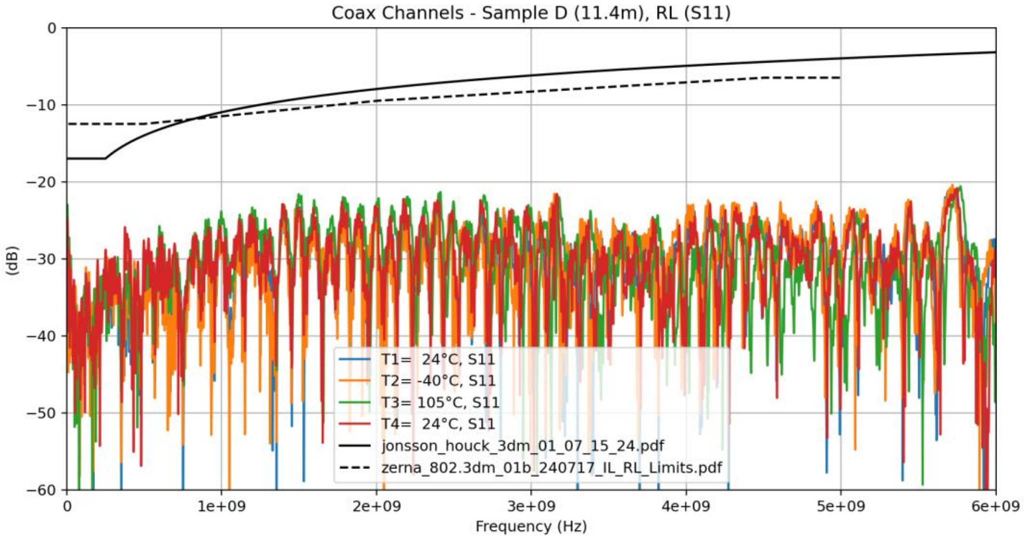


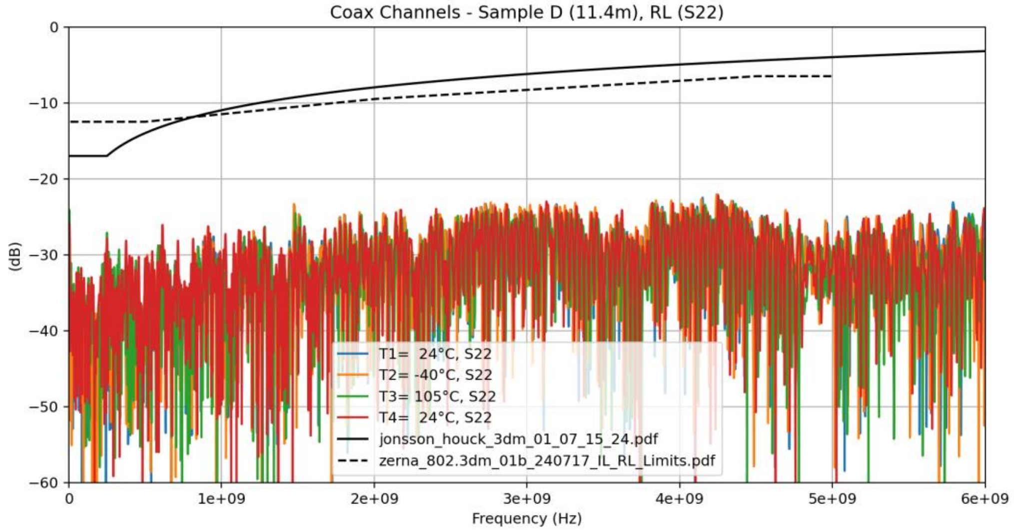




Measurements vs. Temperature, Sample D (11.4 m)





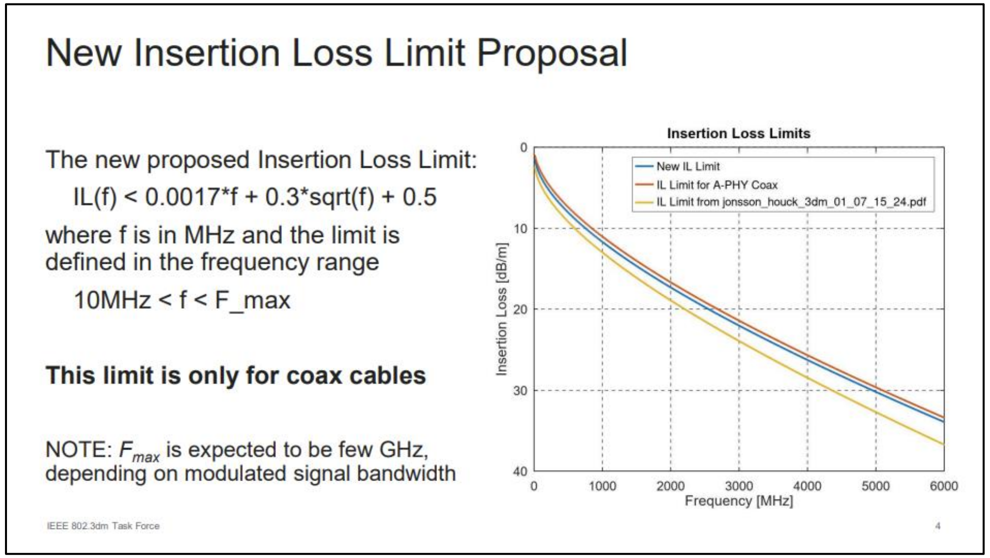


IL Proposal based on ISO Cable Models

- Calculation for 13m CX31a + 2m CX174e with 2x 15% degradation
- According to reflector e-mail from Ragnar Jonsson (2024-06-03):

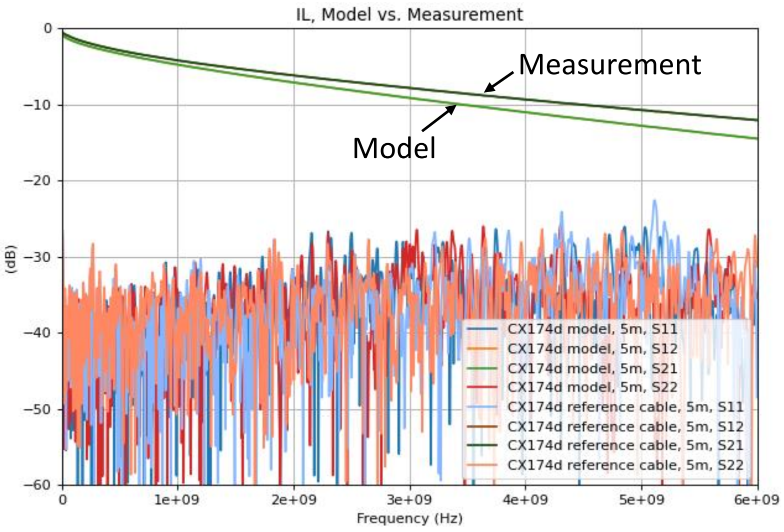
1) The CX31 and CX174 are defined in ISO 19642-11 as a limit on insertion loss, based on the commonly used formula IL = a + b*sqrt(f) + c*f
2) The parameters for the CX31a cables at 20C are approximately a=6e-2, b=1.4e-2, and c=7.4e-5, where IL is in dB/m and f is in MHz (note that these parameters are approximations to the ISO 19642-11 limits, based on curve fitting)
3) The parameters for the CX174e cables at 20C are approximately a=0.11, b=2e-2, and c=2e-4, where IL is in dB/m and f is in MHz (note that these parameters are approximations to the ISO 19642-11 limits, based on curve fitting)
4) The parameters for the total insertion loss for 12m of CX31a + 3m of CX174e at 20C is simply the linear combination: **→ topology 13m CX31a + 2m CX174e**
   - a = 12*6e-2 + 3*0.11 = 1.05 **→ 13*6e-2 + 2*0.11 = 1.0**
   - b = 12*1.4e-2 + 3*2e-2 = 0.228 **→ 13*1.4e-2 + 2*2e-2 = 0.222**
   - c = 12*7.4e-5 + 3*2e-4 = 1.488e-3 **→ 13*7.4e-5 + 2*2e-4 = 1.362e-3**
5) To change from 20C to 100C the parameters can be scaled up by 15% giving
   - a = 1.05 * 1.15 = 1.2075 **→ 1.0 * 1.15 = 1.15**
   - b = 0.228 * 1.15 = 0.2622 **→ 0.222 * 1.15 = 0.2553**
   - c = 1.488e-3 * 1.15 = 1.711e-3 **→ 1.362e-3 * 1.15 = 1.566e-3**
6) Adding 15% design margin gives
   - a = 1.05 * 1.15 * 1.15 = 1.3886 **→ 1.0 * 1.15 * 1.15 = 1.3225**
   - b = 0.228 * 1.15 * 1.15 = 0.3015 **→ 0.222 * 1.15 * 1.15 = 0.2936**
   - c = 1.488e-3 * 1.15 * 1.15 = 1.968e-3 **→ 1.362e-3 * 1.15 * 1.15 = 1.801e-3**
7) Finally rounding the parameter values to “nice” numbers gives the proposed insertion loss limit
   - a = 1.5 **→ 1.3**
   - b = 0.3 **→ 0.3**
   - c = 0.002 **→ 0.0018**

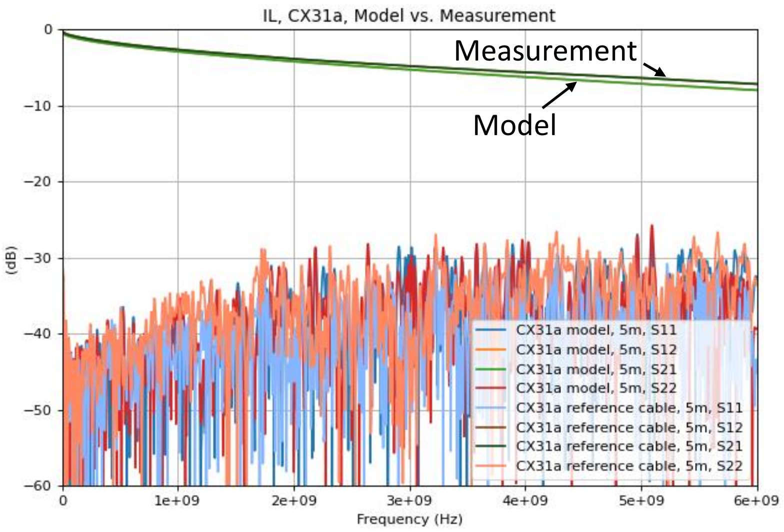
jonsson_3dm_02_08_14_24.pdf



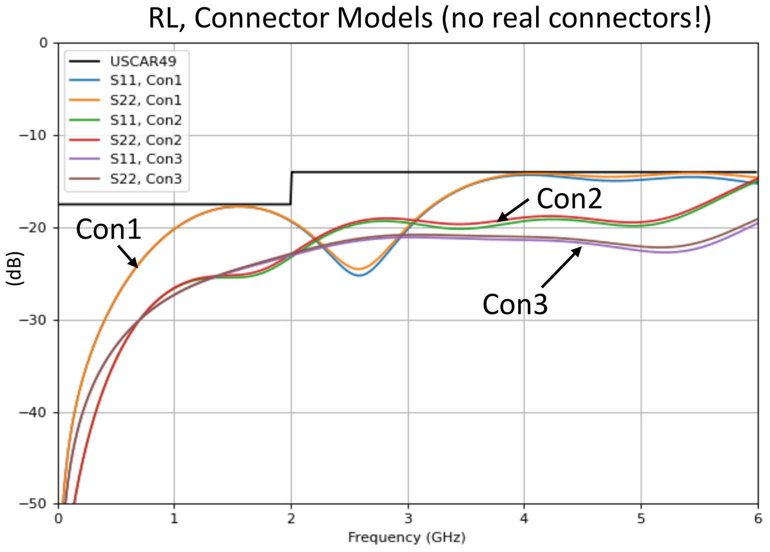
IL(f) < 0.0018*f + 0.3*sqrt(f) + 1.3

Component Models for Simulations



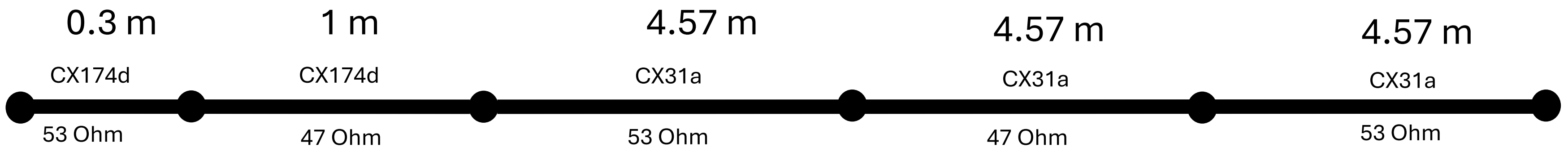


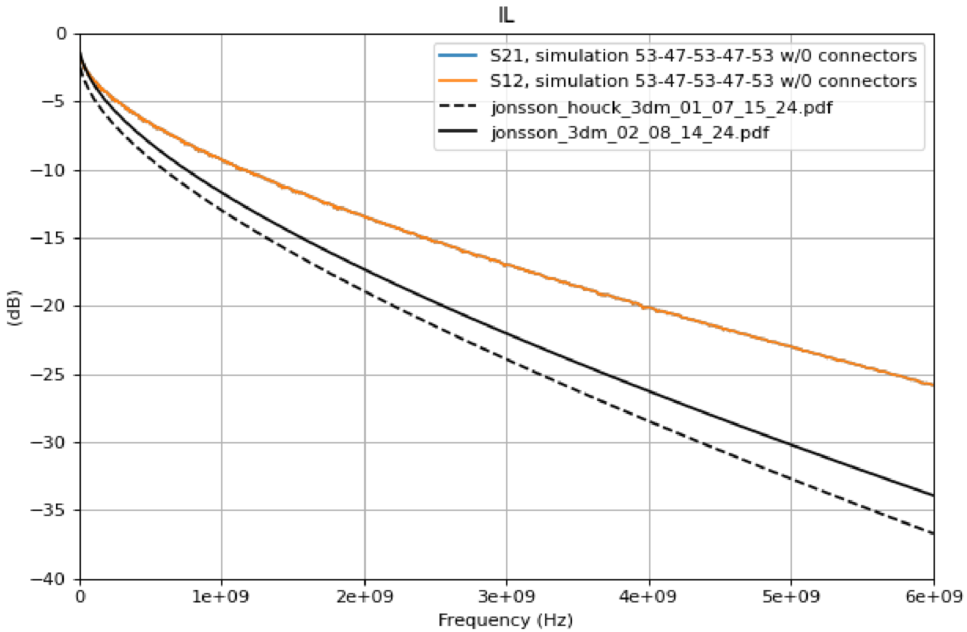
- Cable model IL according to ISO 19642-11 at room temperature
- CX174d and CX31a considered
- Micro reflections empirically corelated with real measurements
- Models parameterized for cable length and nominal impedance
- Diagrams show comparison between model and measurements for 5 m cable lengths → measurements have slightly better IL than ISO models



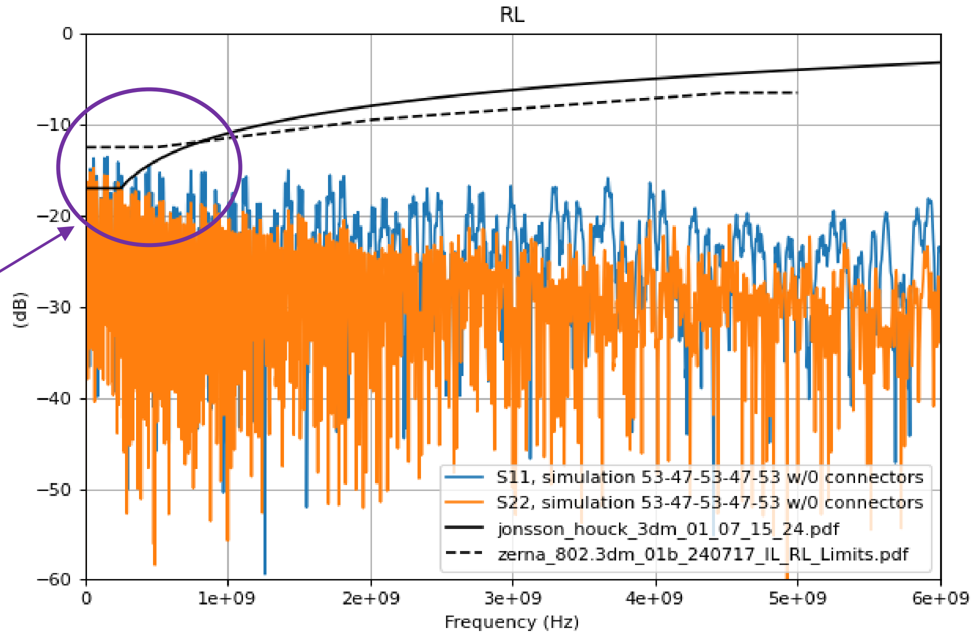
- Connector models based on concatenated waveguide models
- Model adjusted to electrical lengths and IL of typical connectors
- Impedance profiles “optimized” to meet the following cases:
  - Con1 → touches USCAR49
  - Con2 & Con 3 are better

Link Segment Simulation, w/o Connectors





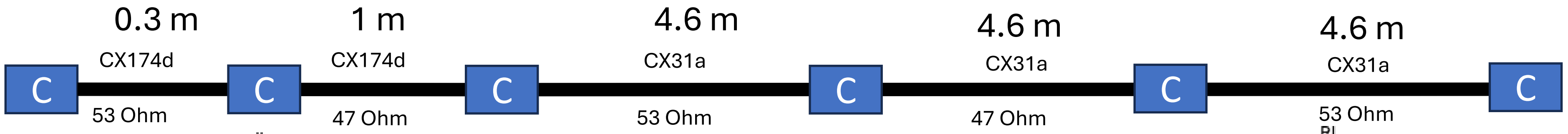
RL at low frequencies caused by segment-to-segment impedance mismatch

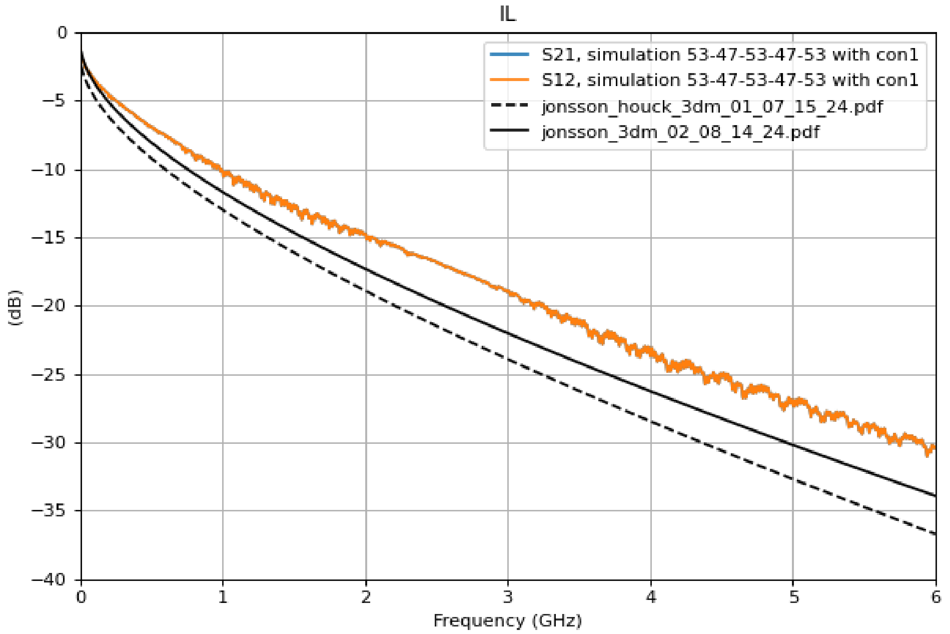


- CX174d cable (more flexible and more lossy) used for the short segments at S11-end
  → using low loss CX44 grade cable here is unlikely (really ?) → use of CX174d decreases RL at S11-end
- Simulation used ISO models for IL at room temperature, real cables have less IL, IL will even decrease at low temperatures
  → considering these effects would increase RL, same for using CX44 grade cable for the long segments (see mueller_3dm_01a_07_01_24.pdf)

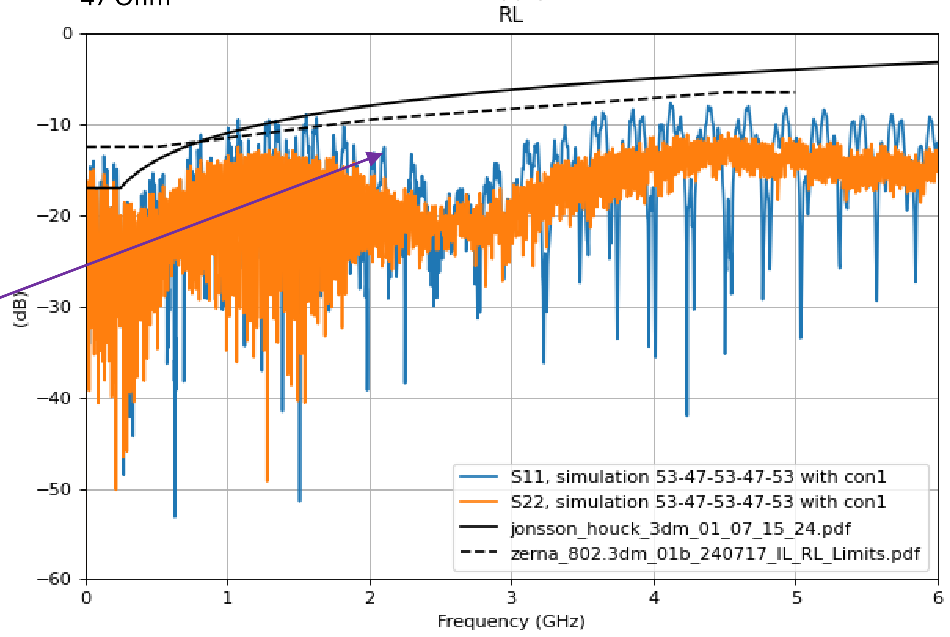
Link Segment Simulation, w/ Connectors

Connector Model Con1 (model that touches USCAR49 limit)



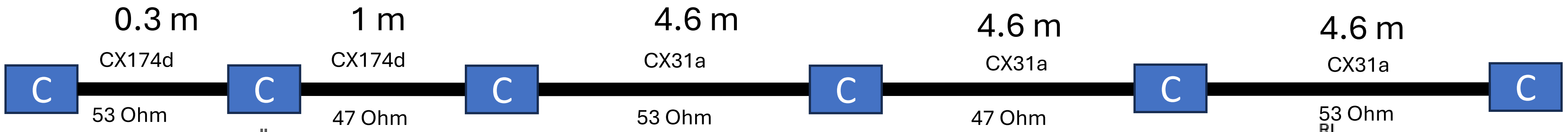


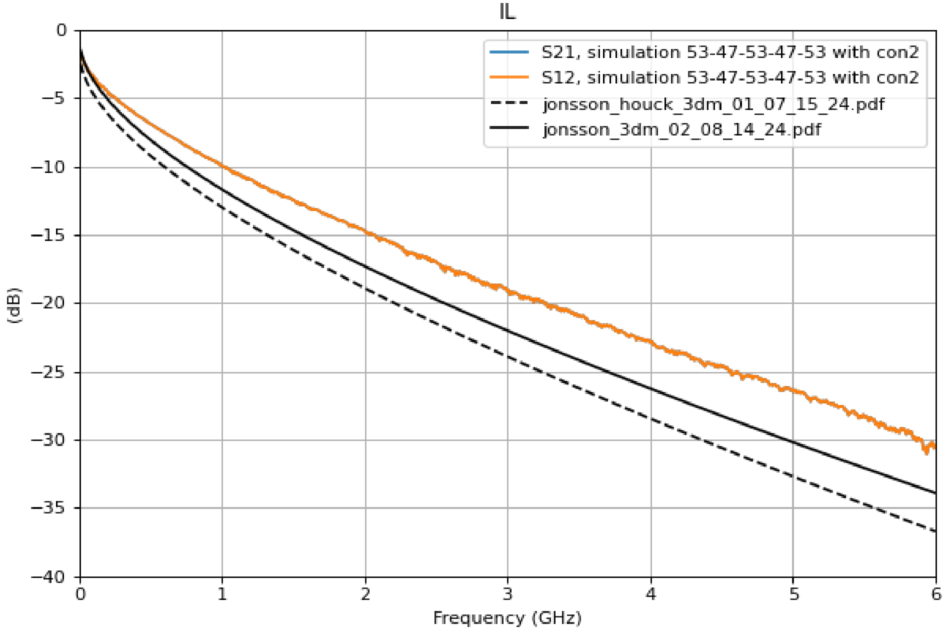
RL upper envelop at higher frequencies is caused by connectors

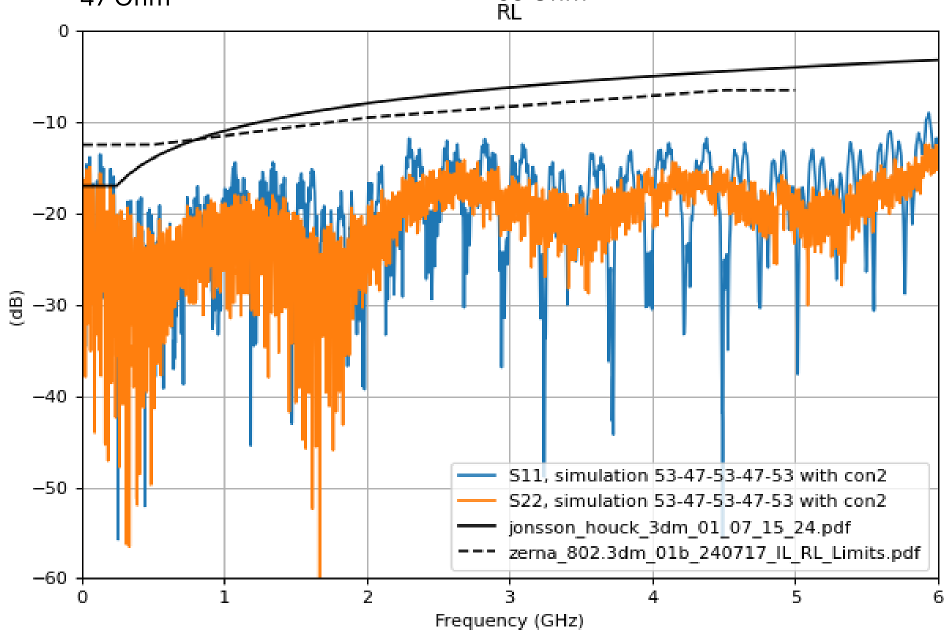


Link Segment Simulation, w/ Connectors

Connector Model Con2 (model better than USCAR49 limit)

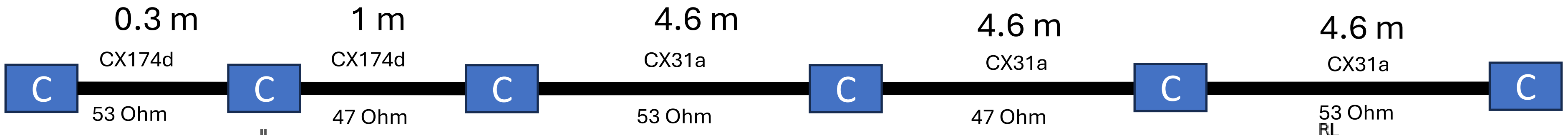


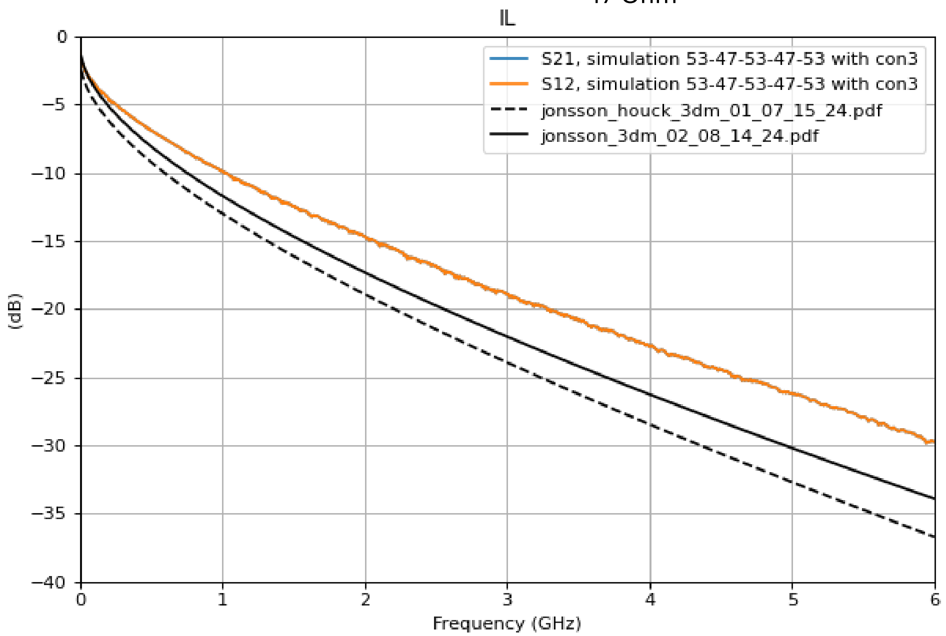


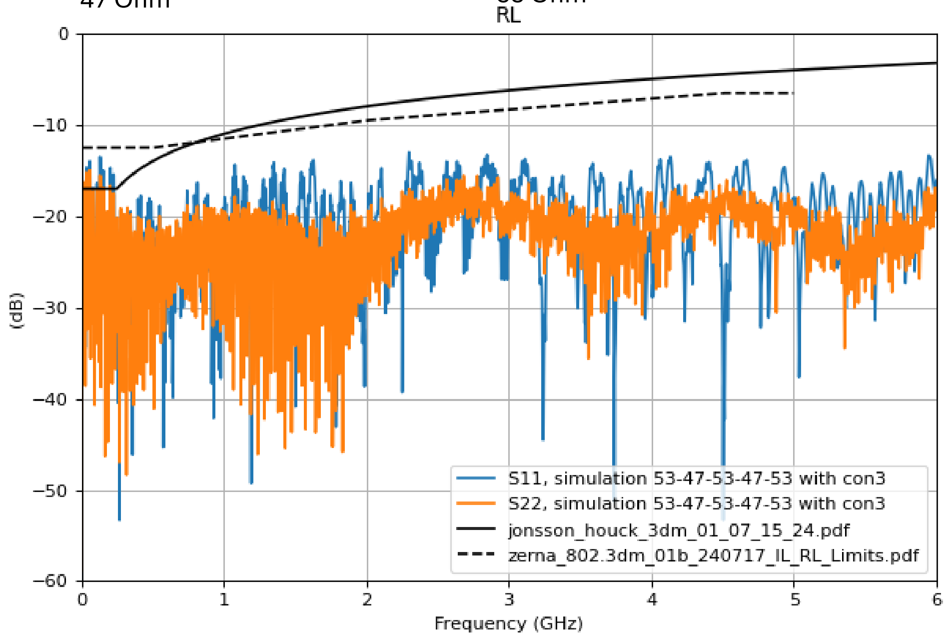


Link Segment Simulation, w/ Connectors

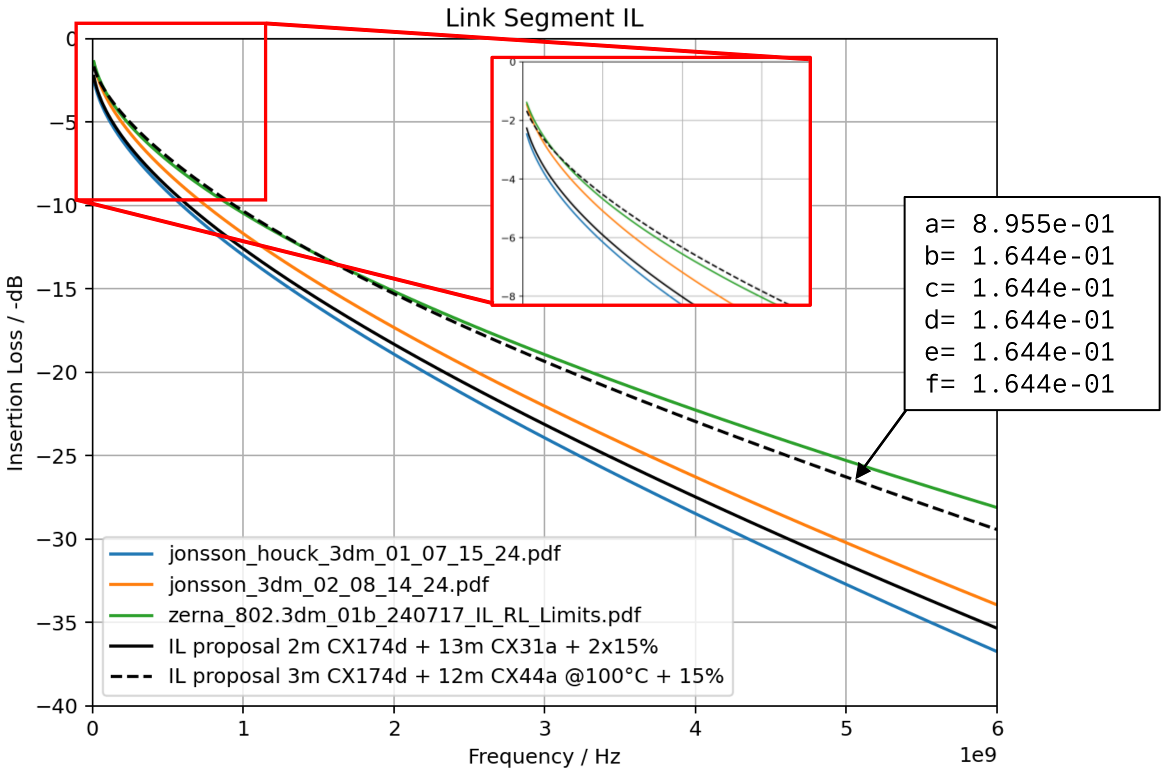
Connector Model Con3 (model better than Con 2 and USCAR49 limit)

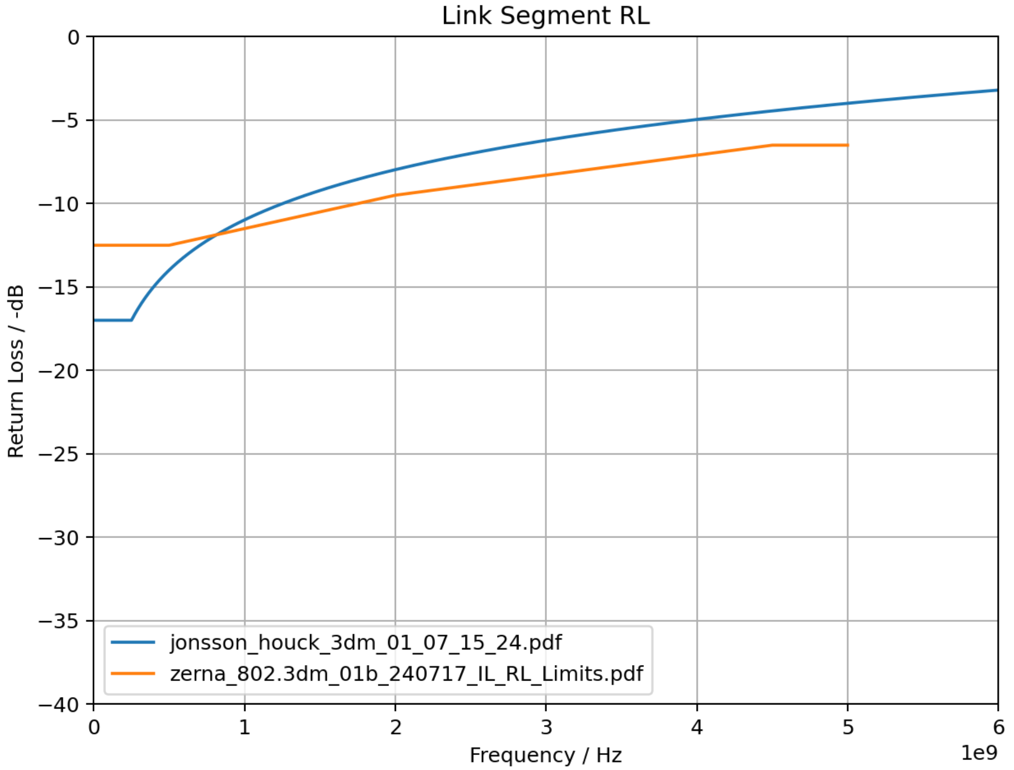






Summary of Discussed Link Segment Limits (Coax only)





Calculation based on 3m CX174d and 12m CX44a would improve the IL! However, coefficients need adaptation in the low frequencies.

Conclusions

- Real measurements are typically far better than worst case simulations and meet all previously proposed limits.
- Component tolerances and existing component specifications shall be considered
  - Segment-to-segment cable impedance mismatch
  - Existing public connector specifications
- Insertion loss limit:
  - Adjustment of IL limit proposed to avoid issues at lower frequencies
  - We may consider to calculate IL limit based on the low loss CX44 grade cable
- Return loss limit:
  - Lower frequencies are determined by segment-to-segment cable impedance mismatch → worst case assumptions require very relaxed limits
  - Higher frequencies are determined by connectors → discussed limit proposals can typically be met but not with worst case connector assumptions (see mueller_3dm_01a_07_01_24.pdf)