Simulations of Coax Channel Responses

Contribution to 802.3dm Task Force Cabling Ad Hoc

August 14, 2024

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Introduction

- This presentation addresses some of the questions raised in the “802.3dm Link segment and noise models Ad Hoc” held on August 1st, 2024
- Different cable combinations are examined, based on cable specifications defined in ISO 19642-11
- The ISO 19642-11 specifications are compared to simulations of good cables
- The impact of different length distributions, connectors, and different temperatures are simulated

Questions from August 1st Ad Hoc

George Zimmerman captured the following questions in his email from August 1st, titled "[802.3_ISAAC] Summary of this morning's channel and return loss ad hoc" (see https://www.ieee802.org/3/ISAAC/email/msg00186.html):

- From what point to what point do we need to define? Link segment only, include MDI, include PCB limits?
- Do we want to define separate differential and single ended requirements? Focus on Coax first.
- How much of the coax cable needs to be the flexible cable? Percentage of total length, max number of meters regardless of total length, etc.
- A better understanding of coax cable connector reflections and current limit lines in other organizations is needed.
- More discussion is needed on noise models.
- Is 15m with 4 in-lines the cable over the lifetime of the cable over the specified operating conditions, or are the limits based on the new cable only?

There was also a request in the meeting for plot showing how different lengths of the flexible cable would influence the overall insertion loss

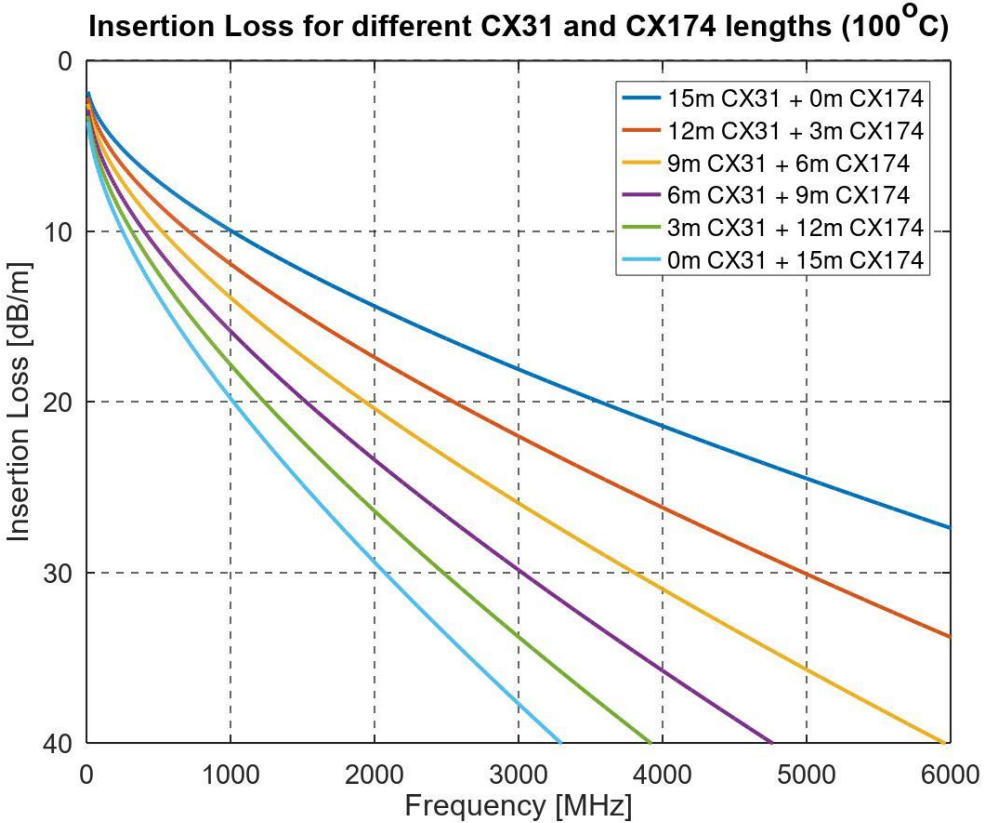
This presentation provides calculations and simulations related to different cable combinations

Insertion Loss for Different Cable Combination

Based on cable specifications defined in ISO 19642-11

Insertion Loss for 15m Coax Cables

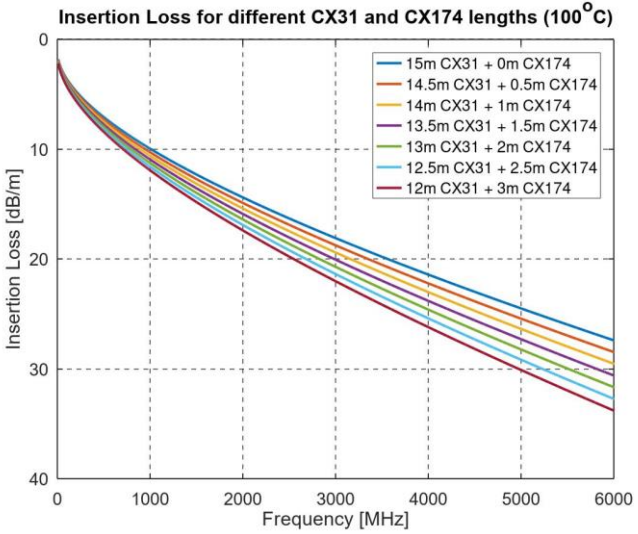
- The plot on the right shows the calculated insertion loss (IL) for15m cables assembled from different combinations of CX31 and CX174 cables (see Note)
- The cables insertion loss are calculated based on CX31 and CX174 limits specified in ISO 19642-11
- The IL is calculated for 100C, by applying the 15% rule specified in Tables 16, 19, 20, etc. of ISO 19642-11

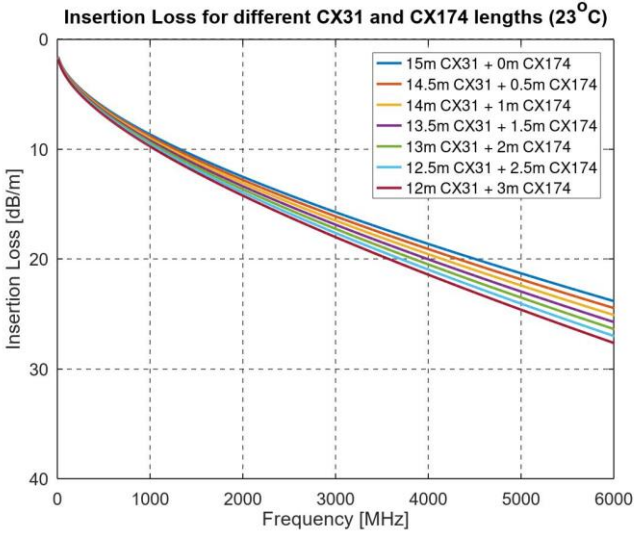


Note: Connectors are not included in the calculations

15m Insertion Loss for Different Combinations

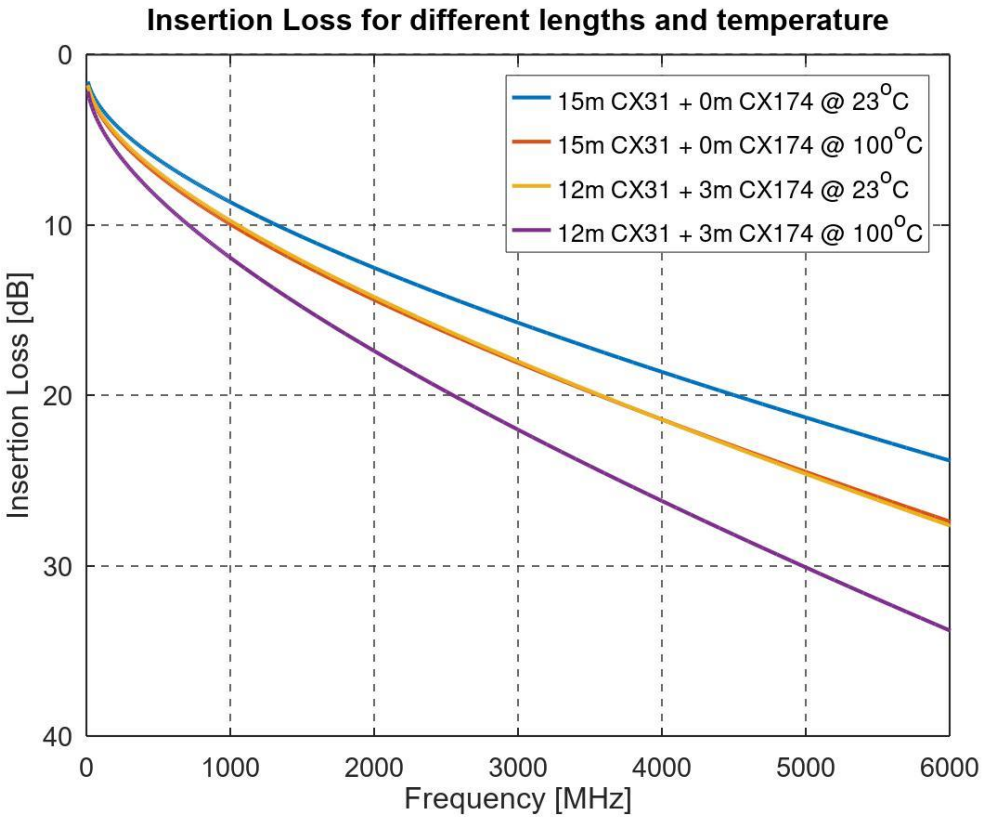
- The plots on the right show insertion loss for different combinations of CX31 and CX174 cables
- All the cables are 15m long, but the length of the flexible CX174 cable ranges from 0m to 3m
- Plot on top shows the IL for cables at 100C, while the plot on the bottom shows IL for cables at room temperature
- Temperature clearly has significant impact on the IL





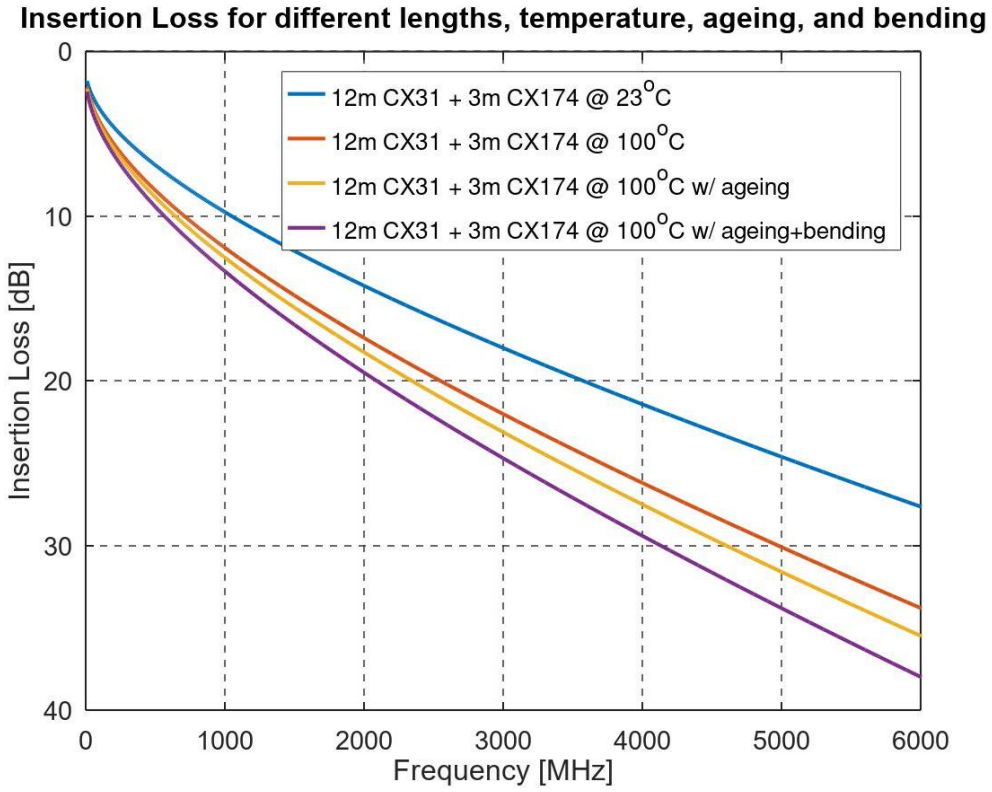
Different Lengths and Temperature

- The plot on the right compares Insertion Loss (IL) for two different compositions at two different temperatures
- In the plot, the 12m CX31 + 3m CX174 cable at 23C has practically the same IL as the 15m CX31 cable at 100C
- Temperature variations can be just as important as cable compositions



Ageing and Bending

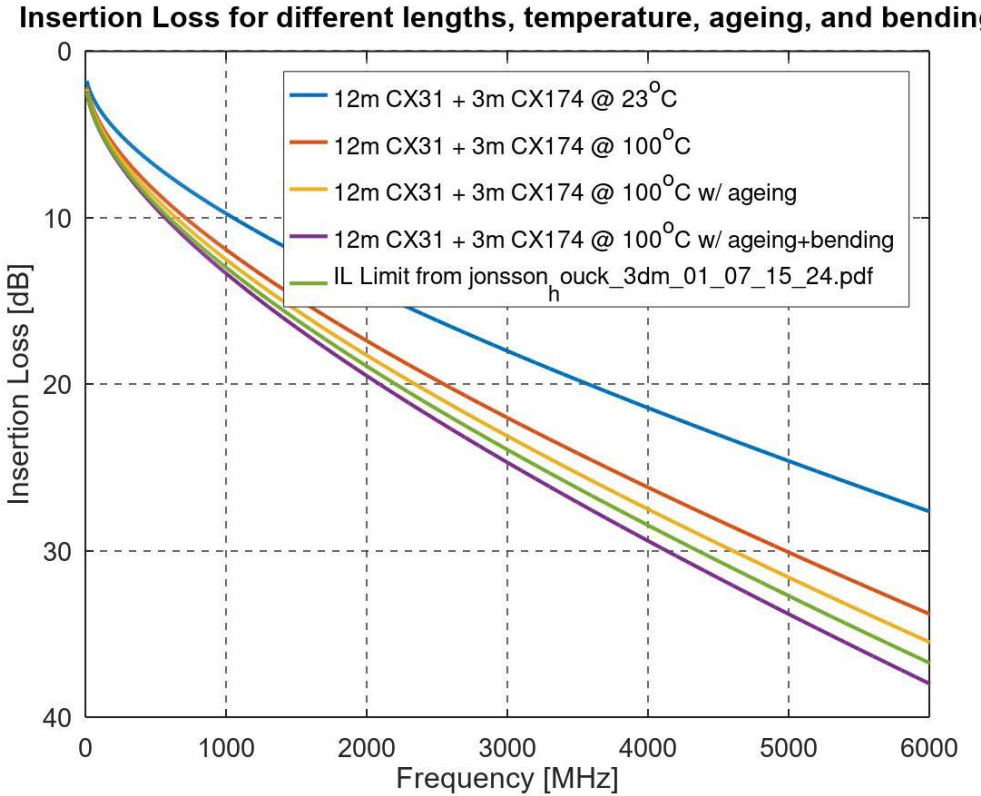
- The plot on the right shows the same cable at different temperatures, and after ageing and bending
- Ageing is modeled as 5% increase in IL, inline with Table 7 of ISO 19642-11 (Note 1)
- There is limited publicly available material on the effect of bending on the IL of Coax cables
- In the plot it is modeled as 20% increase in IL over the CX174 flexible cable segment



Note 1: See also slide 4 of Coax_Cables_Silvano_de_Sousa_ISAAC_Interim_may_2024(002).pdf)

Insertion Loss Limit

- The plot on the right is the same as on previous slide, but also has the previously proposed Insertion Loss Limit from [jonsson_houck_3dm_01_07_15_24.pdf]
- The previously proposed Insertion Loss Limit falls between the two worst insertion loss curves (with and without bending)
- Based on this, it could be argued that the previously proposed Insertion Loss Limit was too strict, rather than too relaxed



Cable Simulations

Using Transmission-Line Theory

Why do Simulation?

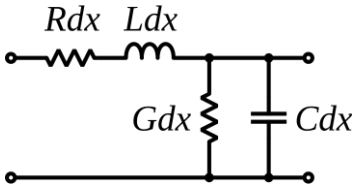
We have limited number of cable measurements

We want to experiment with many different cable structures

We can use the exact same (simulated) cable in different configurations for apples-to-apples comparison

The simulations are to augment (not replace) the cable measurements we have

Channel Model From Transmission-Line Theory



$$\begin{bmatrix} V_1 \\ I_1 \end{bmatrix} = \begin{bmatrix} A & B \\ C & D \end{bmatrix} \begin{bmatrix} V_2 \\ I_2 \end{bmatrix}$$

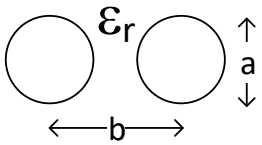
Transmission-Line Theory is used to generate parameterized channel models from channel measurements

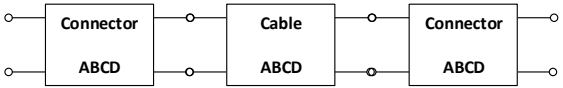
The Primary Coefficients are calculated from the cable properties

We generate two-port model for cable segments based on Primary Coefficients

More complex models are generated by concatenating multiple two-port

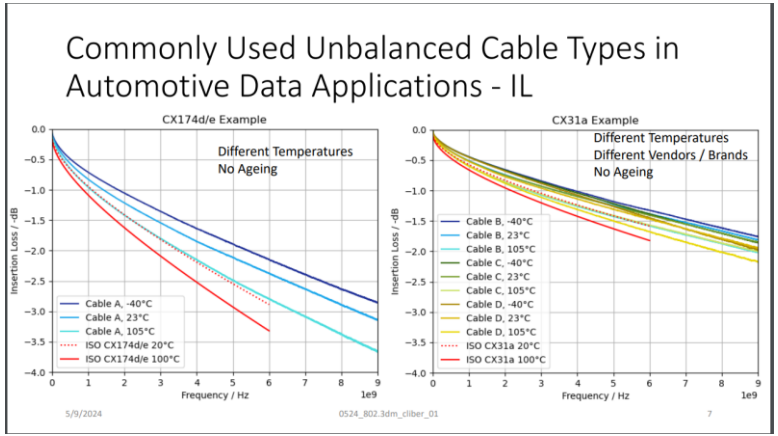
ABCD matrices are used to calculate the composite channel characteristics



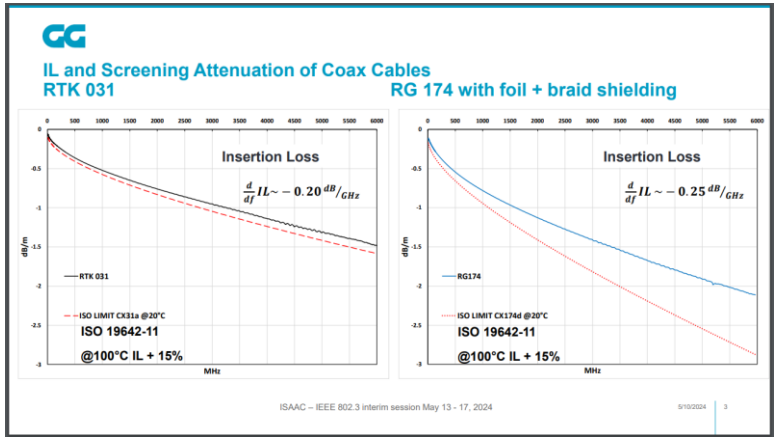


Simulating Real Coax Cables

- There were two presentations on coax cable performance presented at the 802.3dm meeting in May 2024:
  - "Coaxial Unbalanced Media for Automotive Applications" by David Cliber and Bert Bergner
  - "Coaxial Cables Performance" by Jonathan Silvano de Sousa
- The insertion loss presented in both presentations was better than the corresponding Insertion Loss Limits defined in ISO 19642-11
- Our simulated cables are modeled after cables that are similar to the cables in these presentations



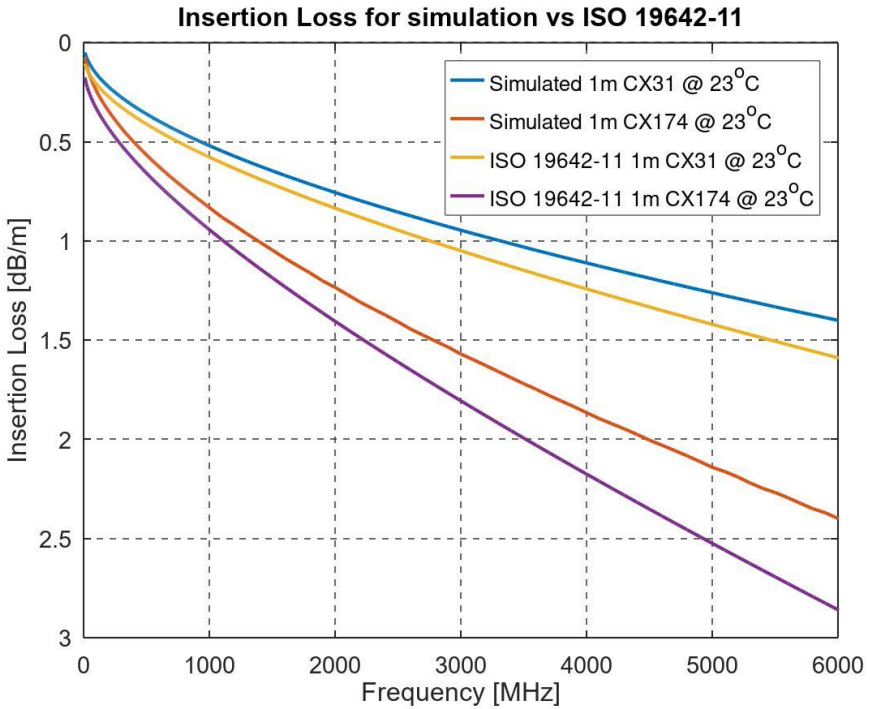
From https://www.ieee802.org/3/dm/public/0524/03May24_802.3dm_Cliber.pdf



From https://www.ieee802.org/3/dm/public/0524/Coax_Cables_Silvano_de_Sousa_ISAAC_Interim_may_2024(002).pdf

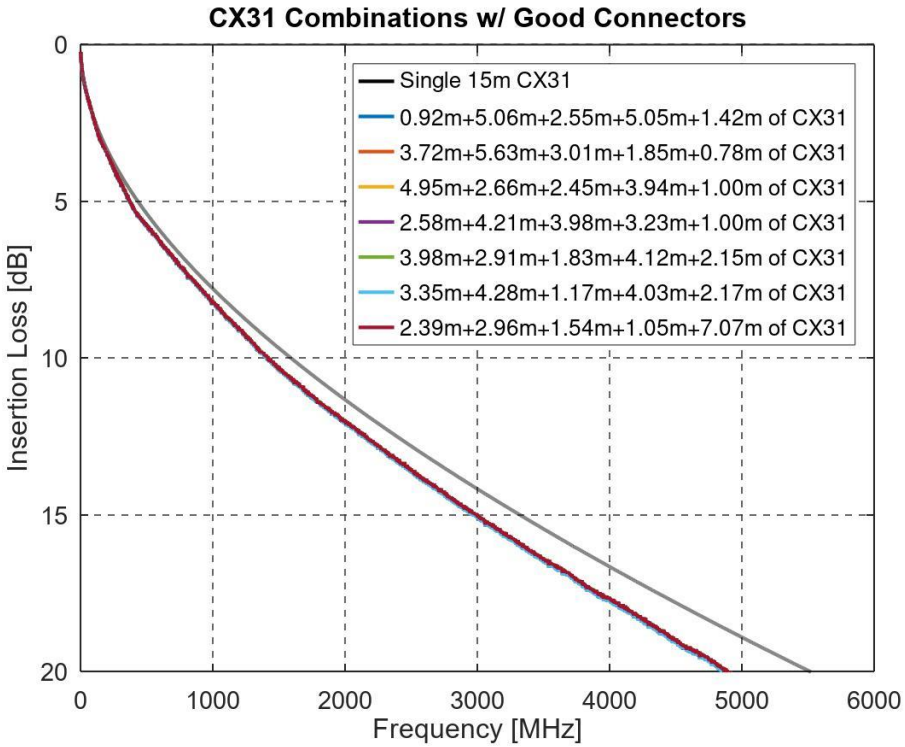
Simulated Insertion Loss

- The plot on the right shows the simulated insertion loss for 1m long cables, compared to the corresponding ISO 19642-11 limits
- Just like the cables from the May presentations, the simulated cables have less insertion loss than the corresponding ISO 19642-11 limits



Insertion Loss with Good Connectors

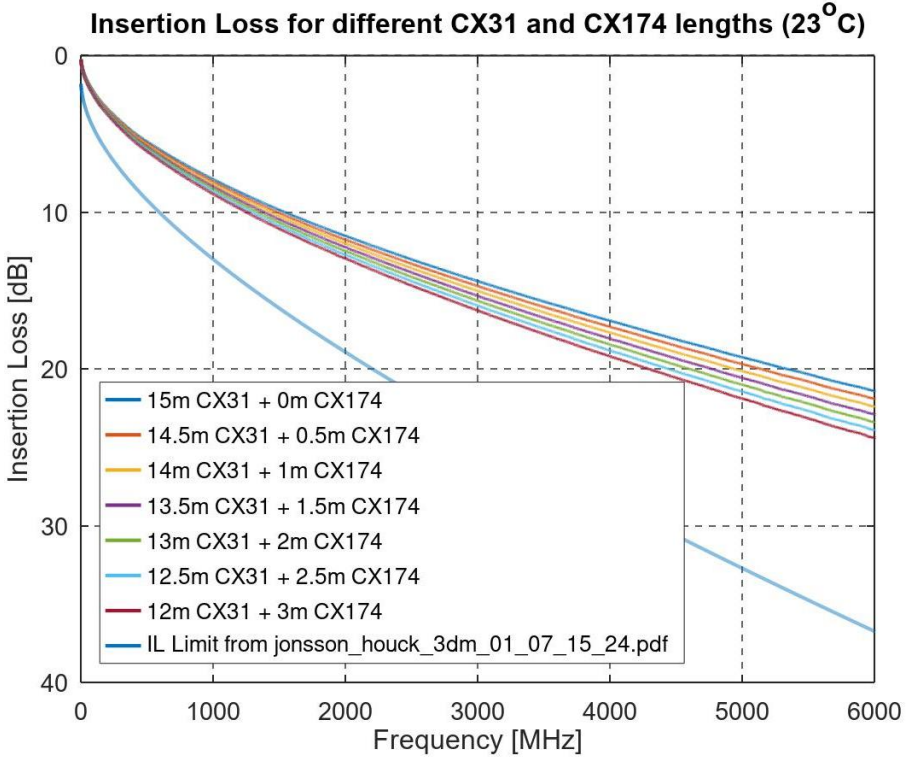
- The plot on the right has 15m CX31 cables combined from link segments of different length
- The simulation was done with good cables and good connectors (See Note)
- The good connectors introduce some extra insertion loss, compared to straight 15m cable, but have otherwise little impact on the insertion loss



Note: The good connectors are modeled with measured data

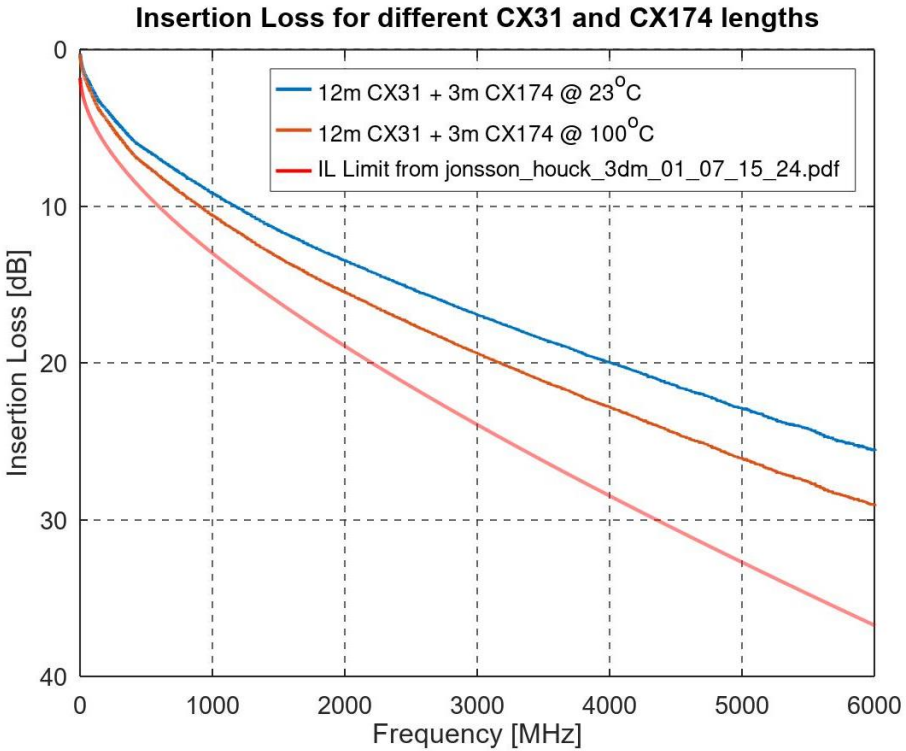
15m Insertion Loss for Different Combinations

- The plot on the right shows insertion loss for different combinations of simulated CX31 and CX174 cables at room temperature
- All the cables are 15m long, but the length of the flexible CX174 cable ranges from 0m to 3m
- The plot also has the previously proposed Insertion Loss Limit from jonsson_houck_3dm_01_07_15_24.pdf, which has ample margin



Simulated Temperature Dependance

- The plot on the right shows insertion loss for the same cable at two different temperatures
- As expected, the cable has higher insertion loss at higher temperature
- The simulated cable insertion loss does not include ageing and bending degradation
- The simulated cables have good margin compared to the Insertion Loss Limit from [jonsson_houck_3dm_01_07_15_24.pdf]



Summary

- Insertion loss for 15m coax cables have been analysed
- Worst case analysis of cable insertion loss based on ISO 19642-11 requirements show that the Insertion Loss Limit proposed in jonsson_houck_3dm_01_07_15_24.pdf is borderline to address valid cable combinations according to ISO 19642-11
- Simulations using models of actual CX31 and CX174 cables shows that real cables can pass the Insertion Loss Limit with some margin

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