

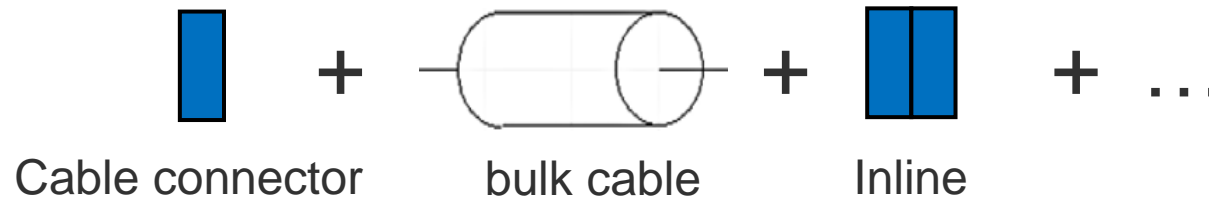
Return loss of automotive coaxial link segments

Thomas Müller, Stephan Kunz and Philipp Grimm (Rosenberger)

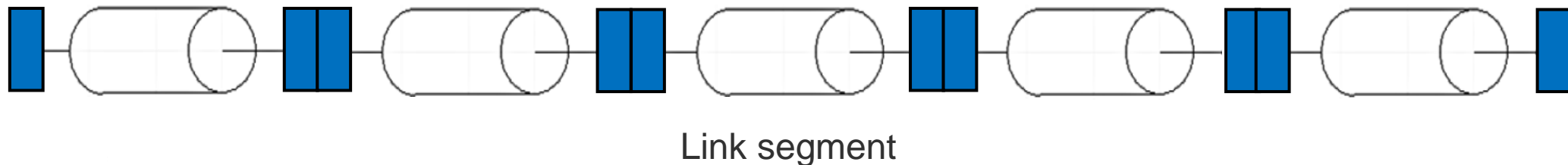
18th of July 2024

Scope

- Share simulation results on automotive coaxial link segment return loss (RL) to support defining appropriate RL requirements
- Method is to combine cable connectors, bulk cable segments and mated connector pairs (inlines) to build up complete link segments



- The link segment topology may be up to 15 m with up to 4 Inlines

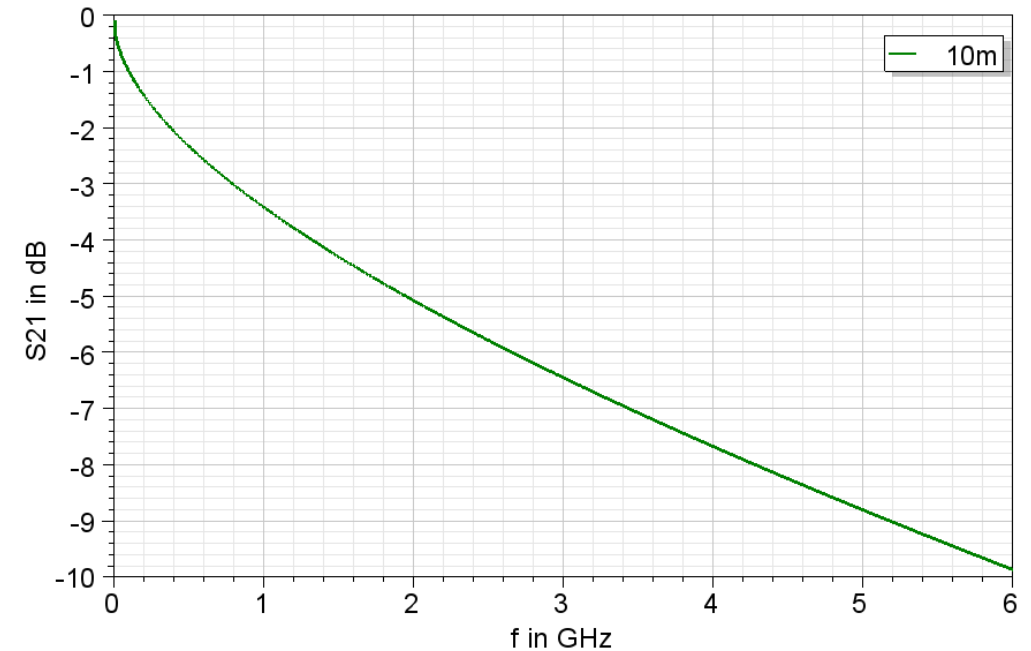


Cable model

- Physical model of automotive coaxial cable type RTK044 including loss, propagation delay and micro-reflections (μR)
- Automotive coaxial cable AWG20 type RTK044 at -40°C
- Low cable insertion loss attenuates connector reflexions the least, causing lowest return loss
- Nominal impedance 50 ± 3 Ohm (6%) with max./min. alteration between segments



Bulk cable model

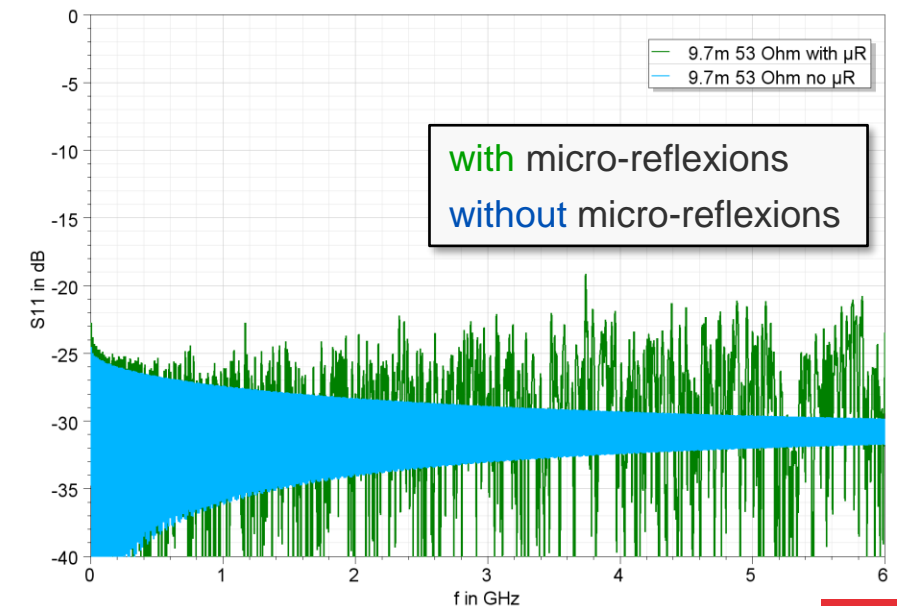
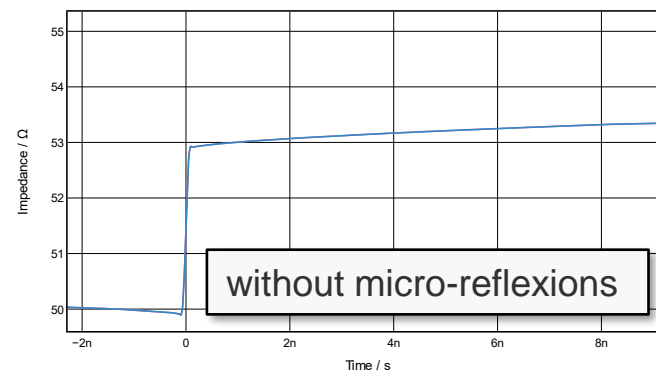
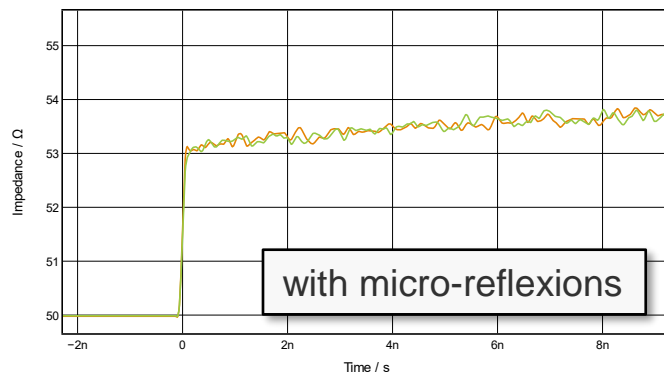


Cable model

- Micro-reflections are caused by minor imperfections that are distributed along the cable and therefore are length dependent
- Micro-reflections restrict the achievable cable RL in the GHz range ([mueller_3cy_01_10_14_20.pdf](#)) and therefore, are considered in the simulation
- The cable causes distributed minor reflexions overlaying with larger locally confined reflexions caused by connectors to a link segment return loss
- Cable impedance and RL comparison



Bulk cable model

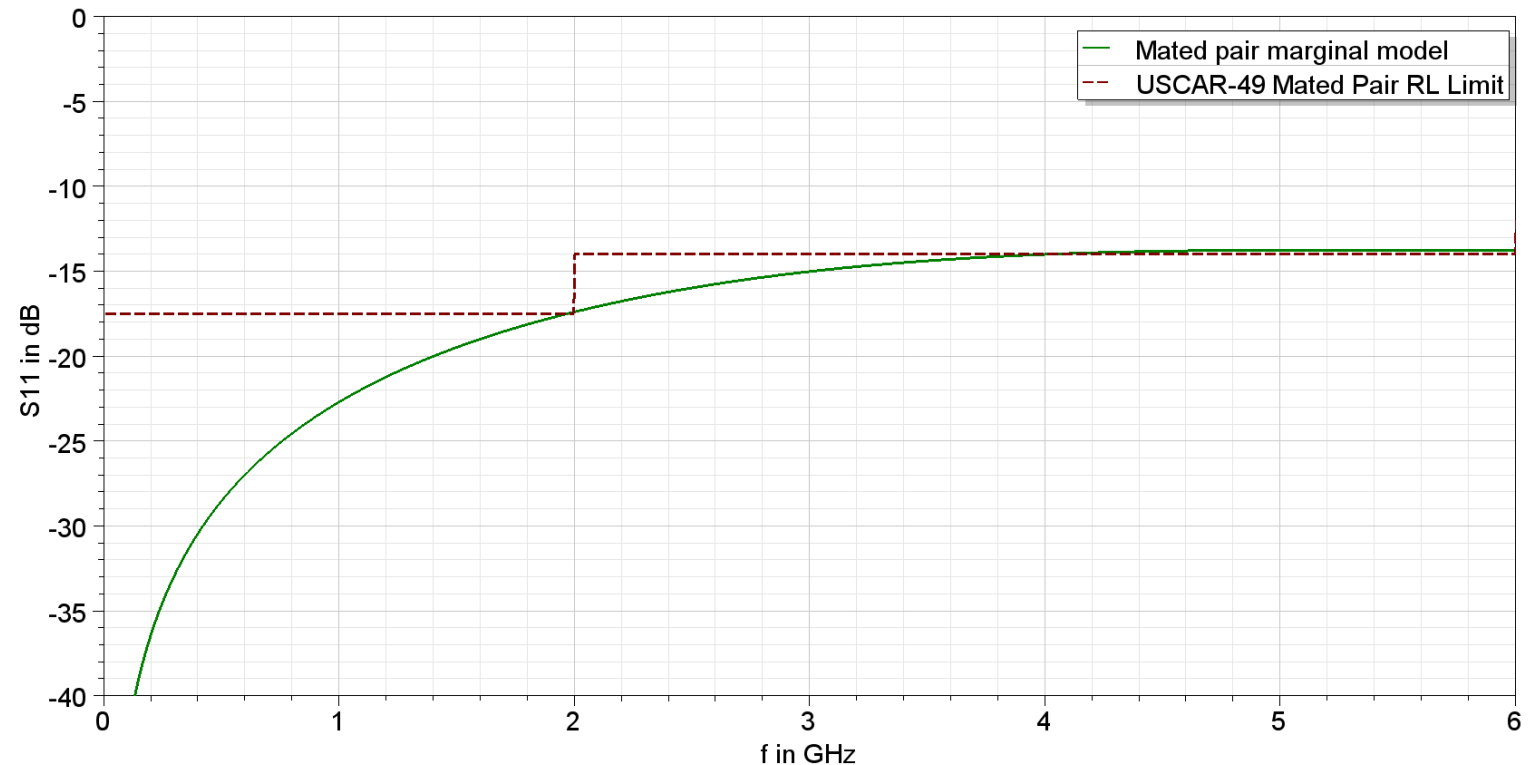


Connector model

- Component models based on physical transmission line model valid for RL, IL and delay
- RL of mated pair marginal to USCAR-49 mini coax requirements [2022-09]

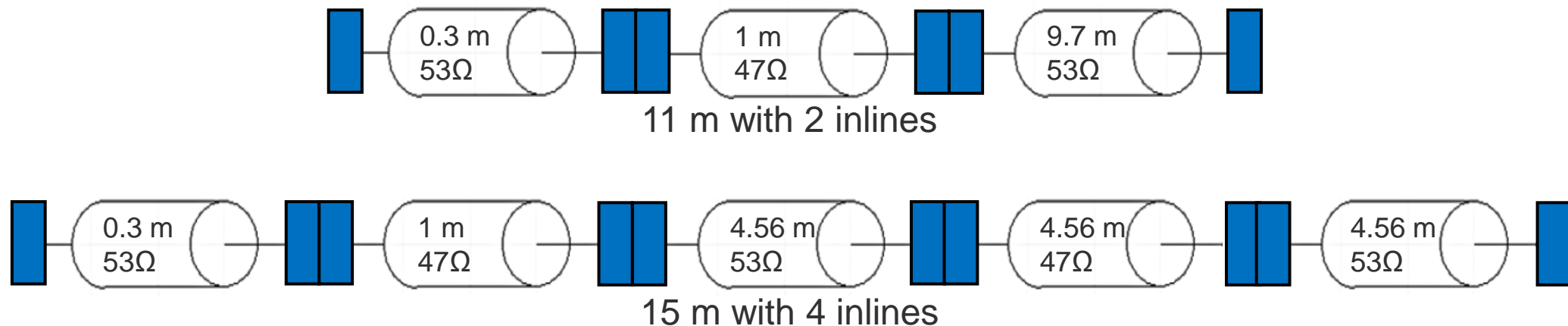


Mated connector pair model



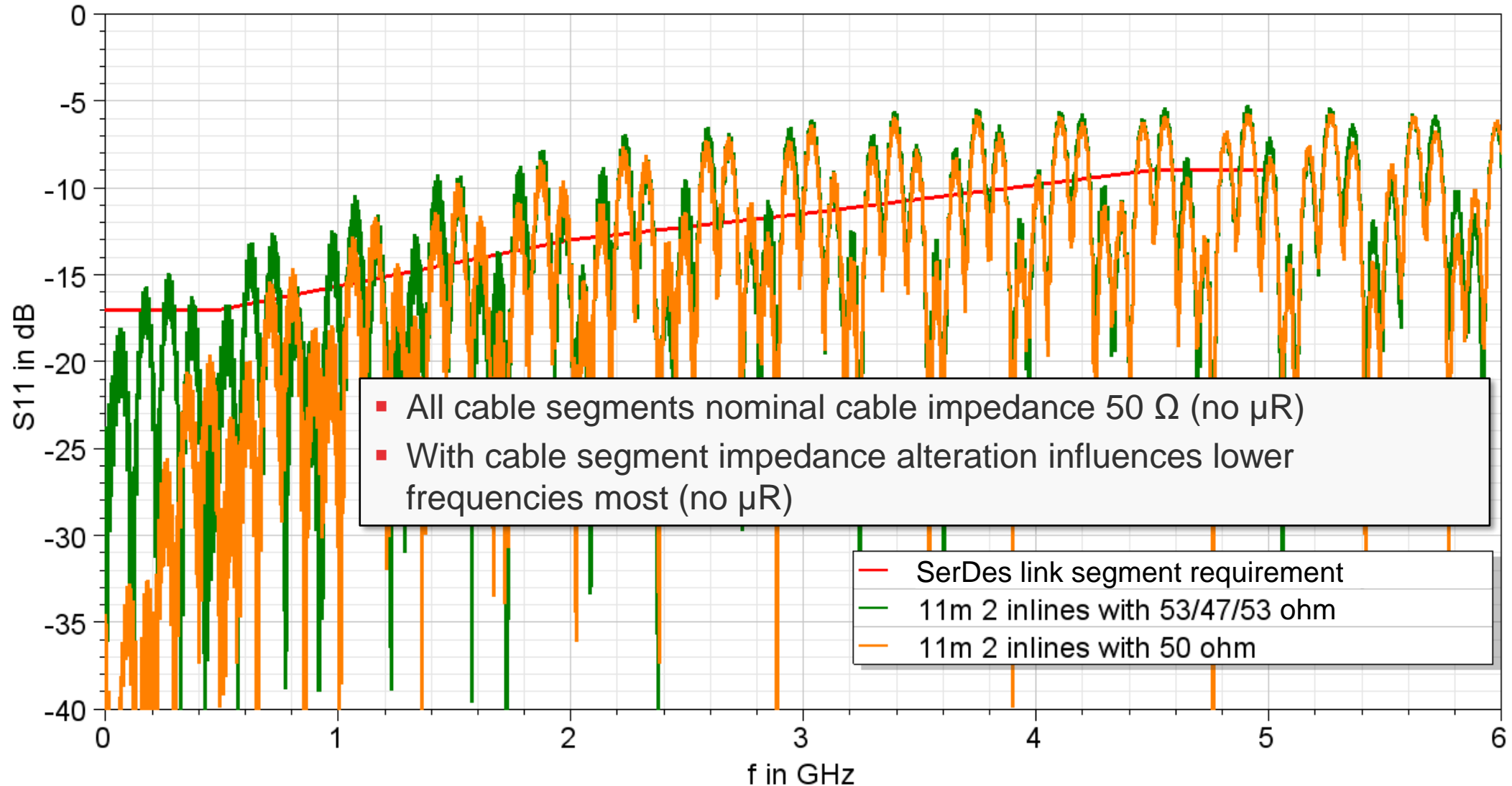
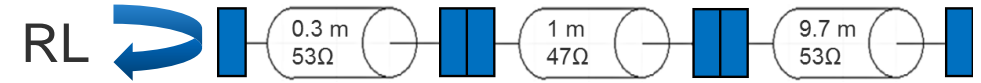
Link segment topology

- Minimum distance between inlines (e.g. 5 x 0.3 m) would lead to worst link segment RL
- Practical worst case with first cable segment at least 0.3 m and second at least 1 m
- Link segment topology based on OEM camera use case in https://www.ieee802.org/3/B10GAUTO/public/may19/wienckowski_3+10G_01a_0519.pdf
- Alternating min. / max. nominal impedance between cable segments $50\Omega \pm 3\Omega$



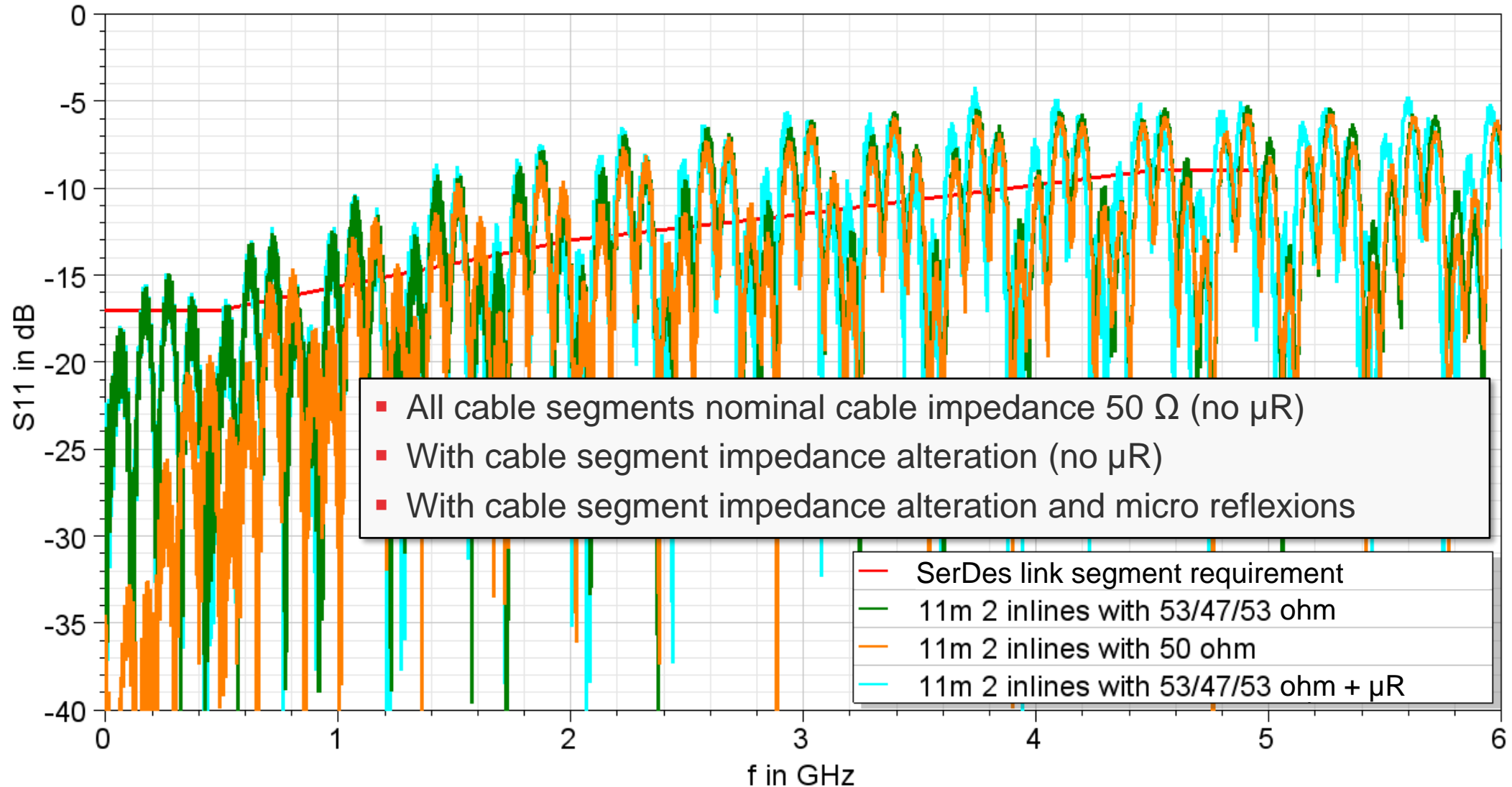
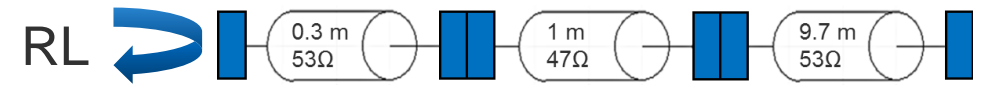
Return loss of automotive coaxial link segments

11 m with 2 inlines



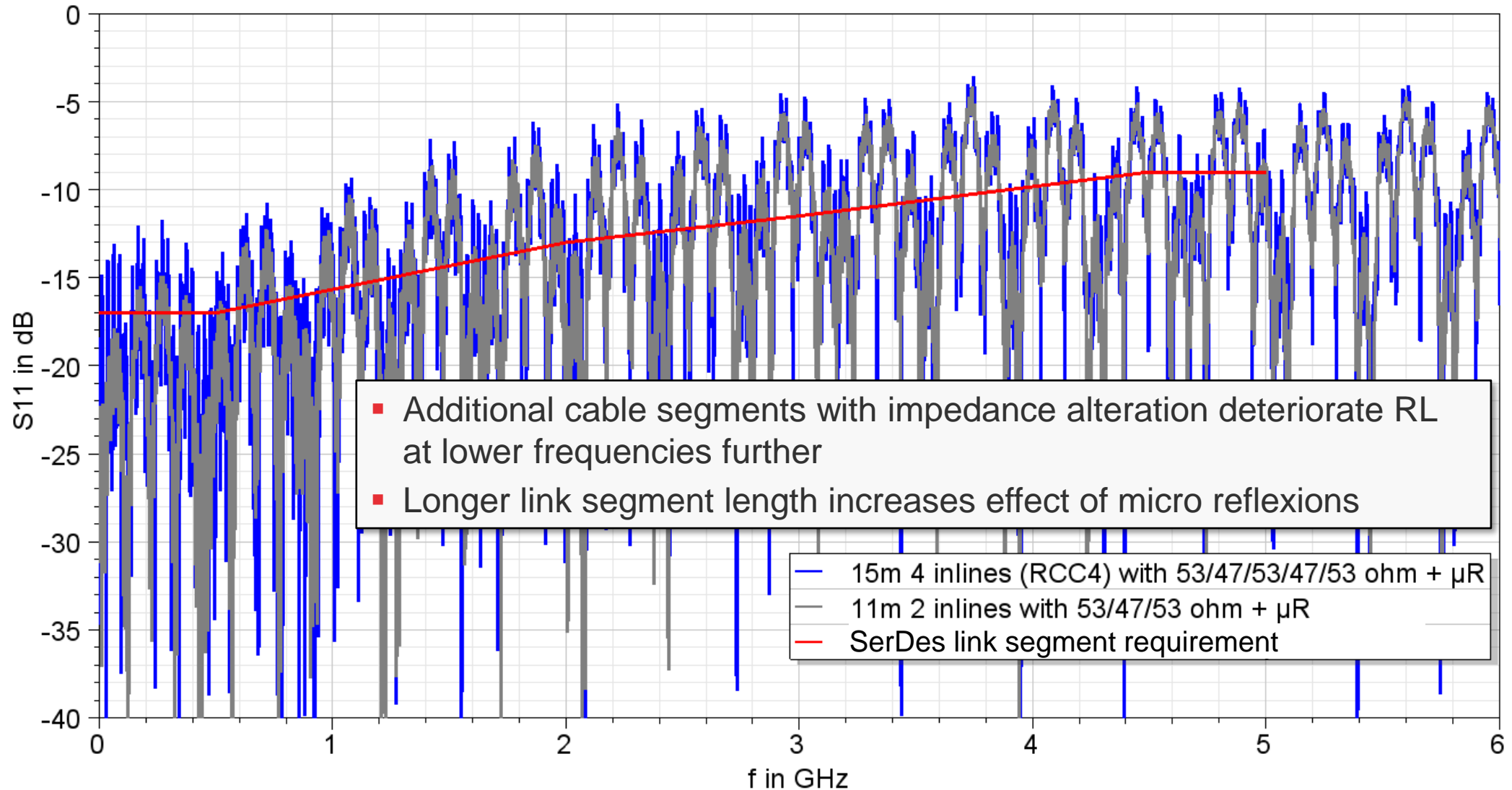
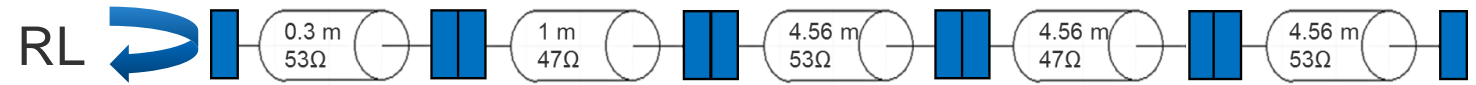
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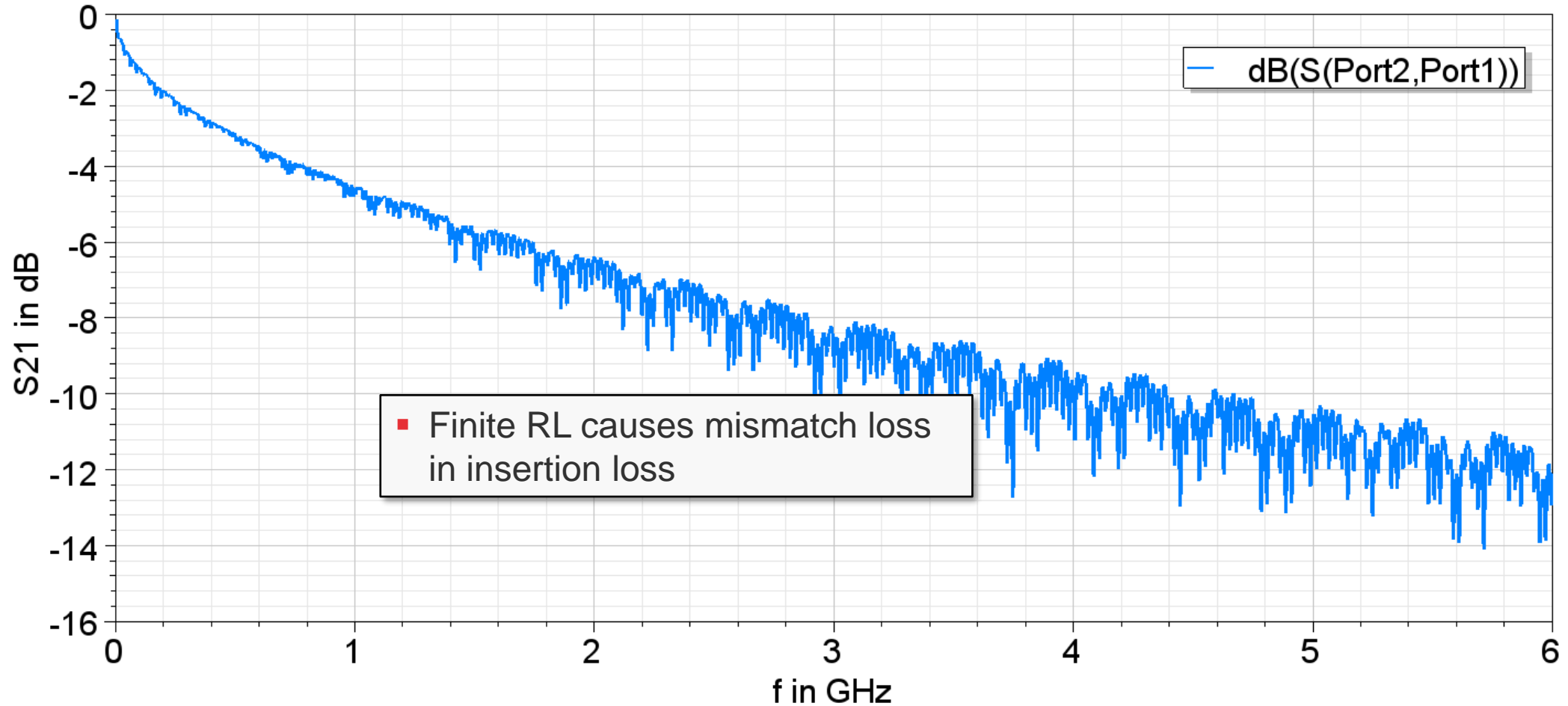
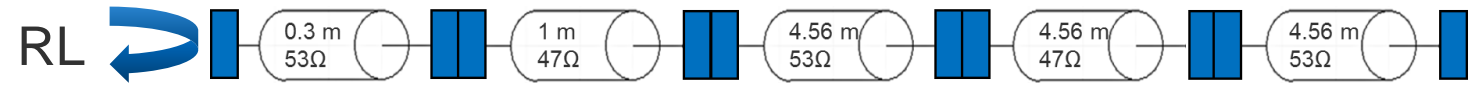
Return loss of automotive coaxial link segments

15 m with 4 inlines



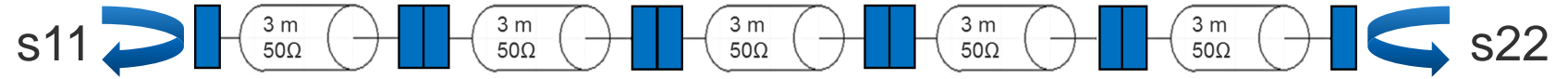
Return loss of automotive coaxial link segments

15 m with 4 inlines



Return loss of automotive coaxial link segments

Measurement results example

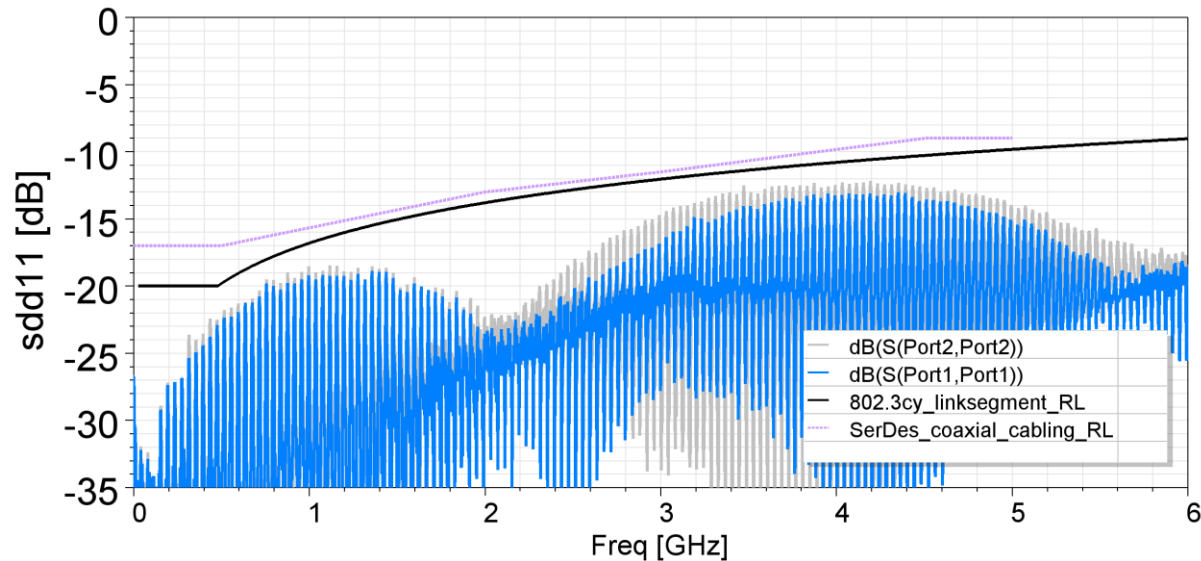


- Automotive Highspeed FAKRA Mini connectors (Rosenberger HFM)
- Cable type RTK044 at room temperature
- Cable segments all from same production lot



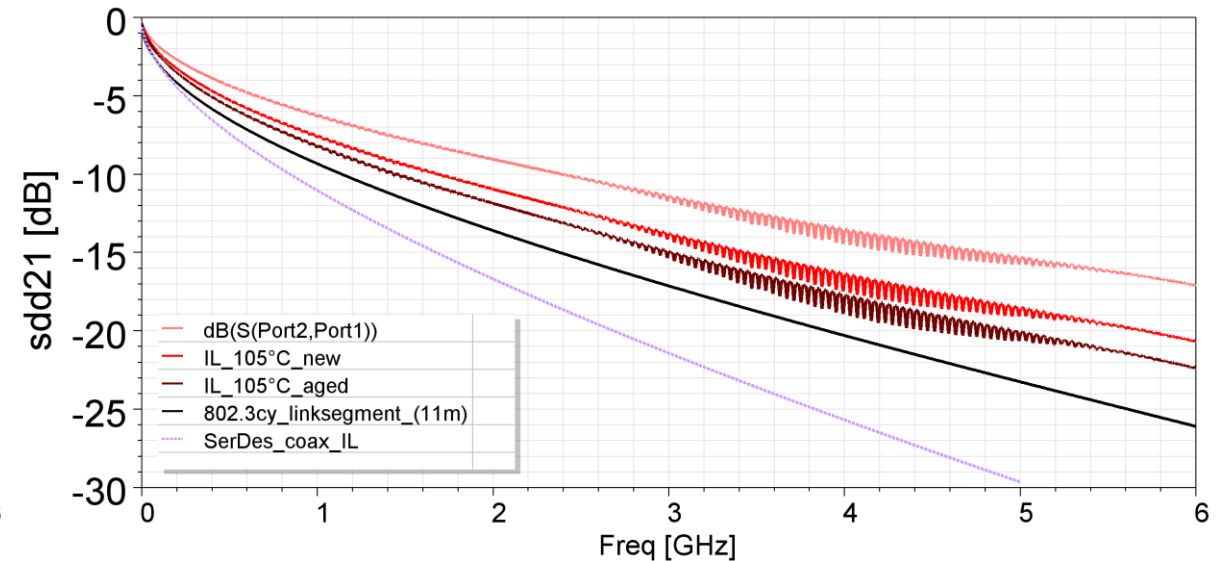
Link segment RL (15m 4 Inlines)

15m_4IL Ansys 2023 R1



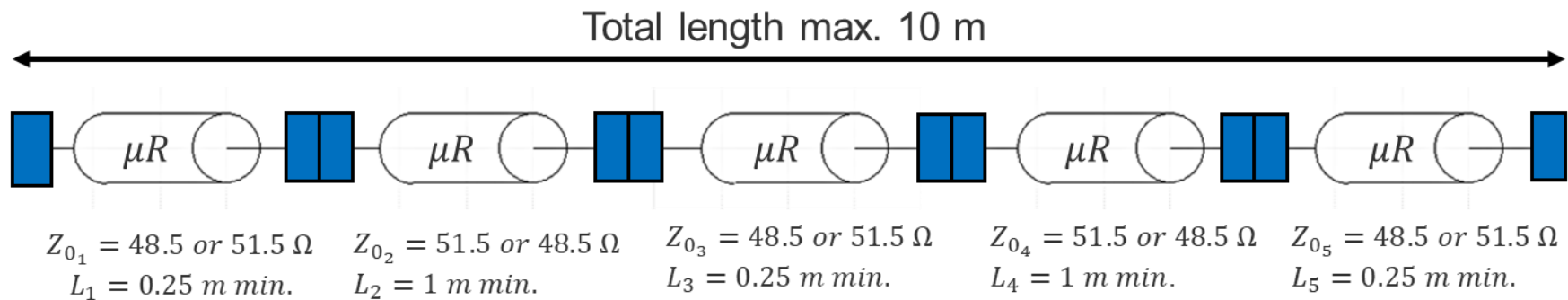
Link segment IL (15m 4 Inlines)

15m_4IL Ansys 2023 R1



Model-based validation of link segments

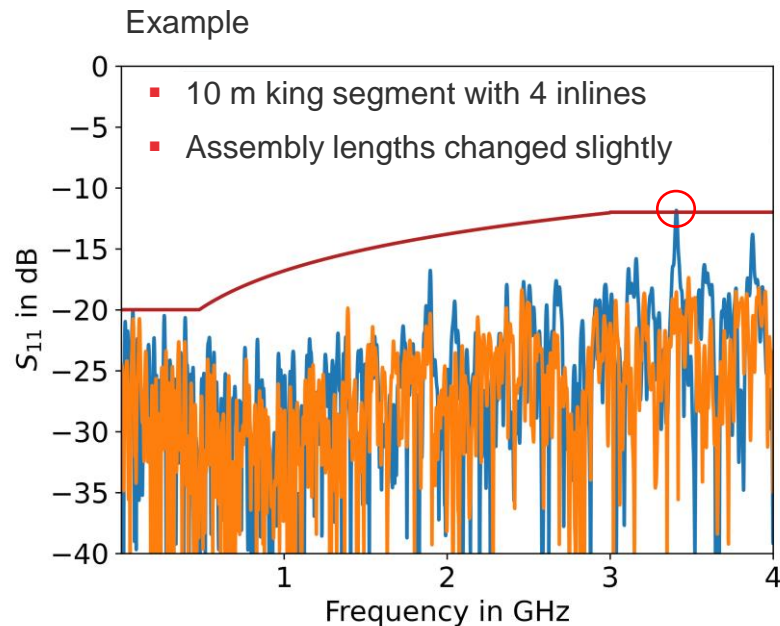
- Random sampling (Monte-Carlo) of lengths sequentially (0.25 m step width)
- Segment lengths depending on each other ($L_1 \uparrow \Rightarrow (L_2, L_3, L_4, L_5) \downarrow$)
- Generation of about 122 thousand variations



Return loss of automotive coaxial link segments

Model-based validation of link segments – example 10GBASE-T1

- Limit violation for around 62 % of the evaluated designs → formal „possibility“ of failure
- On average the limit was violated by 0.8 dB over a very small bandwidth
- 75 % of the failing samples violated for < 0.3 dB

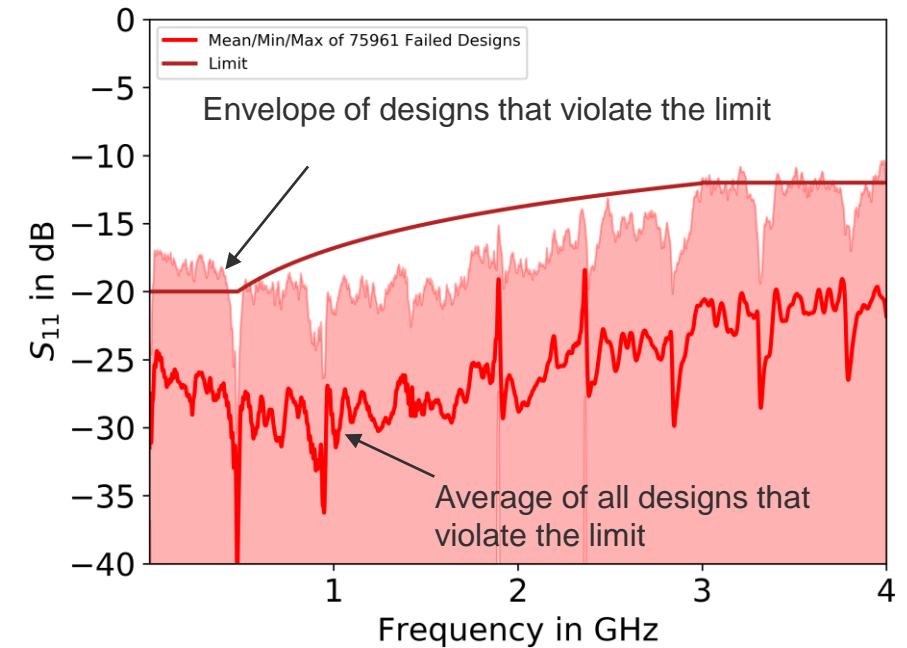


FAIL



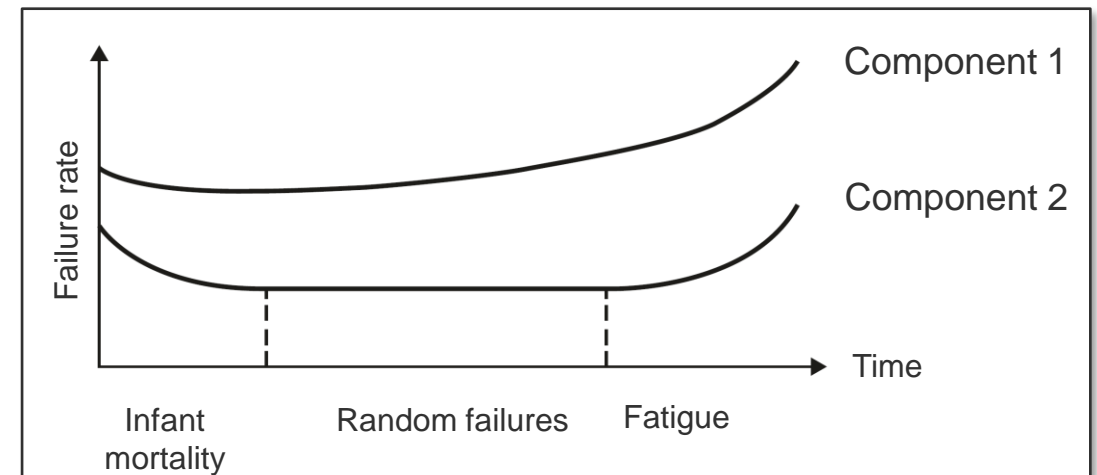
PASS

Small modifications lead to passing channels!



802.3dm for safety critical applications

- Functional safety is essential for the implementation of innovative technologies (OEM statement on relevance of functional safety)
- Manufacturers of cables and connectors have been asked to provide FIT-rates (failure in time) for their components, as like for other passive and active electronic components
- Will our standard be “fit for FIT” to enable safety critical applications or are there potential gaps which we should address in our working group?



Summary

- Simulation results on link segment RL calculations based on automotive cables and connectors have been presented
- If connectors compliant with and marginal to USCAR-49 (mini-coax) are used, the resulting link segment return loss is significantly lower than what was defined in previous projects clause 149.7.1.3.3 (10GBASE-T1) and clause 165.7.1.3.1 (25GBASE-T1) for the differential case
- PHY suppliers may provide feedback, whether the resulting link segment RL based on standardized connectors is acceptable
- Otherwise, connectors with tighter specifications or further topology restrictions may be considered to reach acceptable link segment RL
- RL for STP may be specified based on 25GBASE-T1 with some dB relaxation for lower frequencies and f_{\max} chosen as required, as cabling components and topology are identical

Link segment RL proposal

- Comparison of current link segment RL proposals and additional proposal for further discussion

