Return loss of automotive coaxial link segments

Thomas Müller, Stephan Kunz and Philipp Grimm (Rosenberger)
15th of July 2024

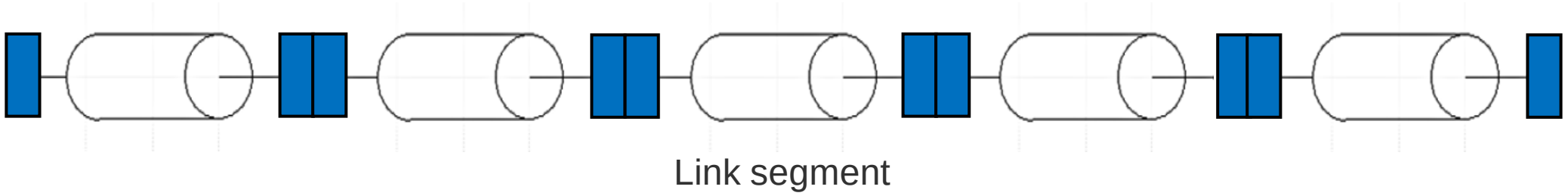
Return loss of automotive coaxial link segments

Rosenberger

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

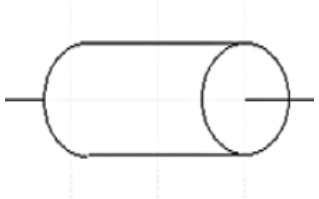


Return loss of automotive coaxial link segments

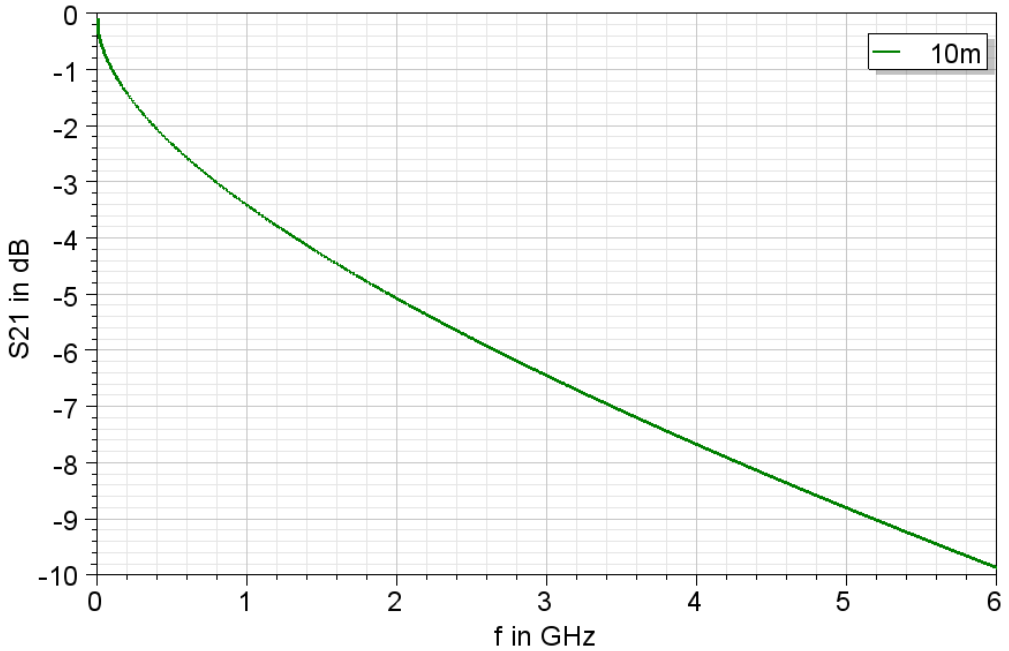
Rosenberger

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

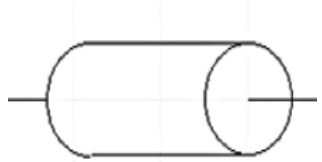


Return loss of automotive coaxial link segments

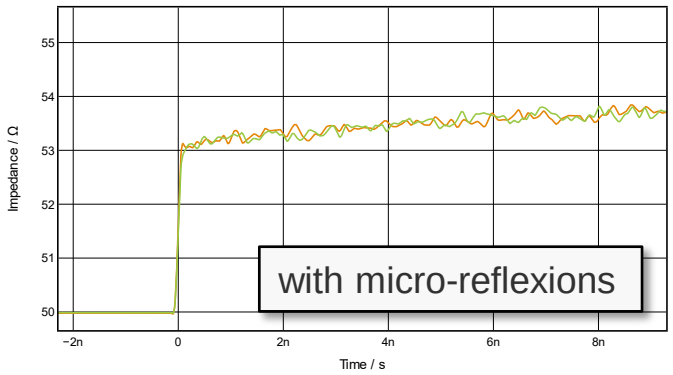
Rosenberger

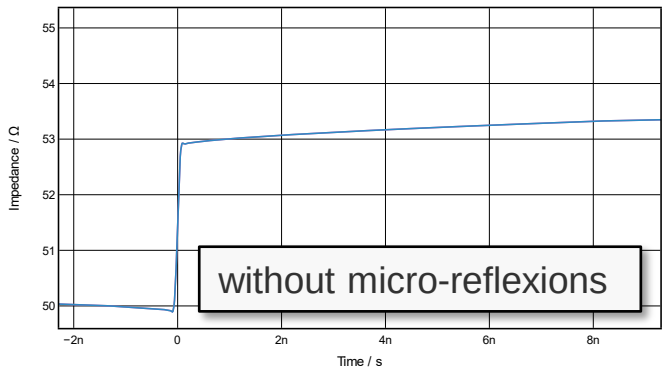
Cable model

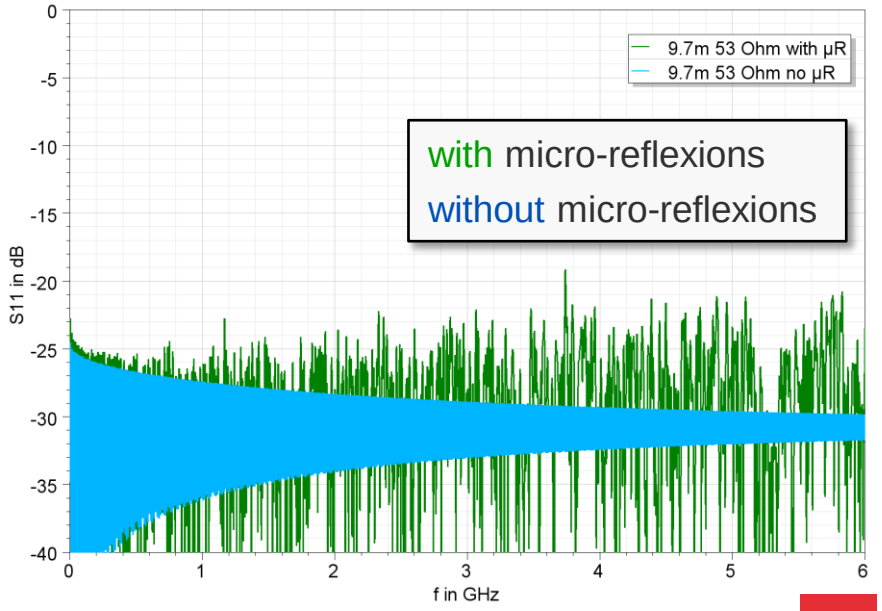
- Micro-reflections are caused by minor imperfections that are distributed along the cable and therefore are length dependent
- Micro-reflections restrict the achievable cable RL in the GHz range (mueller_3cy_01_10_14_20.pdf) and therefore, are considered in the simulation
- The cable causes distributed 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







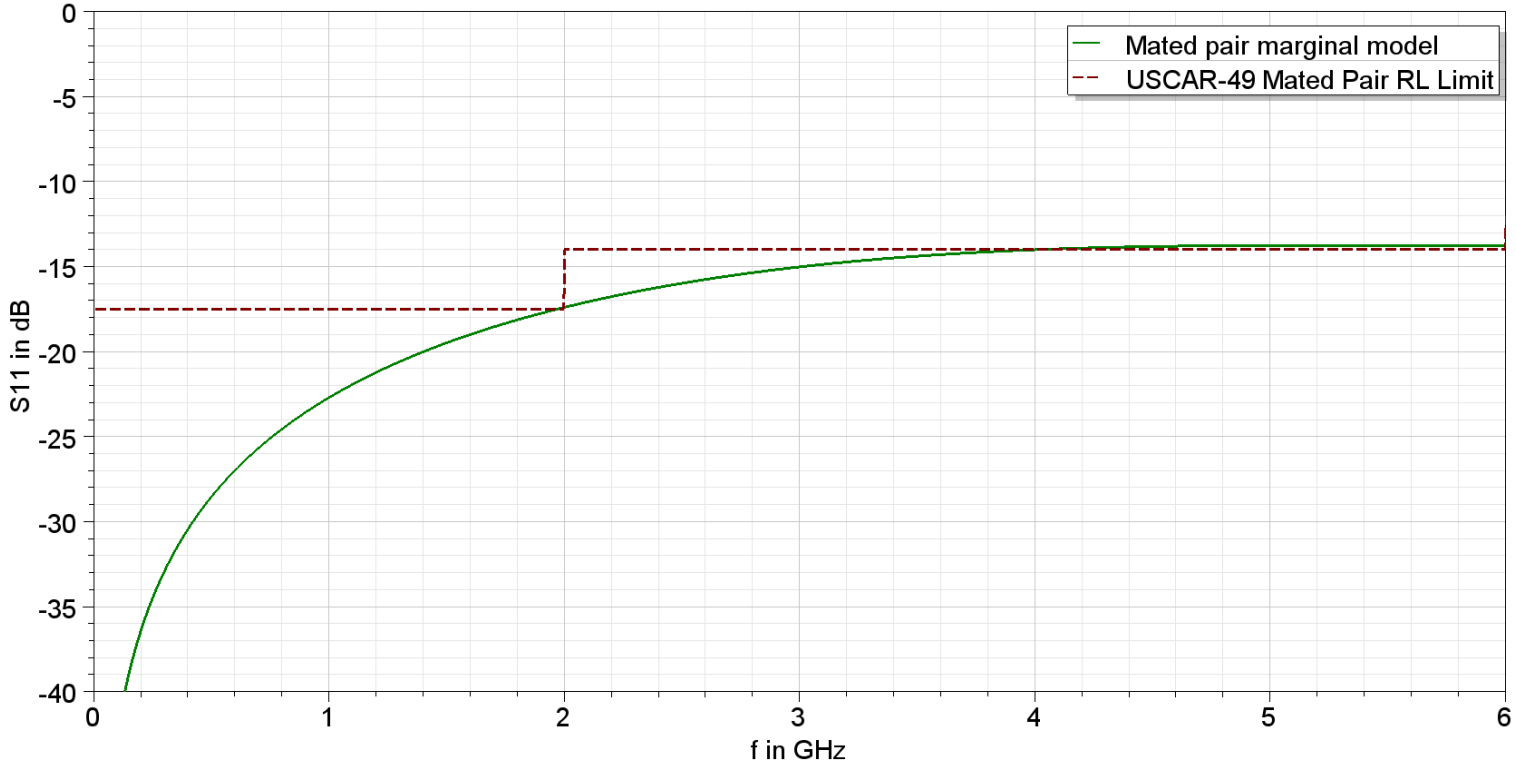
Return loss of automotive coaxial link segments

Rosenberger

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

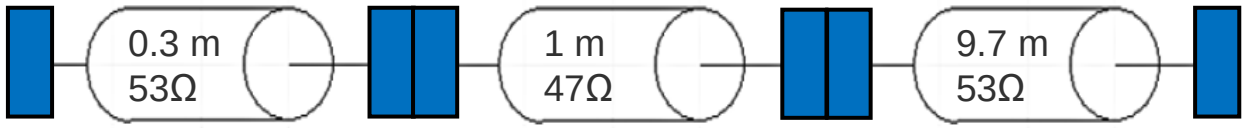


Return loss of automotive coaxial link segments

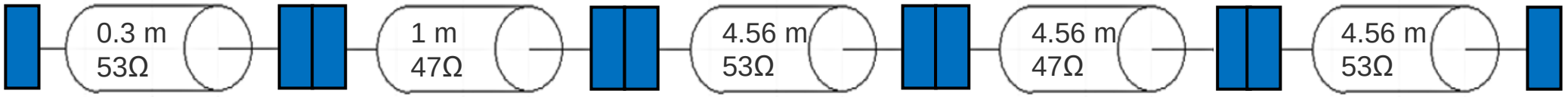
Rosenberger

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 50Ω ± 3Ω



11 m with 2 inlines

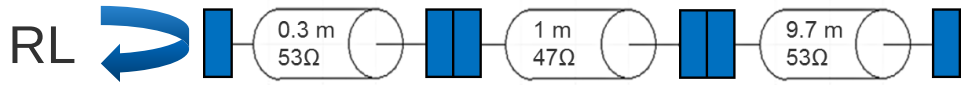


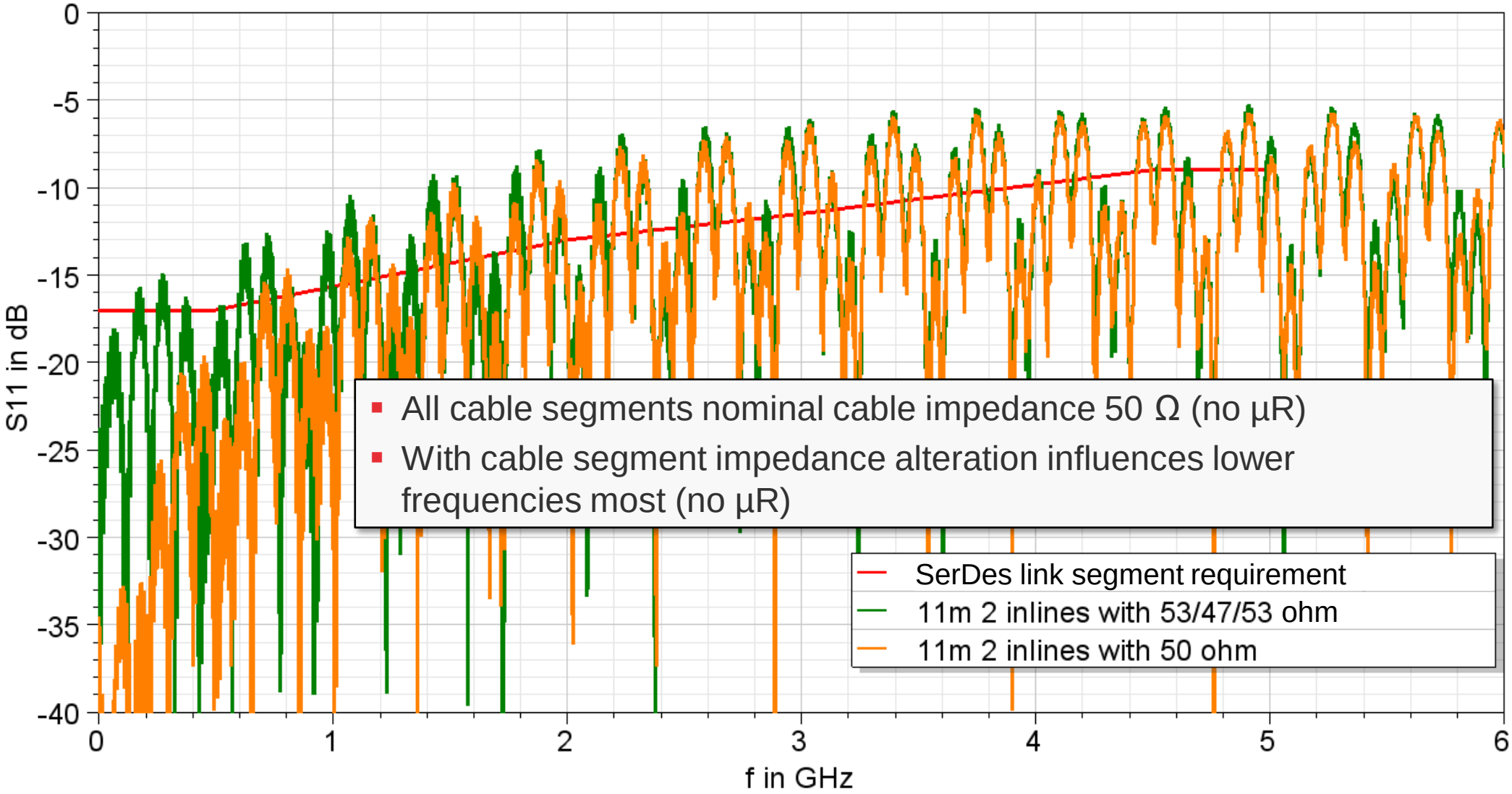
15 m with 4 inlines

Return loss of automotive coaxial link segments

Rosenberger

11 m with 2 inlines



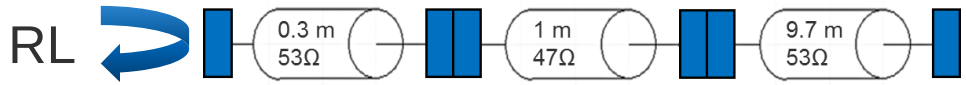


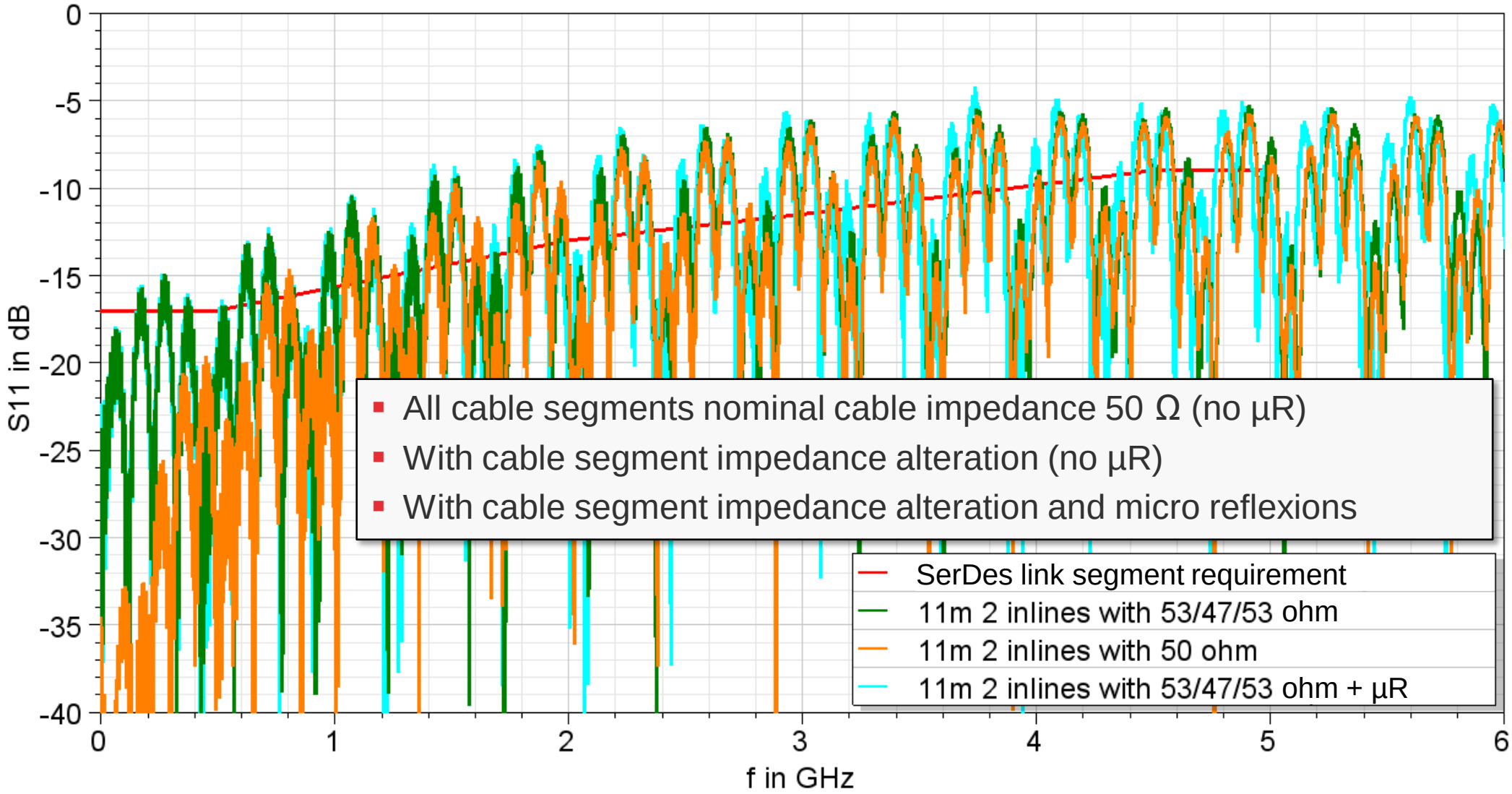
- All cable segments nominal cable impedance 50 Ω (no µR)
- With cable segment impedance alteration influences lower frequencies most (no µR)

Return loss of automotive coaxial link segments

Rosenberger

11 m with 2 inlines

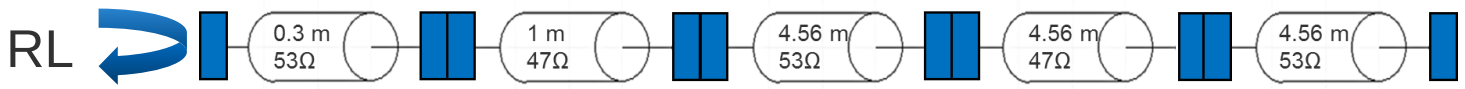


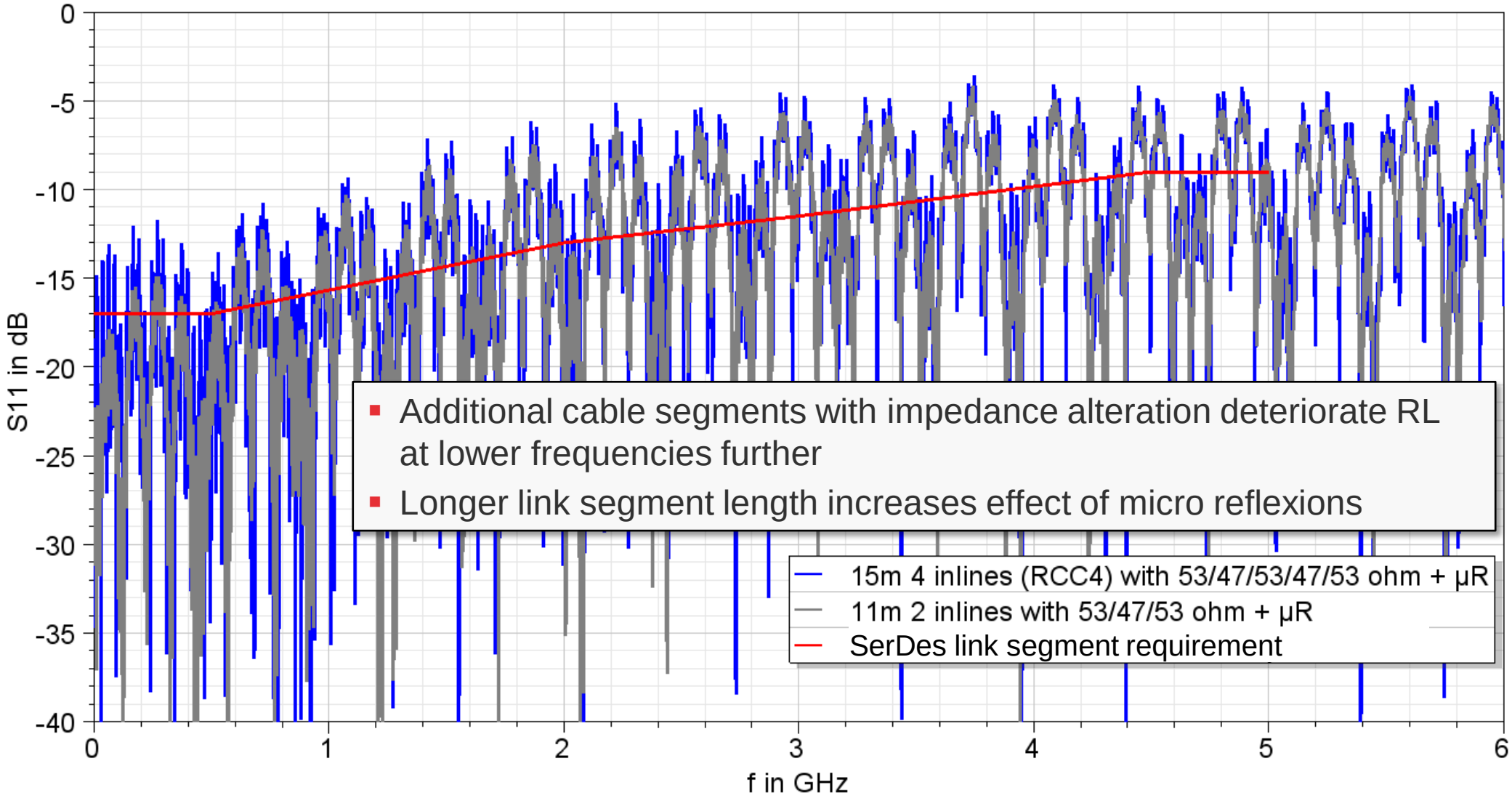


Return loss of automotive coaxial link segments

Rosenberger

15 m with 4 inlines



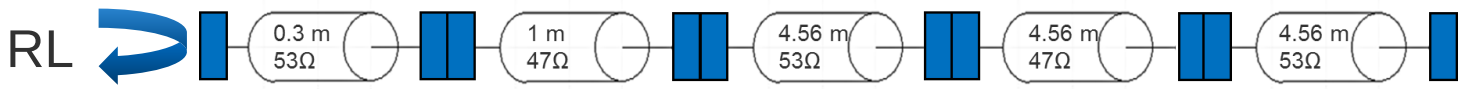


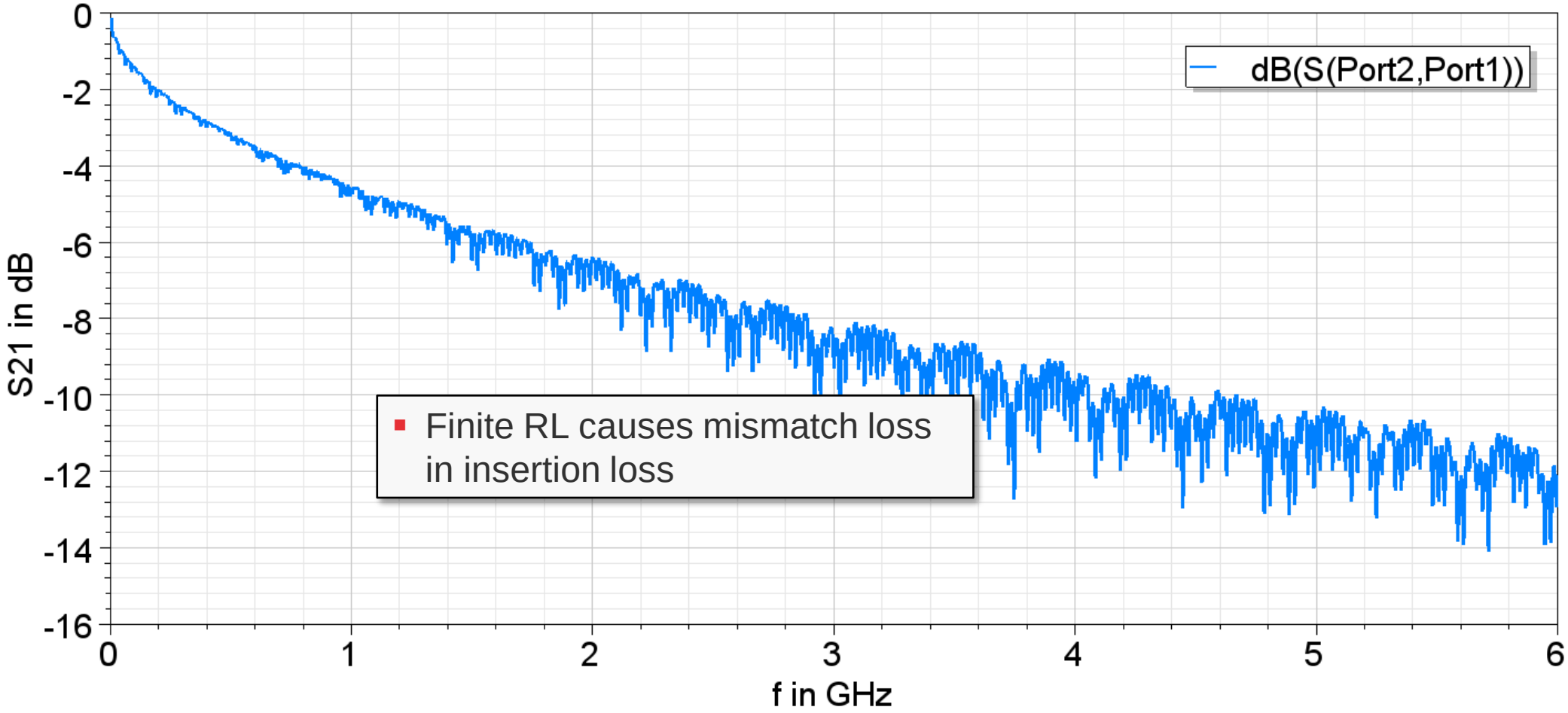
- Additional cable segments with impedance alteration deteriorate RL at lower frequencies further
- Longer link segment length increases effect of micro reflexions

Return loss of automotive coaxial link segments

Rosenberger

15 m with 4 inlines

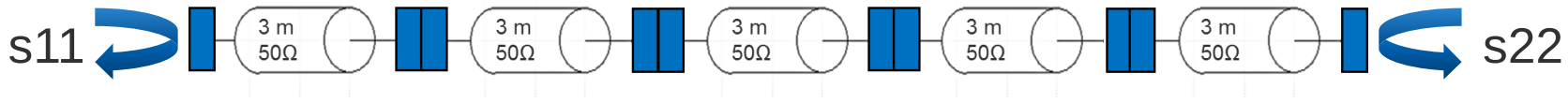




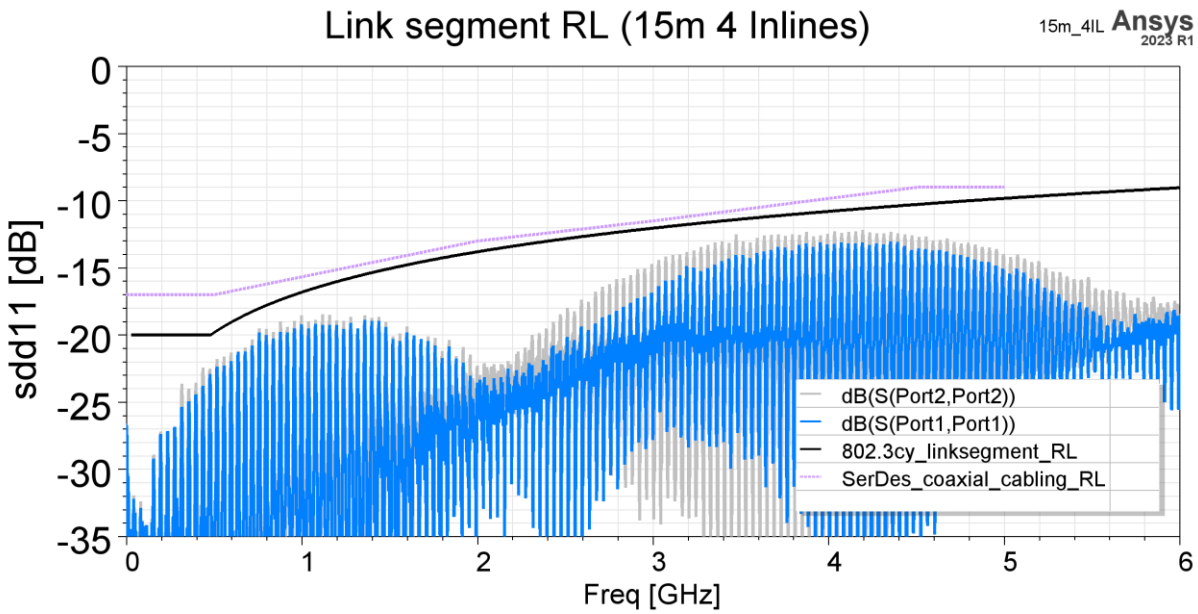
Return loss of automotive coaxial link segments

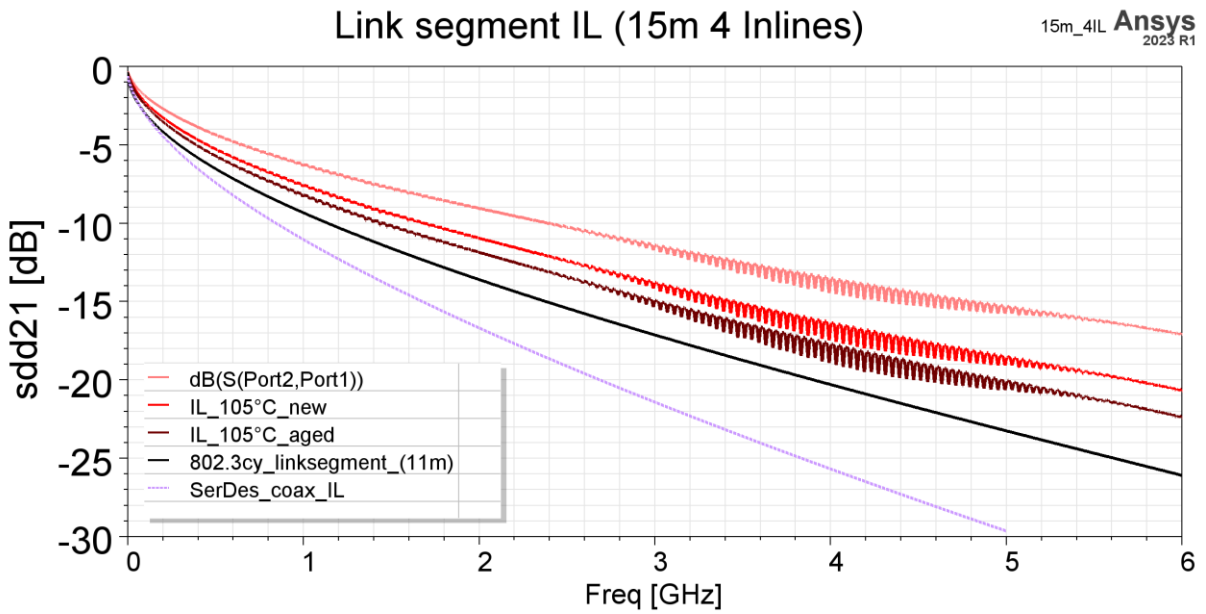
Rosenberger

Measurement results example



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



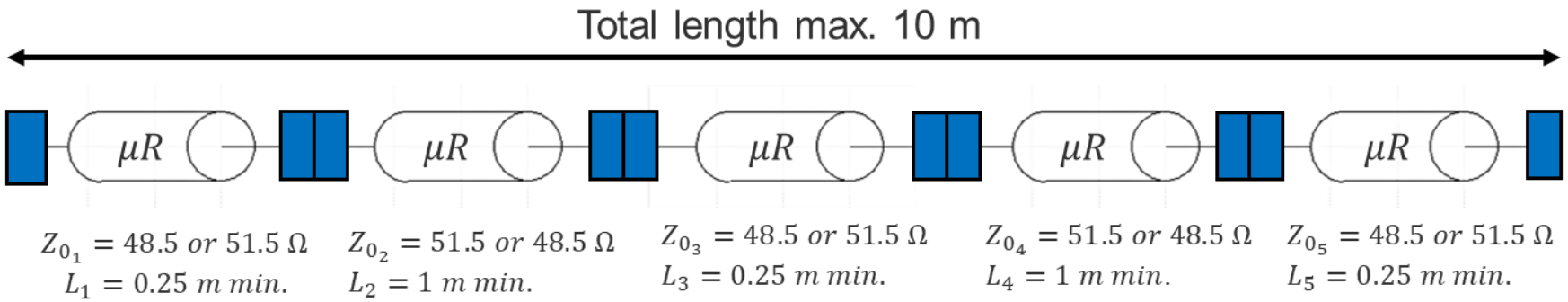


Return loss of automotive coaxial link segments

Rosenberger

Model-based validation of link segments

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

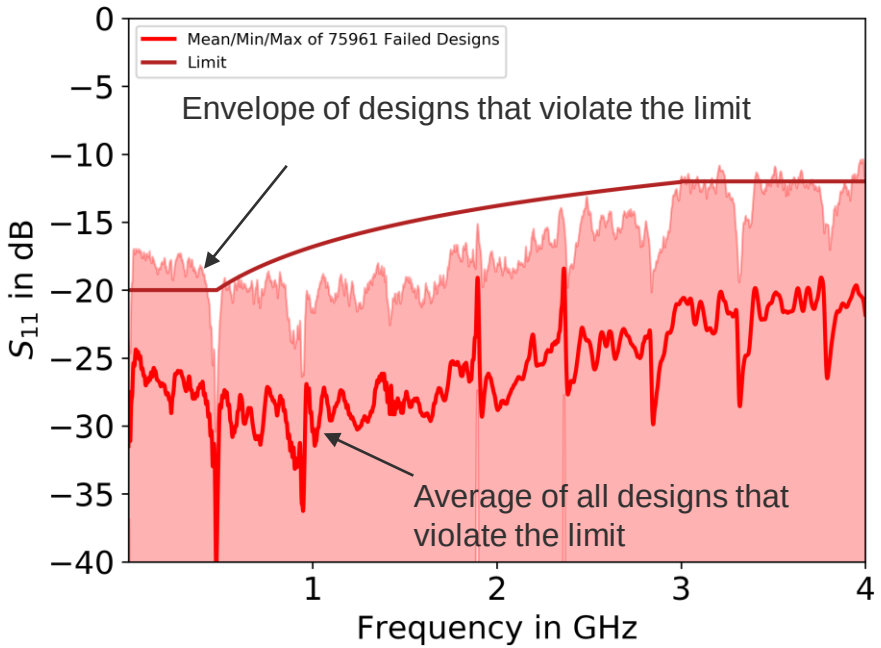


Return loss of automotive coaxial link segments

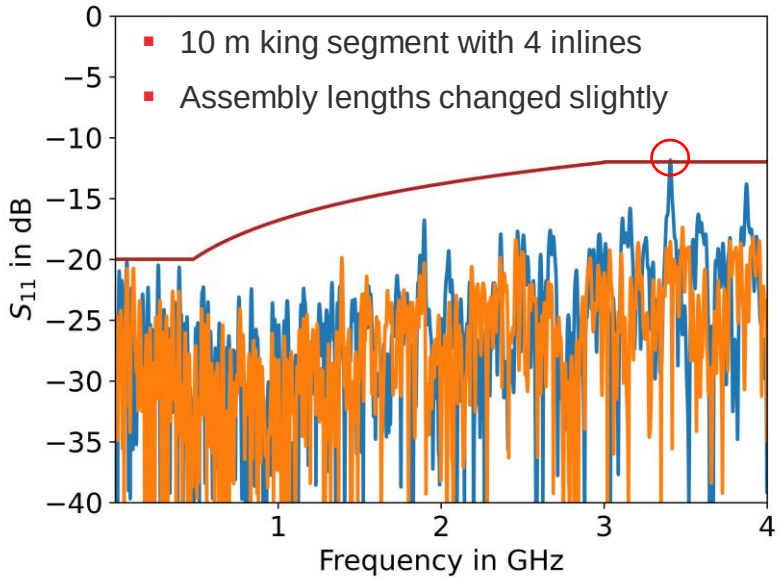
Rosenberger

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



Example



FAIL

PASS

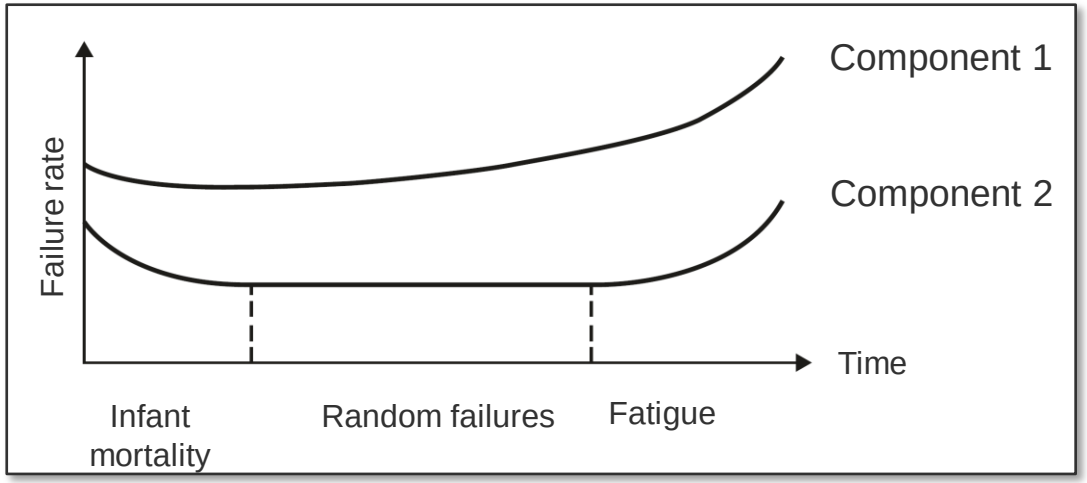
Small modifications lead to passing channels!

Return loss of automotive coaxial link segments

Rosenberger

802.3dm for safety critical applications

- Functional safety is essential for the implementation of innovative technologies (OEM statement on relevane 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?



Return loss of automotive coaxial link segments

Rosenberger

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