# Coaxial Unbalanced Media for Automotive Applications

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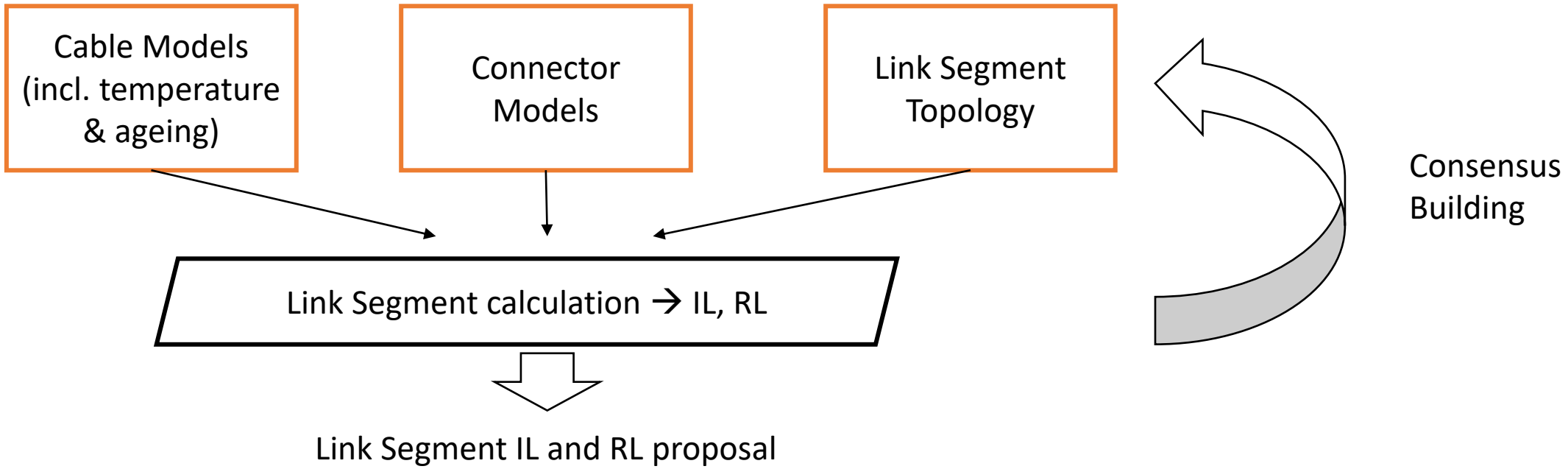
# This Contribution Gives:

- Introduction of coaxial unbalanced cables types that are available and frequently used in automotive applications
- Introduction of commonly used automotive grade connectors for these cables
- Discussion about possible link segment topologies
- The contribution concludes with proposals of preferred coaxial cable and connector types and of reference topologies for the further discussion in the 802.3dm TF.

# How to Develop a Link Segment IL and RL Proposal




This contribution discusses cable models, connector models and topology considerations for unbalanced coaxial link segments.

# Specifications for Automotive Unbalanced Coaxial Cabling Components

- Cable:
  - ISO 19642-11: Road Vehicles – Automotive Cables – Part 11: Dimensions and requirements for coaxial RF cables with a specified analogue bandwidth up to 6 GHz (20 GHz)
- Connectors:
  - USCAR17: Performance Specification for Automotive RF Connector Systems
    → SMB-style electrical terminals, aka FAKRA, frequencies from DC to 6 GHz
  - USCAR49: Performance Specifications for Miniature Automotive Coaxial Connectors
    → Mini Coax connector systems for coaxial style cables with outer diameter of **max. 3.6 mm**, frequencies from DC to 9 GHz

# Commonly Used Unbalanced Cable Types in Automotive Data Applications (ISO 19642-11)

- Characteristic impedance (50 ± 3) Ω
- Outer cable diameter ≤ 3.6 mm to allow miniaturized coaxial connectors
- Center wire construction with 7 strands and CCS possible for flexibility and increased tensile strength
- Screen construction with braid and foil for automotive grade screening attenuation
- Commonly used types, available from many vendors, examples:
  - CX174d/e: 7x CCS core diameter 0.5 mm, braid + foil, outer diameter 2.9 mm, impedance (50 ± 3) Ω
  - CX31a: 7x Cu core diameter 0.9 mm, braid + foil, outer diameter 3.4 mm, impedance (50 ± 3) Ω

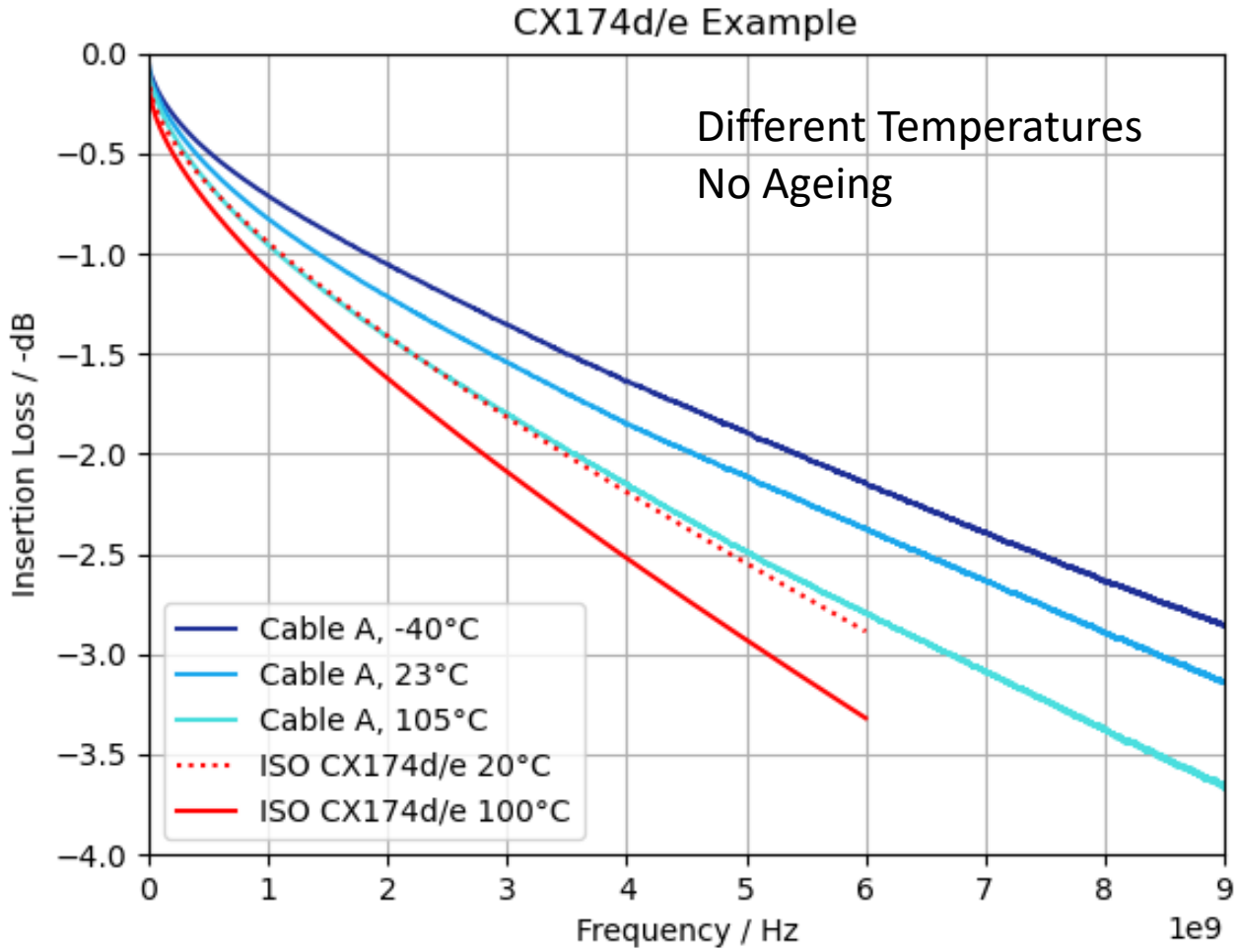
# Unbalanced Coaxial Cable Types for Automotive Applications in ISO 19642-11

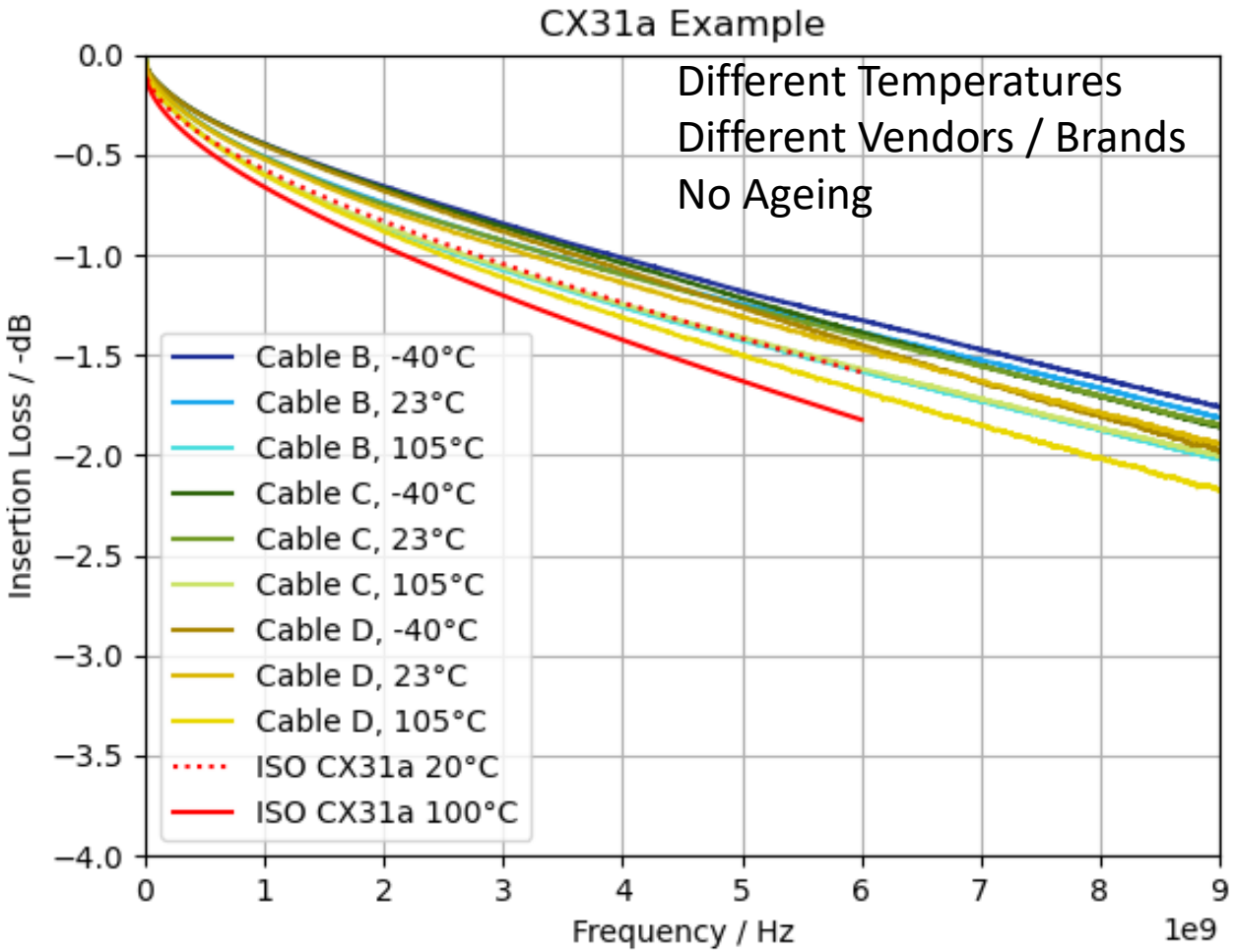
| Cable Types (ISO 19642-11) | CX174? | CX58? | CX31a | CX44? | CX501? | CX502? | CX751? |
|---|---|---|---|---|---|---|---|
| Center Wire (wire / strand diameters are max values) | CX174a: 7x CCS, d= 0.5 mm<br>CX174b: 1x CCS, d= 0.47mm<br>CX174c: 1x Cu, d= 0.57 mm<br>CX174d/e; 7x CCS, d= 0.5 mm | CX58a: 1x Cu, d= 1.05 mm<br>CX58b/c: 7x Cu, d= 1.12 mm | 7x Cu, d= 0.9 mm | 1x Cu, d= 0.87 mm | CX501a/b: 7x Cu, d= 0.57 mm<br>CX501c: 7x Cu, d=0.63 mm | CX502a: 7x Cu, d= 1.01 mm<br>CX502b: 1x Cu, d= 1.07 mm<br>CX502c: 1x Cu, d= 0.97<br>CX502d: 7x Cu 0.975 | 1x CCS, d= 0.27 mm |
| Screen | CX174a: braid, no foil<br>CX174b/c/d/e: braid & Al foil | Braid & Al foil | Braid & Al foil | CX44a/c: braid & Al foil<br>CX44b, braid & Cu foil | CX501a: braid & Al foil<br>CX501b: braid, no foil<br>CX501c: braid & Cu foil | CX502a: braid & Cu foil<br>CX502b/c/d: braid & Al or Cu foil | CX751a/c: braid, no foil<br>CX751b: braid & Al foil |
| Outer Diameter (max) | 2.9 mm | 5.0 mm | 3.4 mm | 3.6 mm | 3.2 mm | CX502a/b: 4 mm<br>CX502c/d: 3.6 mm | CX751a/b: 3.2 mm<br>CX751c: 3.6 mm |
| Characteristic impedance | (50 ± 3) Ω | (50 ± 3) Ω | (50 ± 3) Ω | CX44a/b: (50 ± 2) Ω<br>CX44c: (50 ± 3) Ω | (50 ± 3) Ω | (50 ± 3) Ω | (75 ± 3) Ω |
| Max. frequency for IL (acc. to ISO) | 6 GHz | 6 GHz | 6 GHz | CX44a/b: 20 GHz<br>CX44c: 9GHz | 6 GHz | 6 GHz | 6 GHz |

CCS … copper cladded steel

highlighted types on focus in this contribution

# Commonly Used Unbalanced Cable Types in Automotive Data Applications - IL



# Commonly Used Automotive Connectors for Unbalanced Coaxial Cable Types

- USCAR 17 Style (FAKRA), based on SMB ferrule:
  - Random examples


Acceptance criteria USCAR 17

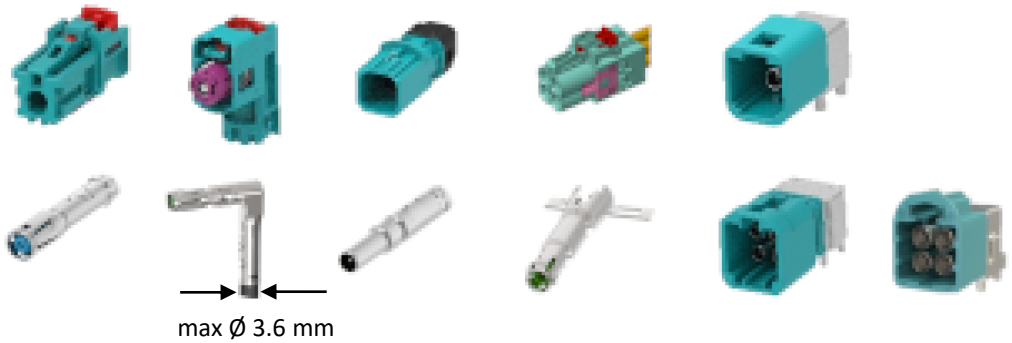
| Frequency (GHz) | RL (dB) |
|---|---|
| ≤ 2 | ≥ 15.56 |
| 2 < f ≤ 3 | ≥ 13.98 |
| 3 ≤ f ≤ 6 | ≥ 12.74 |

Mated connector pair acc. to procedure in USCAR 17

  - Widely used, many vendors, many types
  - Well established and standardized in automotive specs.

# Commonly Used Automotive Connectors for Unbalanced Coaxial Cable Types

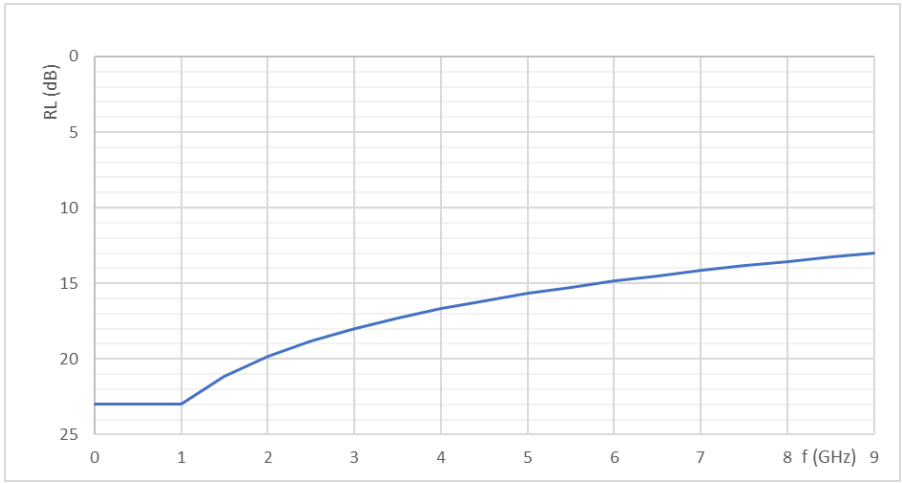
- USCAR 49 Style – Mini Coax:
  - For cables with outer diameters ≤ 3.6 mm
  - Random examples




  - Widely used, many vendors, many types
  - Well established and standardized in automotive specs.

Requirement according USCAR 49

$$RL \geq \begin{cases} 23\,dB & 0.01\,GHz \leq f \leq 1\,GHz \\ \left(23 - 10\dfrac{log_{10}(f/GHz)}{log_{10}}\right)dB & 1\,GHz < f \leq 9\,GHz \end{cases}$$




Mated connector pair acc. to procedure in USCAR 49

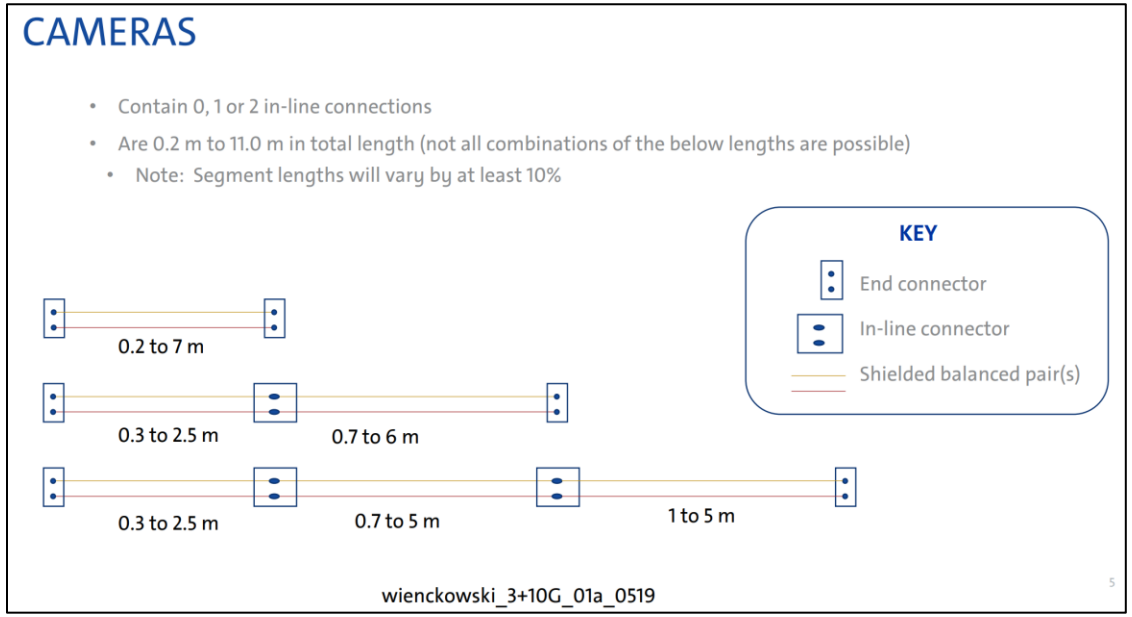
# Topology – Objective and Previous Work

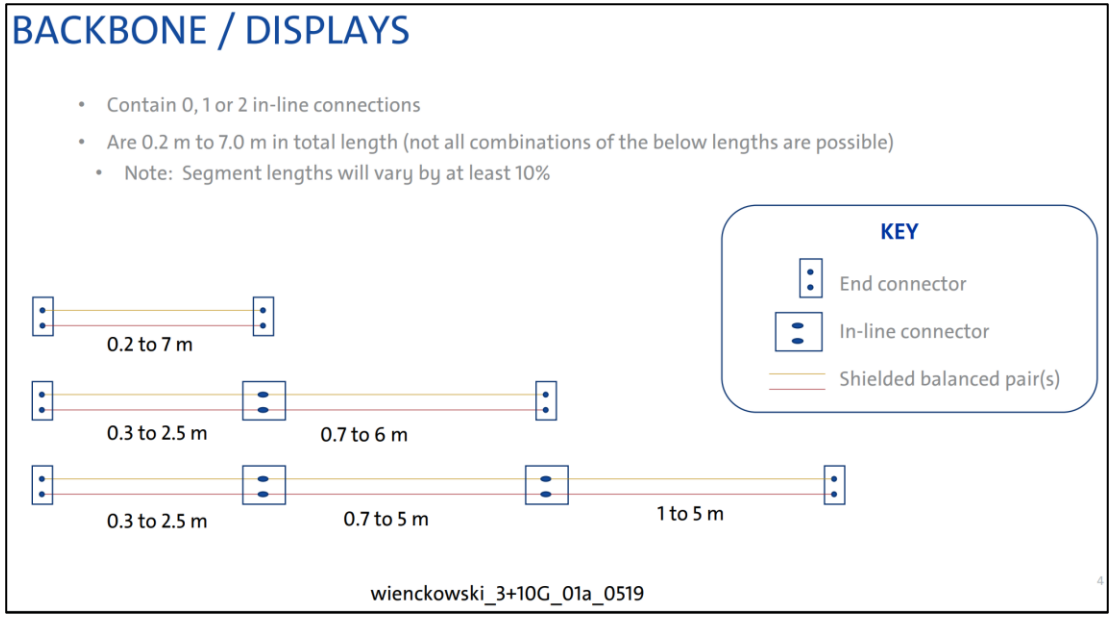
- IEEE 802.3dm objective:
  "Define performance characteristics of link segments suitable for use with automotive balanced-pair cabling and automotive unbalanced coaxial cabling supporting use of up to **4 inline connectors and up to at least 15m reach** on at least one type of automotive cabling."
- Previous topology discussion in IEEE 802.3 projects with focus to automotive applications:
  - https://www.ieee802.org/3/B10GAUTO/public/may19/wienckowski_3+10G_01a_0519.pdf : „OEM CONSOLIDATED GREATER THAN 10GB/S ETHERNET TOPOLOGIES"
  - https://www.ieee802.org/3/cy/public/adhoc/wienckowski_3cy_01_01_12_21.pdf : WORST CASE CABLE TEMP

  - Note: These contribution were part of the 802.3cy project. However, the discussed link segment topologies for camera and display applications are considered as representative for automotive use cases.

# Topology – Previous Work (Recap)

- Camera and display uses cases in wienckowski_3+10G_01a_0519.pdf:

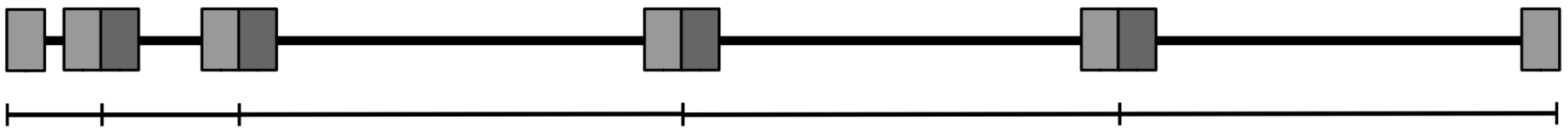



Note: 802.3cy had the objective to support link segments up to at least 11 m with up to at least 2 inline-connectors.

# Topology – Proposal for Reference Link Segment

- Consensus for reference link segment needed to analyze link segment requirements for 802.3dm
- Proposal for reference link segment based on previous work, “extrapolated“ to 802.3dm objectives (up to at least 15 m and up do at least 4 inline-connectors):




$L_{A1}$ = 0.3 m

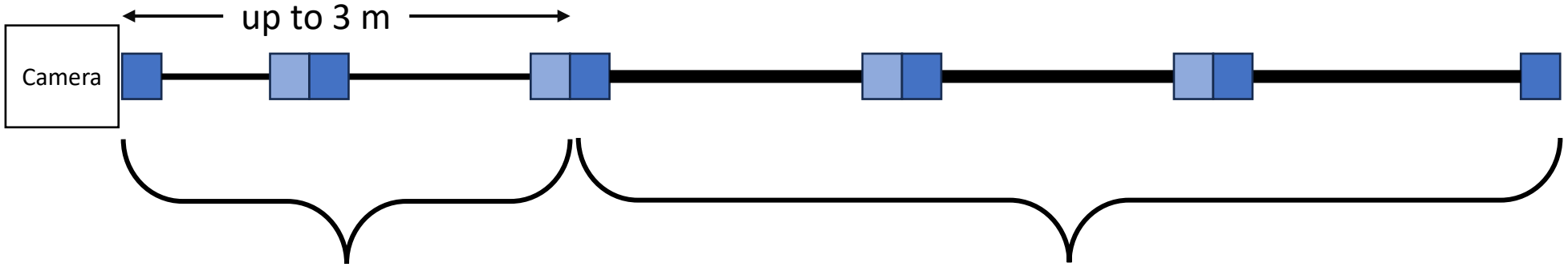
$L_{A2}$ = 1 m

(adopted by OPEN Alliance TC9 for component budget calculation for 2.5/5/10GBASE-T1 applications)

- This reference link segment considers:
  - Previous work in wienckowski_3+10G_01a_0519.pdf → segments 0.3 m and 1 m (“worst case” assumption for return loss)
  - Extrapolation to 15m and 4x inline-connectors by equally distributes segments lengths for segments 3, 4 and 5 up to the total length of 15 m

# Topology – Mixed Cable Grades

- Automotive applications require mixing of cable grades in the same link segment
- Example:




Small diameter, flexible cable with higher insertion loss (CX174d grade)
- Mirror hinges
- Door / trunk lid hinges

Larger diameter, more rigid cables with lower insertion loss (CX31a grade)

- Automotive applications use different cable grades in the same link!
- Proposal: Consider up to 3 m flexible cable (higher loss) for link segment insertion loss definition.

# Proposals for 802.3dm Link Segment Definition

- Use CX174d/e (flexible) and CX31a (low loss) cable grades for calculation of link segment insertion loss requirements
- Consider USCAR 17 and USCAR 49 connectors for calculation of return loss requirements (link segment and MDI)
- Use link segment topology 0.3--1--4.57--4.57--4.57 as reference for link segment return loss analysis
- Use 3 m flexible cable (CX174d/e) and 12 m low loss (CX31a) cable for link segment insertion loss analysis