Channel Framework for 10SPE Automotive Point-to-Point Links

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Ahmad Chini, Broadcom Limited

Stefan Buntz, Marc Schreiner, Daimler AG

Contributors and Supporters

Contributors

Mehmet Tazebay, Broadcom Limited
Mehdi Kilani, Broadcom Limited
Jay Cordaro, Broadcom Limited

Supporters

Bernd Körber, FTZ Zwickau
Bert Bergner, TE Connectivity
Dan Dove, Dove Networking
Dave Dwelley, Linear Technology
Dinh Thuyen, Pulse
Dongok Kim, Hyundai
Eric DiBiaso, TE Connectivity
Hideki Goto, Toyota
Farid Hamidy, Pulse
Jens Wülfing, TE Connectivity
Jinhwa Yun, Hyundai
John Hess, Bel Fuse
Josetxo Villanueva, Renault
Kirsten Matheus, BMW
Larry Matola, Delphi
Michael Rucks, Delphi
Nobukatsu Kitajima, Renesas
Richard Mei, Commscope
Sterling Vaden, Surtec Industries

Purpose of presentation

- **Establish a consensus on how to get to baseline channel models that will be used for evaluating PHY proposals for 10SPE. Therefore channel models must be,**
  - Acceptable to PHY participants
  - Acceptable to cabling, connector & magnetics' participants
  - Acceptable to OEM & Tier1 participants
  - Verified by measurement data
- **Will require alignment on all fronts so that a good solution can be attained and everyone comes to a consensus!**

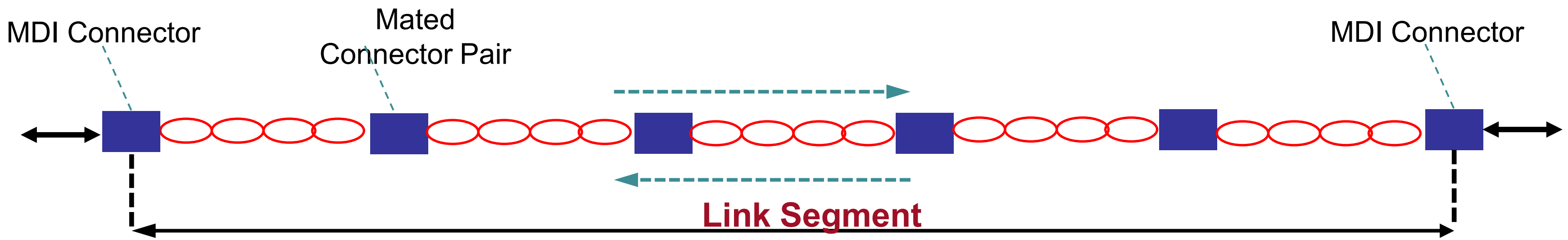
Outline

- **Wire Pair properties**
- **Link segment properties and parameters**
- **Automotive Link Segments available today**
- **Example Automotive Link Segments (CAN, Flex Ray, 100BASE-T1)**
  - CAN & FlexRay general specifications
  - CAN & FlexRay measurements (IL, Delay and impedance), comparing five different cable types.
  - Pair-to-Pair cross effects for 100BASE-T1 cables (jacketed versus unjacketed)
  - Cable assembly and multi-pin connectors
- **Framework does not imply or preclude any signaling solutions.**

Wire Pair Properties

- Conductor material (copper)
- Conductor diameter
- Differential Characteristic Impedance (100Ω/120Ω nominal)
- Frequency Range and Attenuation
- Pair to Pair Crosstalk
- Dielectric Material of Choice and its Properties
  - e.g. PVC cables (very economical, however temperature behavior is worse then other materials)
- Effect of Aging, Bending, Temperature & Humidity

Link Segment Properties



- Between two linked-up units running up to 10Mbps over Unshielded Twisted Pair(s) (UTP) with length up to 15m for passenger vehicles / 40m for commercial vehicles
- Consisting of:
  - 6-connector structured UTP cabling with at least 15m of balanced copper cables including two end connectors.
  - Mated Connector Pairs (maximum four, connectors may be part of Multi-Pin connectors)

Link Segment Parameters

- **For a given 100Ω terminated segment**
  - Differential Characteristic Impedance (100Ω nominal)
  - Differential Insertion loss
  - Differential Return Loss
  - Differential XTALK
  - Impedance Variation
  - Common Mode to Differential Mode Conversion
  - Common Mode to Differential Cross Mode Conversion
- **These parameters**
  - Will apply to the whole link segment
  - Need to be considered for environmental factors
  - Tolerances are to be determined
- **Can look into similar requirements for automotive as to those listed under ANSI/TIA-568C.2 / ISO/IEC 11801 for premises, ANSI/TIA-1005 / ISO/IEC 24702 for industrial (i.e. FlexRay Spec and ISO11898-2/CAN).**

Automotive Link Segments available today

- **There are commonly used "Automotive Qualified" UTP cables in the market place. These cables share some consistent characteristics (described earlier in the presentation).**
  - e.g. ~100Ω/120Ω Differential Characteristic Impedance (Z_L)
- **Other characteristics (described earlier in the presentation) also matter to PHY architecture and vary between different manufacturers and cable types. Examples include**
  - Insertion loss (IL)
  - Return loss (RL)
  - Varying XTALK (AXTALK) properties
  - CM-DM/DM-CM Conversion (EMC properties)
- **Similar issue with link segment. E.g. no consistent constraints on mated connectors**

Example Automotive Link Segments

- Link segment parameters for automotive bus systems CAN & FlexRay are reviewed as examples, measured parameters are presented.
- Alien crosstalk measurements are provided for 100BASE-T1 type cables. Jacketed and unjacketed cables are compared.
- Connector assembly techniques for automotive cable harness are presented.

General Specification of **CAN & FlexRay**

- **FlexRay (Specification 2.1 Rev. B):**
  - Differential Impedance Z_L: $80\Omega < Z_L < 110\Omega$ (typ. 100Ω) (@5MHz)
  - Cable delay: $\tau < 10$ns/m
  - Cable attenuation/insertion loss: $\alpha < 0{,}082$ dB/m (@5MHz)
- **CAN (ISO 11898-2):**
  - Differential Impedance Z_L: $95\Omega < Z_L$ *$< 140\Omega$ (typ. 120Ω)
  - Cable delay: typ. 5ns/m (no limit specified)
  - Cable resistance (DC) typ. 70 mΩ/m (no limit specified)

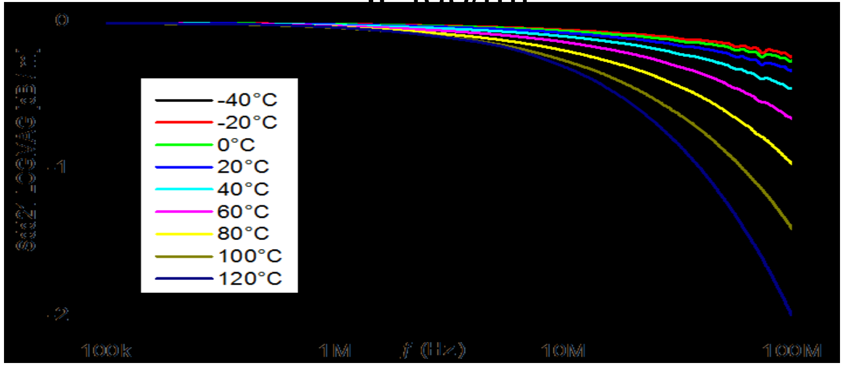
* For CAN there is no reference frequency defined, for which Z_L is valid

CAN & FlexRay cables measured

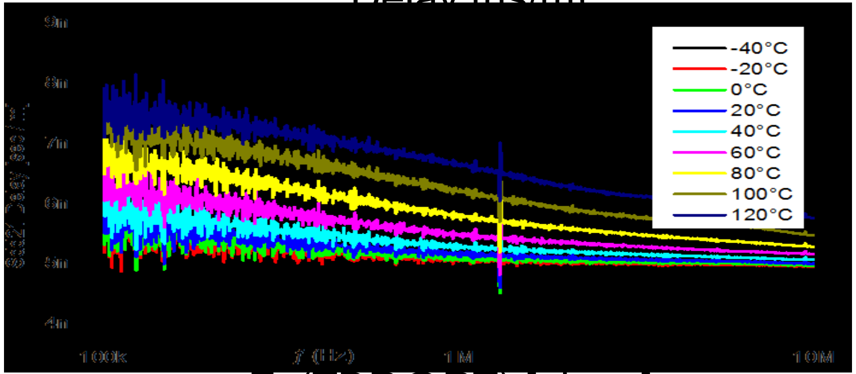
Sample	Type	Description
#1	FLRYW 2x0.35mm²	**FlexRay cable type** UTP cable, unjacketed - Cable insulation: PVC
#2	FLR9Y 2x0.35mm²	**FlexRay cable type** UTP cable, unjacketed - Cable insulation: none-PVC
#3	FLR9YHYW 2x0.35mm²	**FlexRay cable type** UTP cable with jacket - Cable insulation: no-PVC - Jacket: PVC
#4	FLR9YYW 4x0.5mm²	**Commercial CAN cable type** UTQ cable with jacket - Cable insulation: none-PVC - Jacket: PVC
#5	FLYY85 4x0.5mm²	**Commercial CAN cable type** UTQ cable with jacket - Cable insulation: PVC - Jacket: PVC

#1 - FLRYW 2x0.35mm²

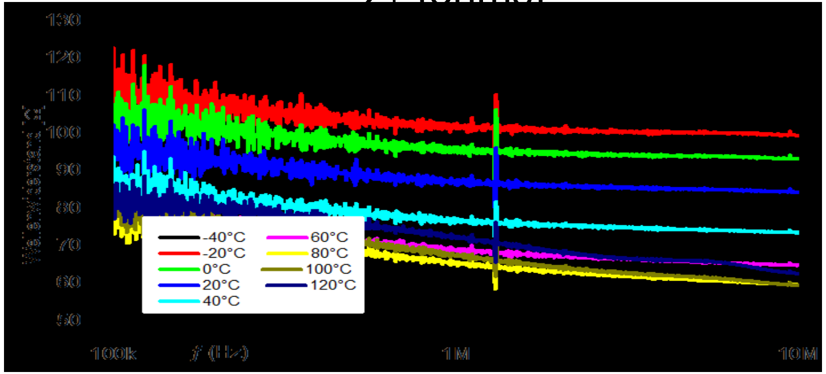
IL [db/m]



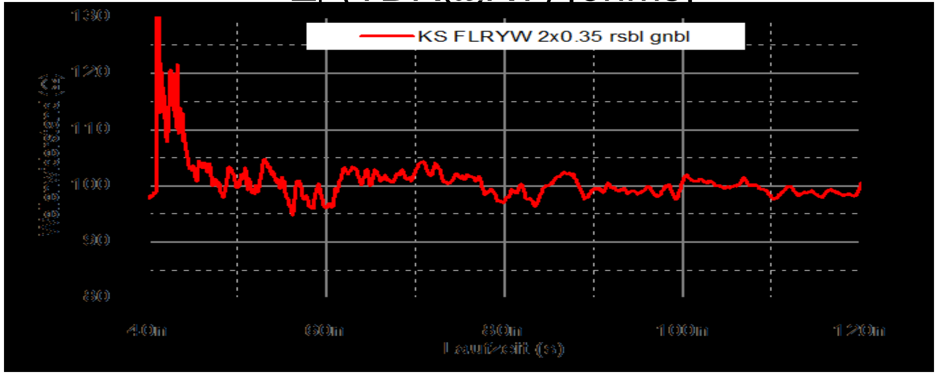
Delay [ns/m]



Z_L [ohms]

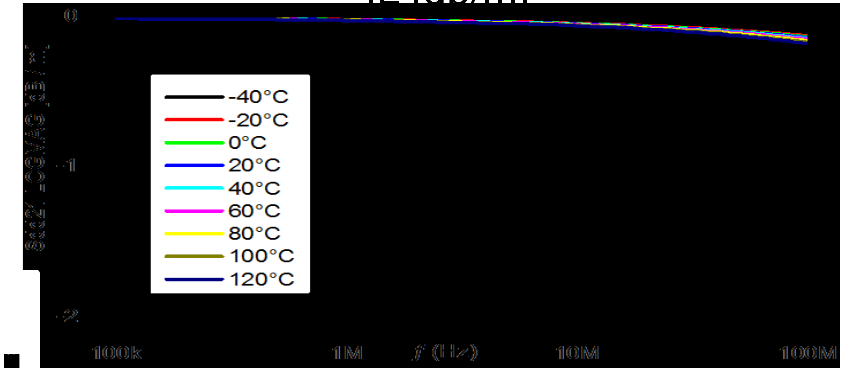


Z_L (TDR@RT) [ohms]



#2 – FLR9Y 2x0.35mm²

IL [db/m]



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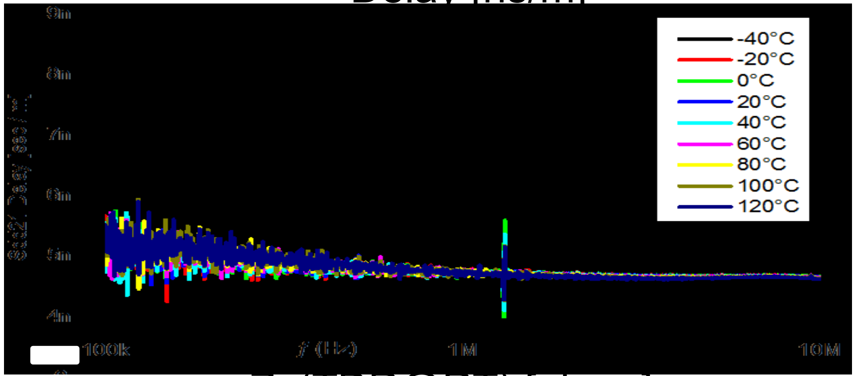
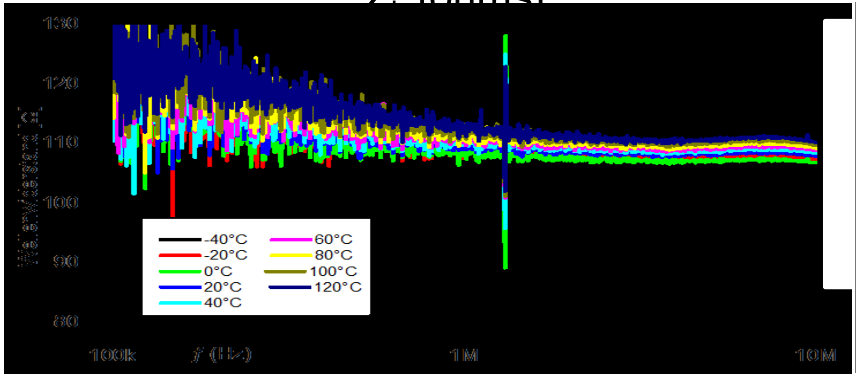
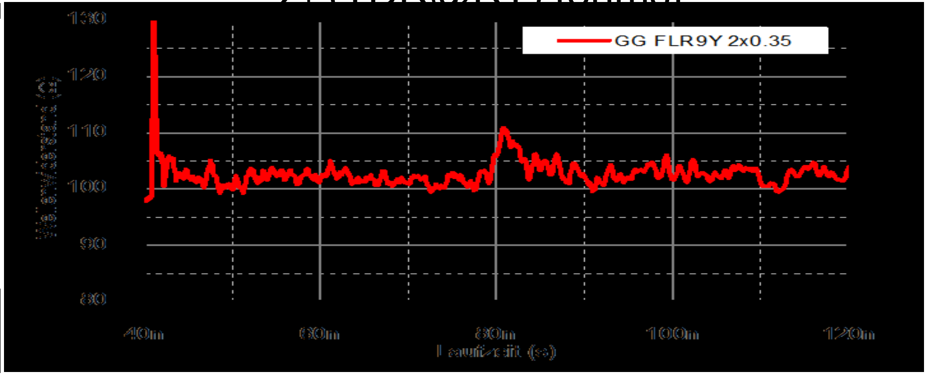


Z_ [ohms]

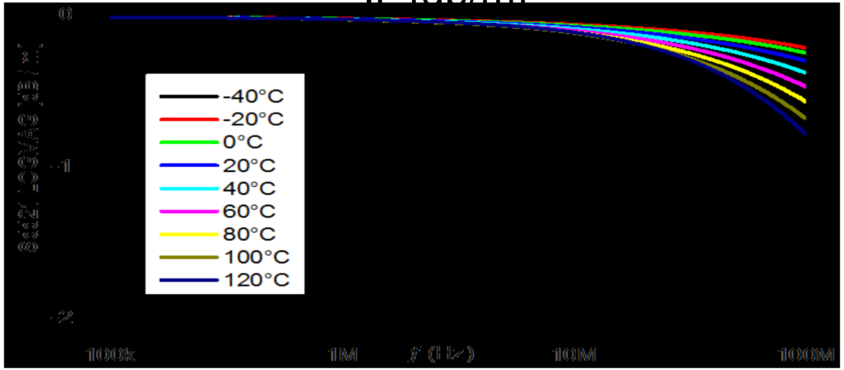


Z_ (TDR@RT) [ohms]

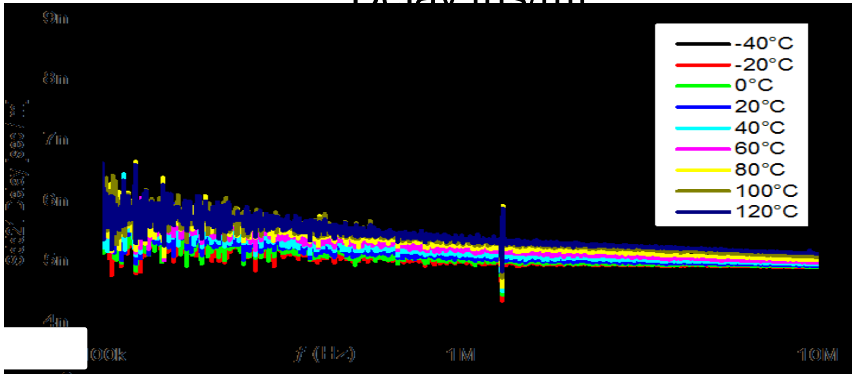


#3 – FLR9YHYW 2x0.35mm²

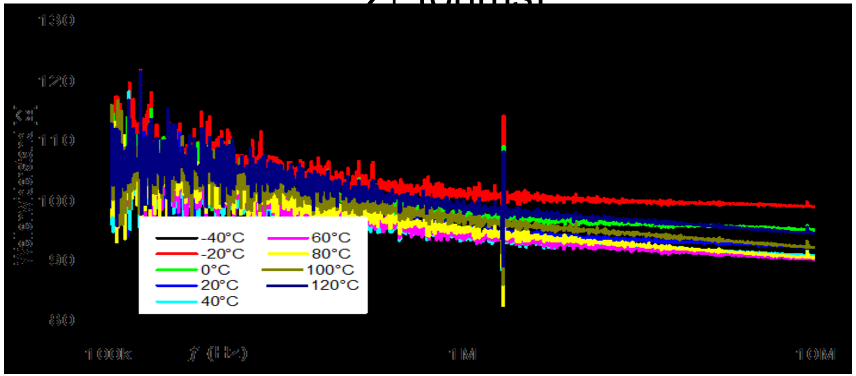
IL [db/m]



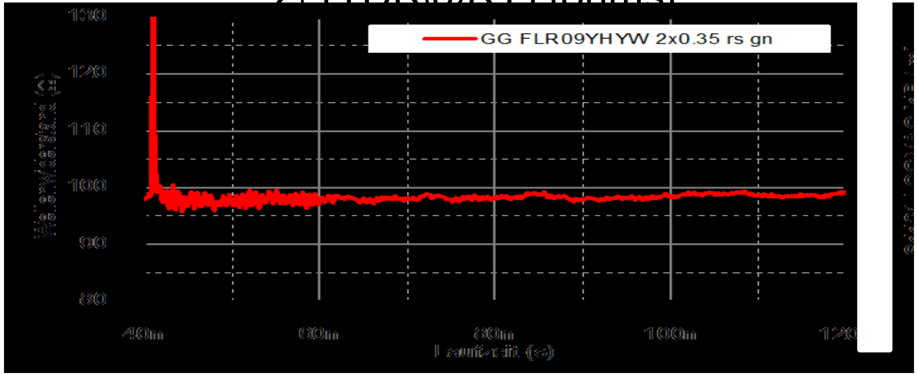
Delay [ns/m]



Z_c [ohms]

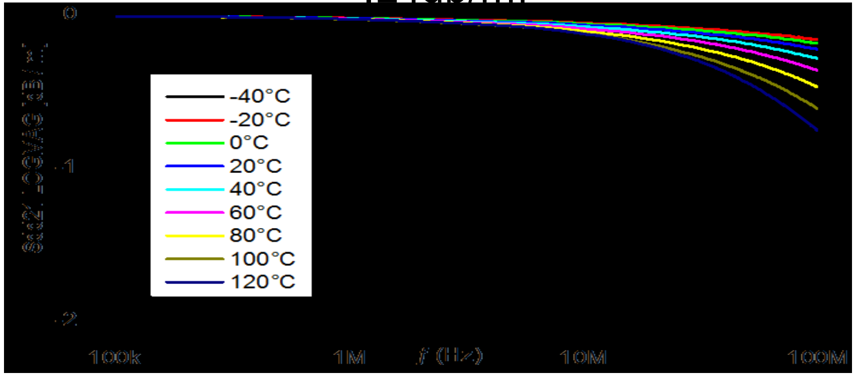


Z_c (TDR@RT) [ohms]

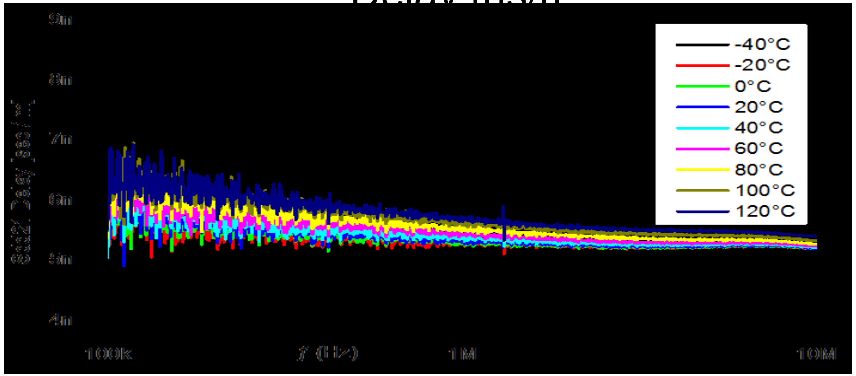


#4 – FLR9YHYW 4x0.35mm²

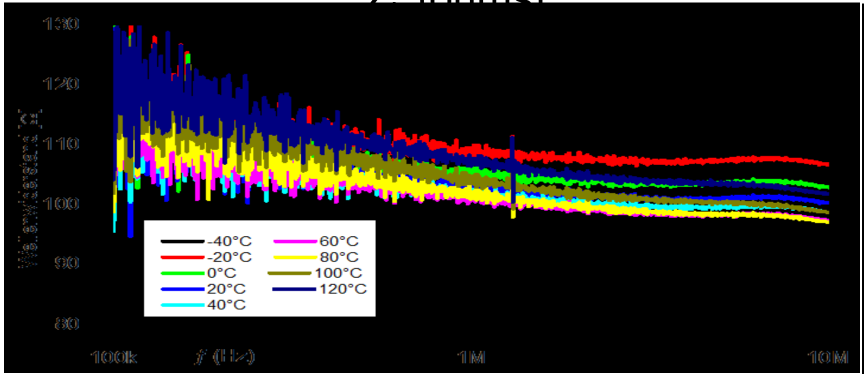
IL [db/m]



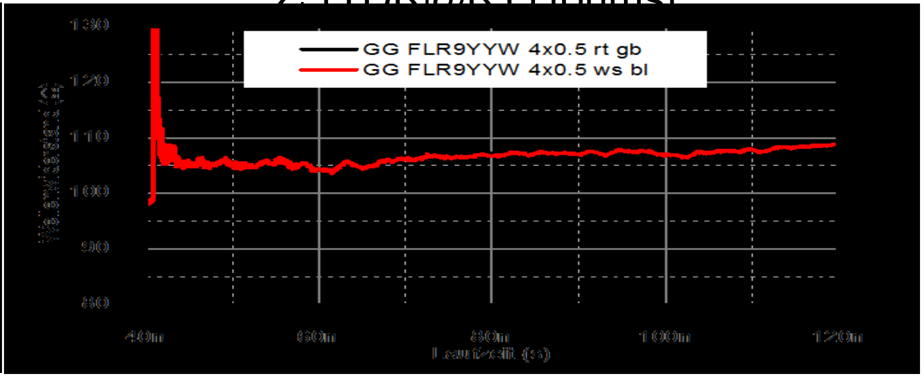
Delay [ns/m]



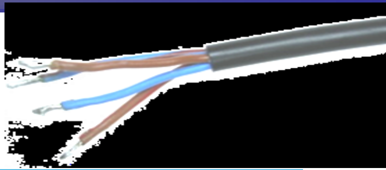
Z [ohms]



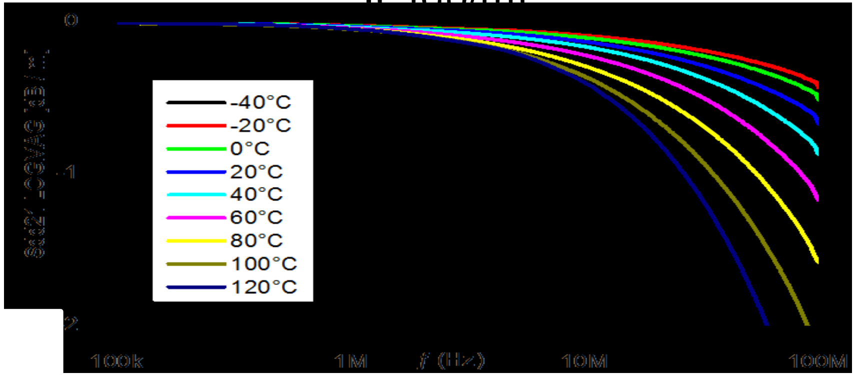
Z (TDR@RT) [ohms]



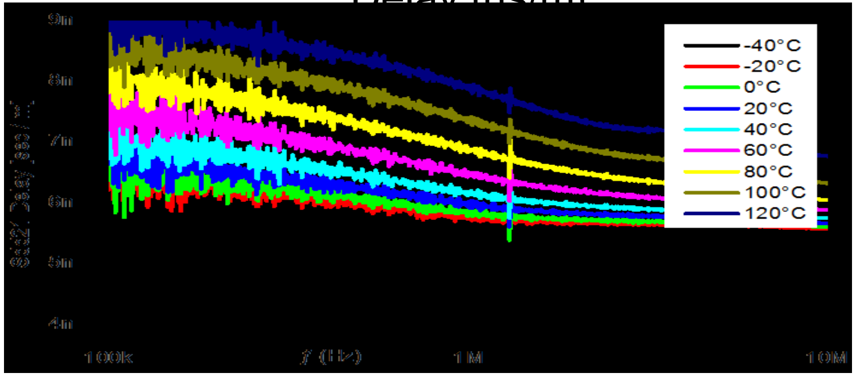
#5 – FLYY85 4x0.5mm²



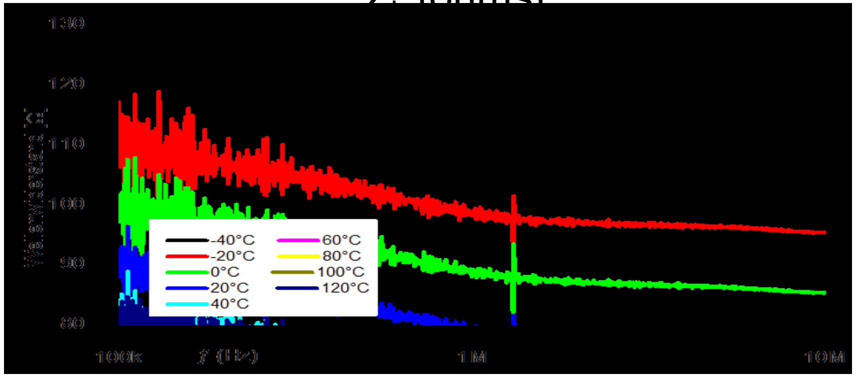
IL [db/m]



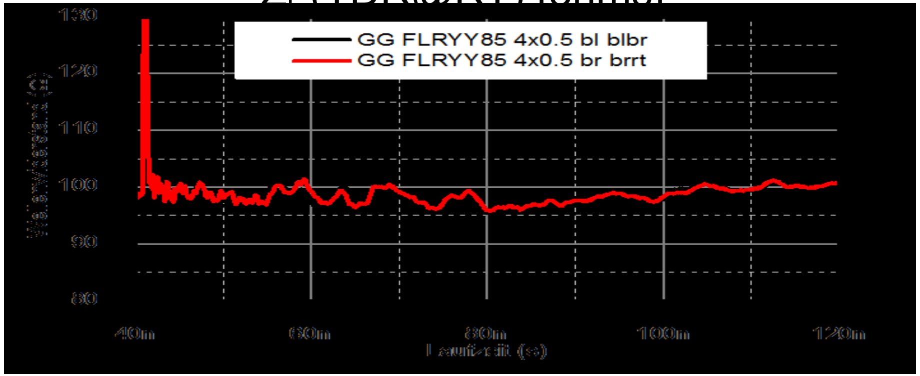
Delay [ns/m]



Z [ohms]



Z (TDR@RT) [ohms]



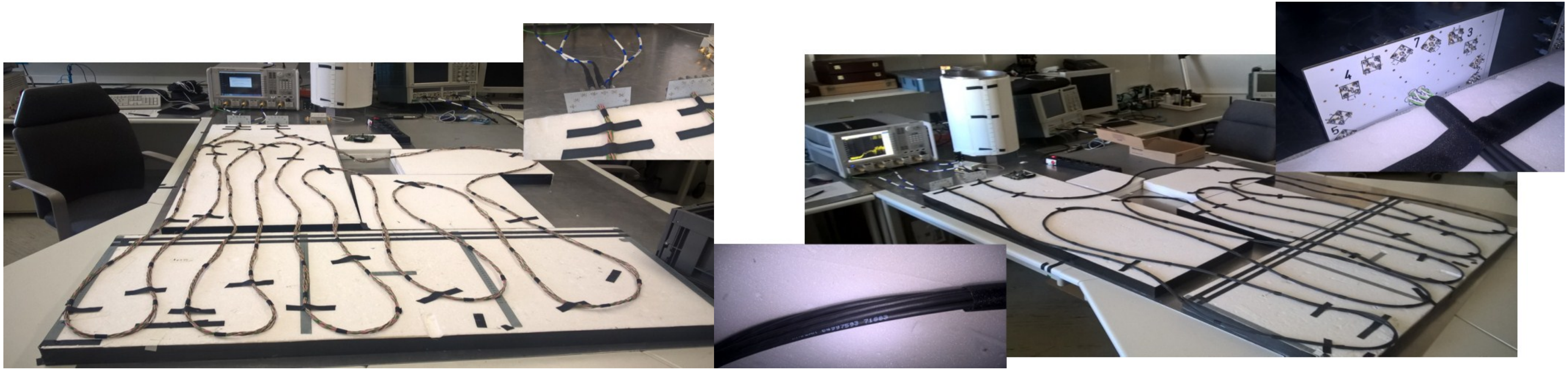
Measurement summary for **CAN & FlexRay**

Sample	Type	IL@5MHz/120°C [dB/m]	Delay* [ns/m]	ZL@5MHz [Ω]
#1	FLRYW 2x0.35mm²	0.1570	5.0 … 7.5	61…102
#2	FLR9Y 2x0.35mm²	0.0413	4.7 … 5.5	104…108
#3	FLR9YHYW 2x0.35mm²	0.0639	5.0 … 6.0	91…102
#4	FLR9YYW 4x0.5mm²	0.0701	5.5 … 6.5	98…109
#5	FLYY85 4x0.5mm²	0.2032	5.8 … 9.0	57…101

- Measured data shows a wide variety of RF parameters, even CAN or FlexRay specs are violated by some cables at high temperatures
- Cable parameter can drastically vary especially with PVC materials
- RL is not measured here, but Z_L gives a hint on expected RL, especially low Z_L is to be expected with high temperatures in combination PVC.
- **From an economic perspective automotive industry tends to prefer to use PVC insulation materials.**
- **120Ω cables are not preferred, as real measured impedance of cable even tends to be below 100Ω (e.g. 80Ω or even lower, „FLR-structure“)**

Alien XTALK with and without Jacket

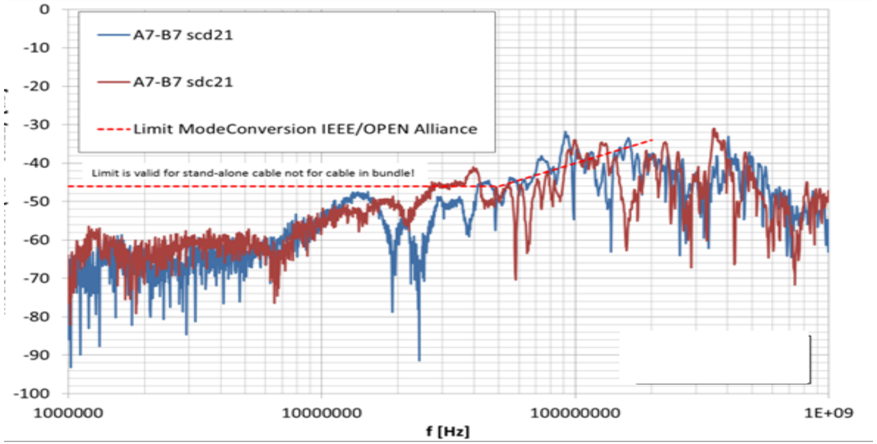
- **Alien XTALK and Mode Conversion in 6-around-1 bundles are measured and comapred for the following 100BASE-T1 cabling;**
  - UTP without jacket 2x0.13mm, lay length 15mm
  - UTP with jacket, 2x0.13mm, lay length 13mm („very good unjacketed UTP“)



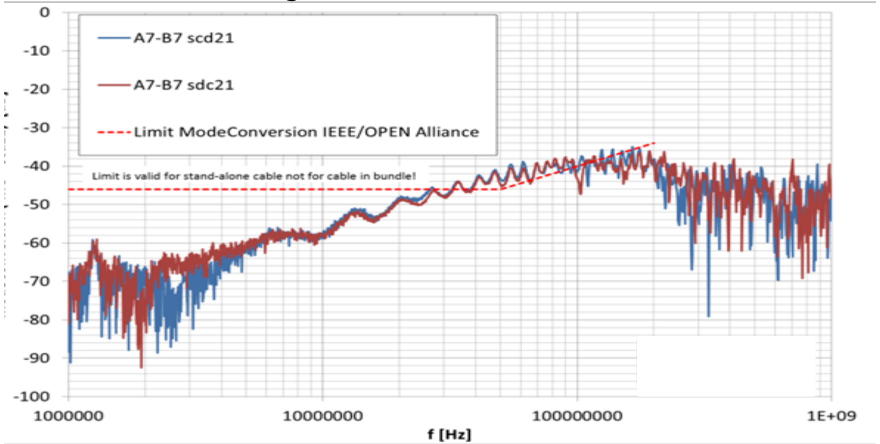
Measurement Results – Mode Conversion

- Mode Conversion measured in the bundle is higher then measured alone (both cables fullfill Mode Conversion measurement as specified for 100BASE-T1)
- Mode Conversion of a 10SPE cable will be even worse!

UTP w/o jacket



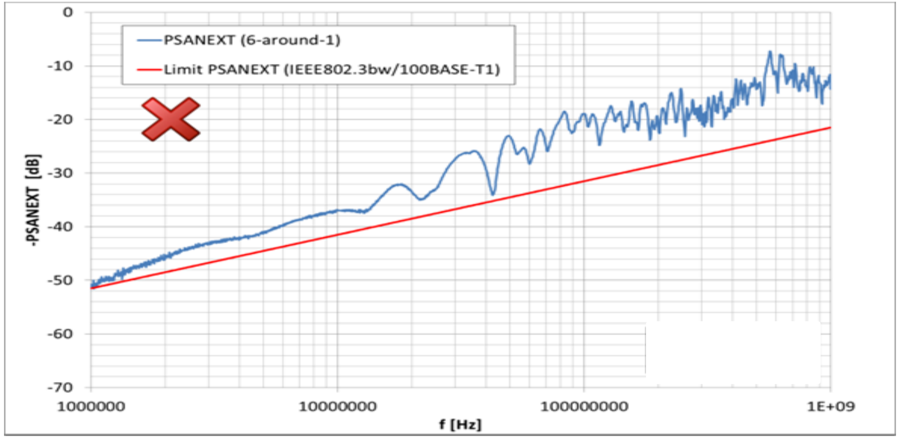
UTP with jacket



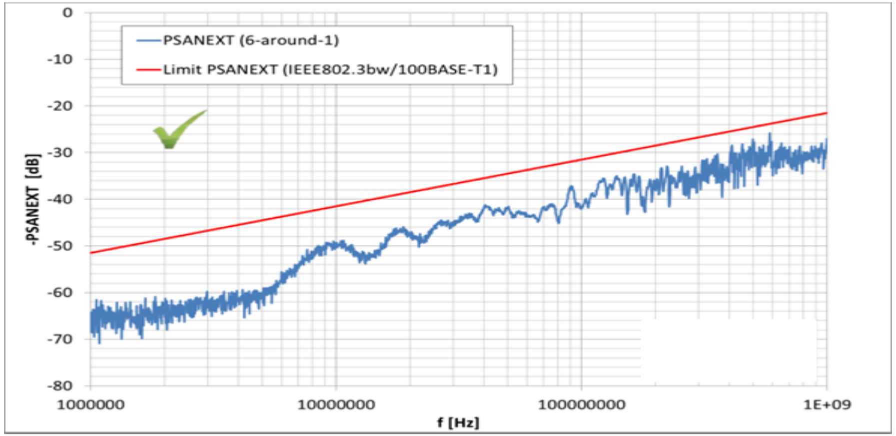
Measurement Results - PSANEXT

- PSANEXT is ~10dB…15dB higher without Jacket

UTP w/o jacket



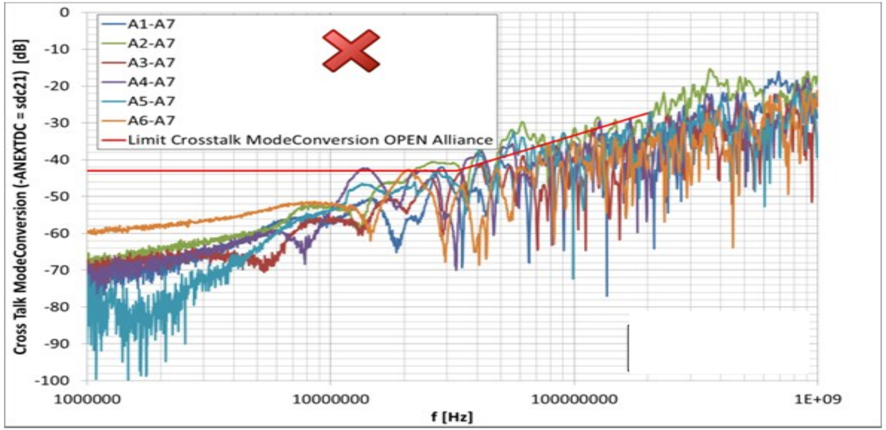
UTP with jacket



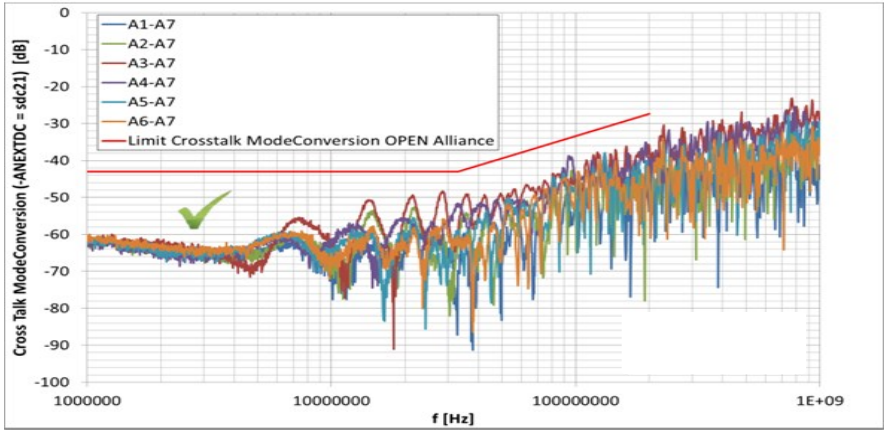
Measurement Results - ANEXTDC

- ANEXTCD (not shown here) is comparable to ANEXTDC
- ANEXTDC is ~10dB higher without jacket

UTP w/o jacket



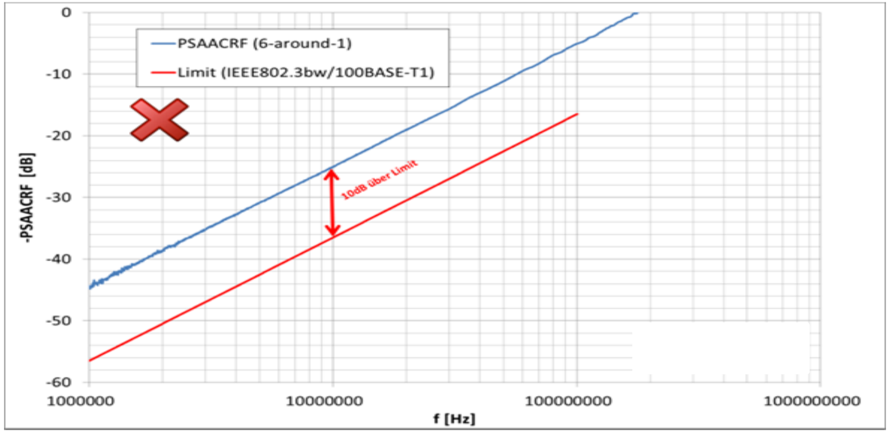
UTP with jacket



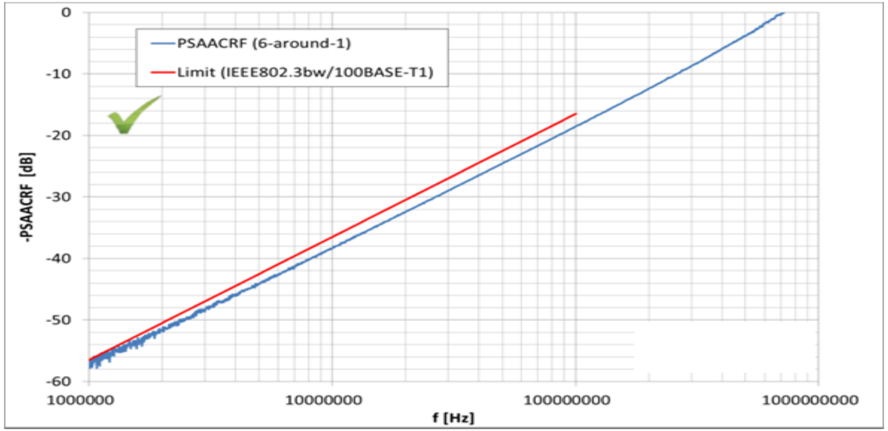
Measurement Results -PSAACRF

- PSAACRF is ~10dB…15dB higher without jacket

UTP w/o jacket



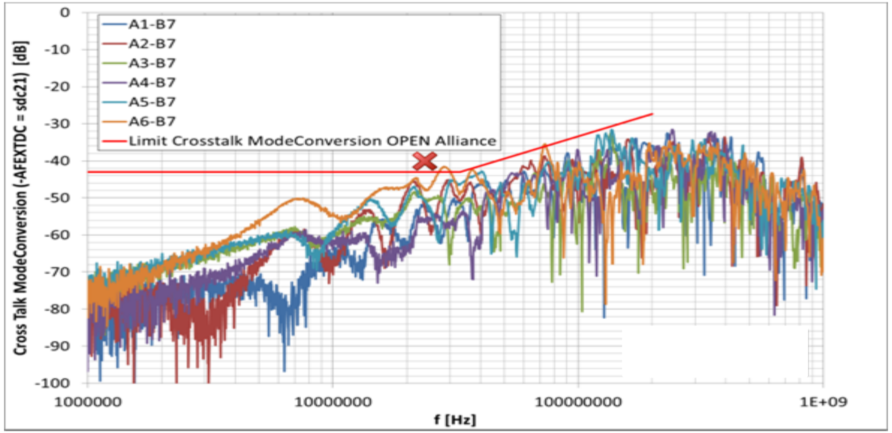
UTP with jacket



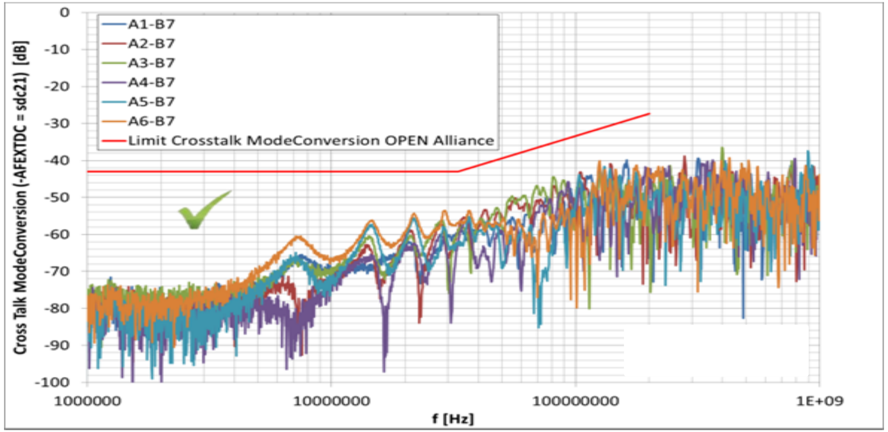
Measurement Results - AFEXTDC

- AFEXTCD (not shown here) is comparable to AFEXTDC
- AFEXTDC is ~10dB…15dB higher without jacket

UTP w/o jacket



UTP with jacket



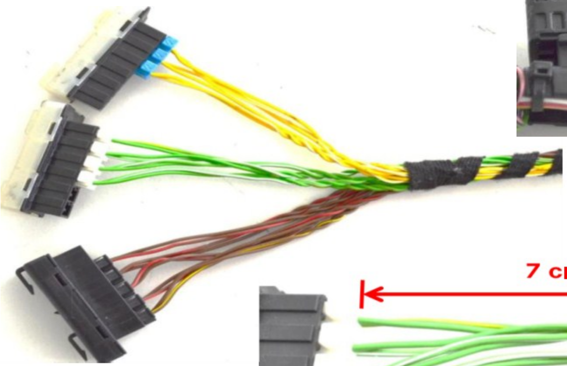
Summary of Alien XTALK Analysis

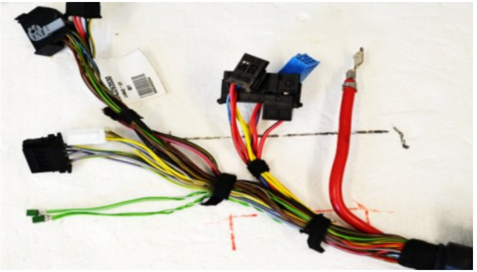
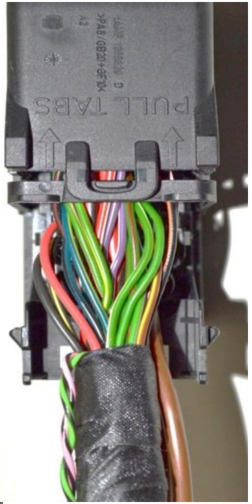
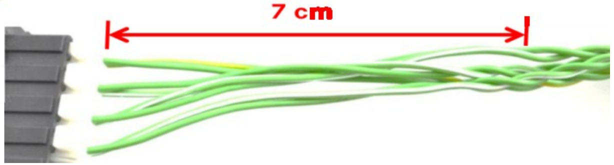
- All Alien XTALK values are 10dB…15dB worse with an unjacketed cable compared to a jacketed cable
- Except for Alien XTALK, the measured unjacketed cable is inline with 100BASE-T1 requirements (i.e. also Mode Conversion)
- 10SPE will probably have worse Mode Conversion values resulting in incresed Alien XTALK.

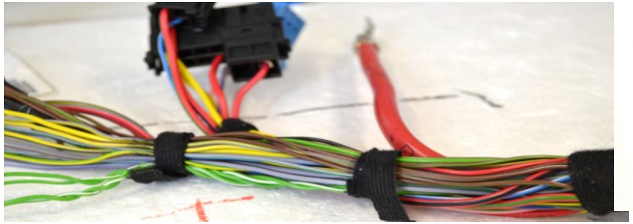
- ***From an economic perspective, automotive industry tends to prefer using unjacketed cables (easier assembly, more economic). Special attention need to be given to Alien XTALK performance.***

Connector Assembly Techniques for Automotive Cable Harness

- Cable/connector assembly of UTP cables is very cost sensitive. Lower performance is expected when looking for an economical cabling solution for 10SPE. See the following examples:





- Flexible pinning in Multi-Pin connectors is state-of-the-art for CAN cabling (in a reasonable range of pinning configurations…).

Conclusions

- The existing “Automotive Qualified” cables show performance variations under different environmental conditions
- Economic cables (unjacketed, with PVC insulation) show strong parameters variation:
  - The DM Impedance and therefore Return Loss can vary drastically with different harness wiring options. In this presentation, only a few cases considered.
  - Insertion loss is strongly temperature dependent
  - UTP without jacket have much increased AXTALK effect on the victim.
- Economical connector assembly provides additional challenges.
- If multi-drop is considered, additional parameters (e.g. topology) influence link performance.
- Need to choose the right channel model (UTP cabling, connectors, magnetics) for a proper PHY feasibility analysis.
- Automotive EMC requirements have to be additionally imposed on the link segment requirements.

Let’s fill in the blanks for the properties described in this presentation to create an automotive channel model for 10SPE

Thank You!