SPE for automotive and the transfer into industrial automation

By Dr. Michael Wollitzer

Rosenberger Hochfrequenztechnik

September 22, 2020

Single Pair Ethernet System Alliance

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SPE for automotive and the transfer into industrial automation

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One of the worldwide leading manufacturers of standard and customer specific connectivity solutions.

Dr. Michael Wollitzer

Head of R&D at Rosenberger

- A Ethernet/IP-Networking is agnostic to PHY-layer
- B Motivation for Single Pair Ethernet
- C EMC-Considerations
- D Lessons learned in Automotive Applications
- E Power over Datalines (PoDL) reduces Harness Complexity

A

Ethernet/IP-Networking is agnostic to PHY-layer

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Ethernet and the OSI-Layer-Model

Application Layers do not care about physical Implementation

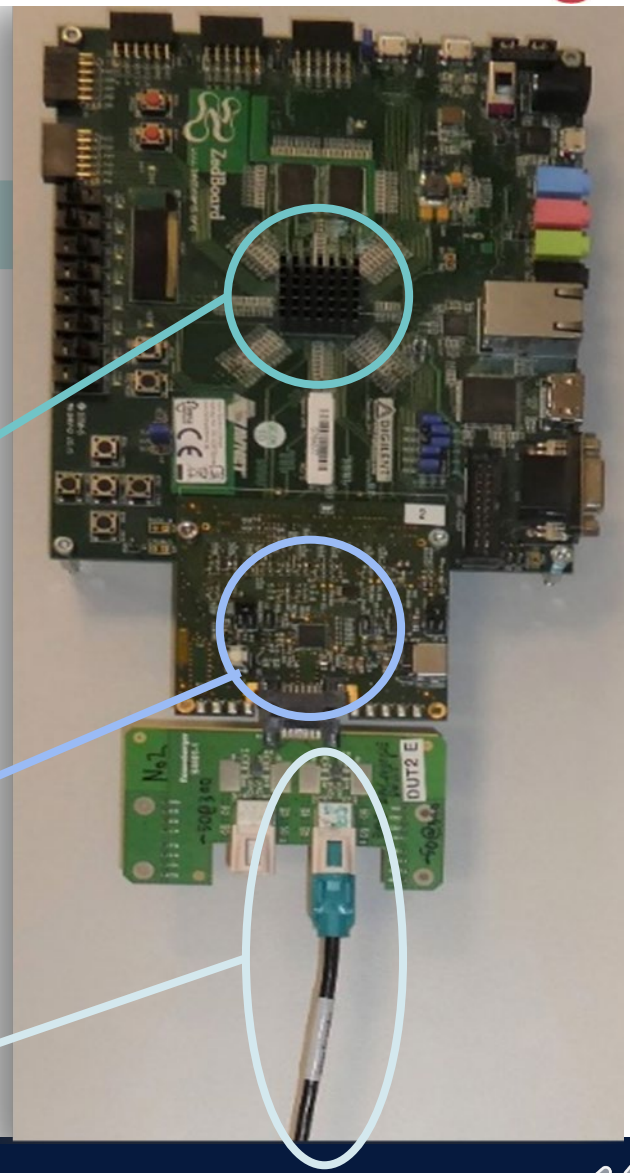
OSI-Layer	„Ethernet“	
7 Application Layer	Application Layer (DNS, FTP, HTTP, NNTP, SMTP, SNMP, SSH, TELNET, …)	Switch Router
6 Presentation Layer		
5 Session Layer		
4 Transport Layer	Transport-Layer (TCP/IP)	
3 Network Layer	Internet-Layer (TCP/IP)	
2 Data Link Layer	Logical Link Control (LLC), IEEE 802.2 Media Access Control (MAC), IEEE 802.1	
1 Physical Layer	Reconciliation, IEEE 802.3 Physical Coding Sublayer (PCS) Physical Medium Attachment (PMA) Physical Medium Dependent (PMD)	Hub

Media Independent Interface, MII, GMII, …

Media Dependent Interface,

Medium

CAT-Cable, SPE, Optics, …



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Ethernet and the OSI-Layer-Model

7	Application Layer
6	Presentation Layer
5	Session Layer
4	Transport Layer
3	Network Layer
2	Data Link Layer
1	Physical Layer

7	Application Layer
6	Presentation Layer
5	Session Layer
4	Transport Layer
3	Network Layer
2	Data Link Layer
1	Physical Layer

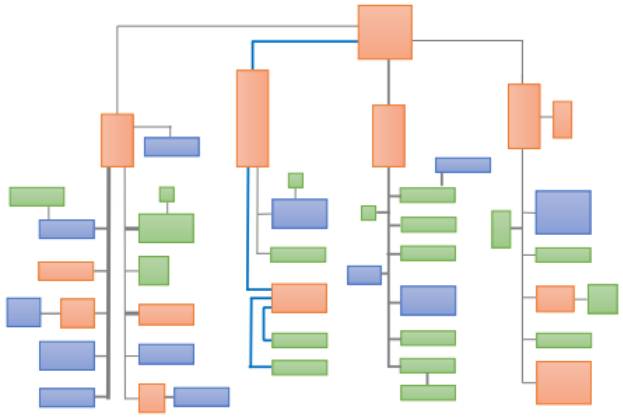
Medium

Single Pair Ethernet
System Alliance

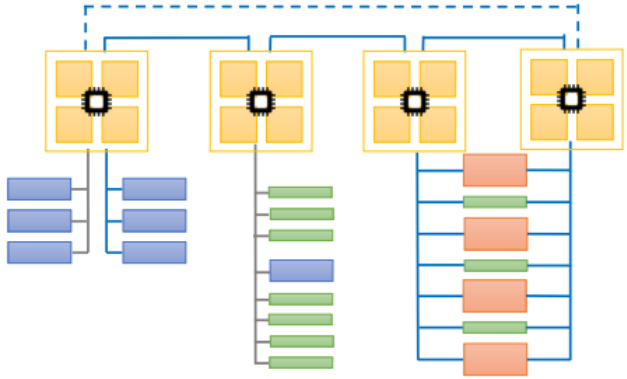
Trends in architecture

- Zone architecture
- Redundancy for autonomous driving
- Asymmetrical date rates

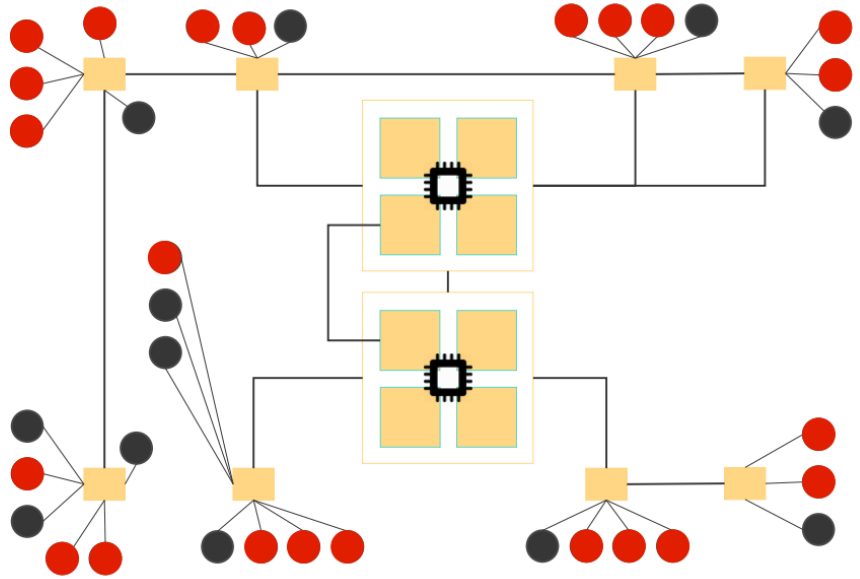
Traditional architecture



Domain architecture



Zone architecture



Asymmetric Data Requirement

B

Motivation for Single Pair Ethernet

Convergence to Single Pair Ethernet

The wild zoo of Standards for Networking of Devices will Converge to (Single Pair) Ethernet

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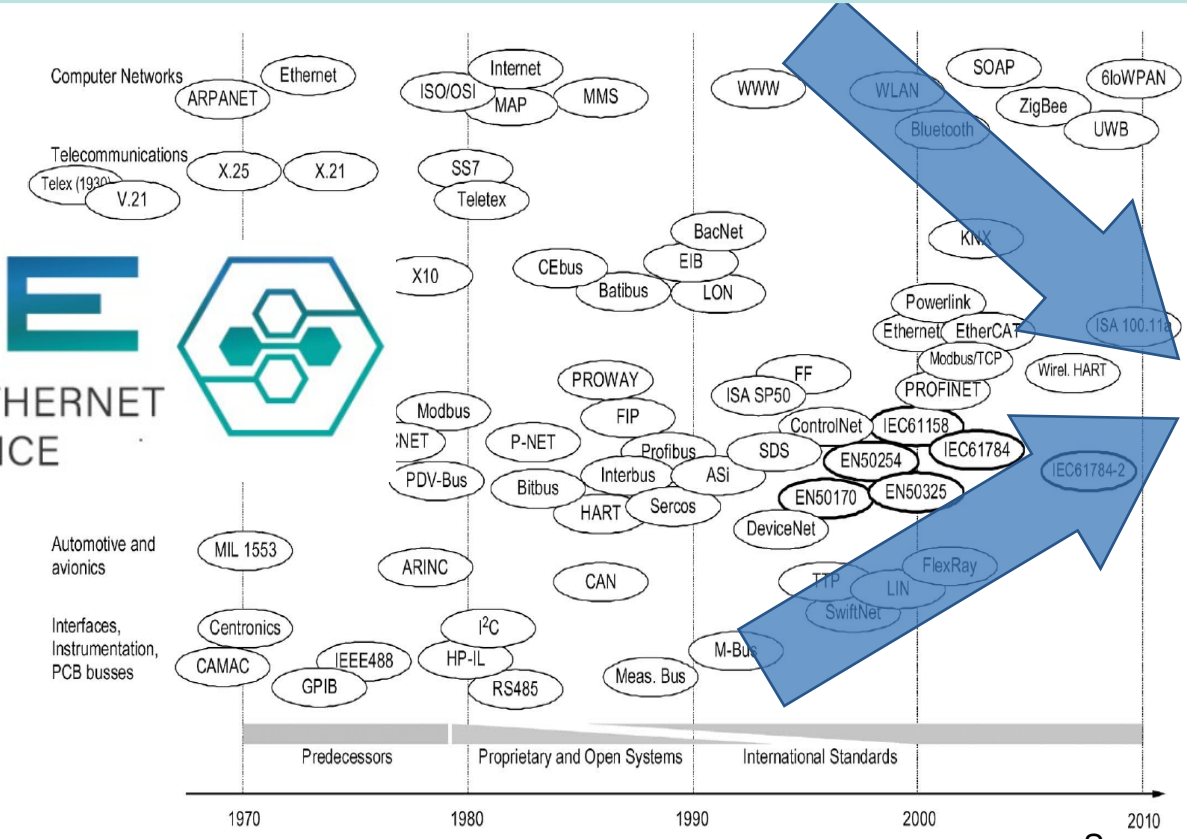
SINGLE PAIR ETHERNET
SYSTEM ALLIANCE



Control Networks will converge to Ethernet

Single Pair Ethernet is a promising candidate due to its compact form factor

Source: Thilo Sauter, IEEE Trans. IE, Vol. 57, No.11, 2010, pp. 3585ff

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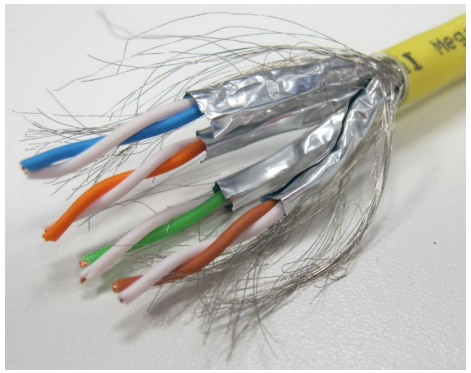
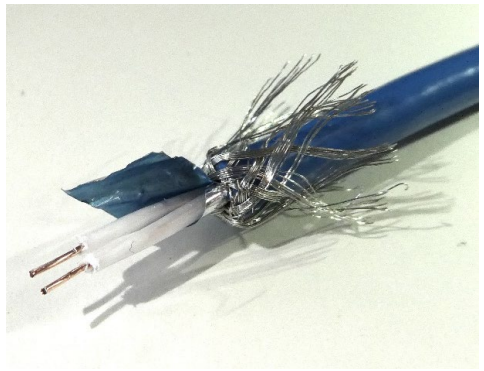
Motivation for Single Pair Ethernet

Why Single Pair Ethernet?

- Current physical layer implementation: eight wire (four pair) CAT-cables
- Connectivity via RJ45 (eight terminals plus shield)





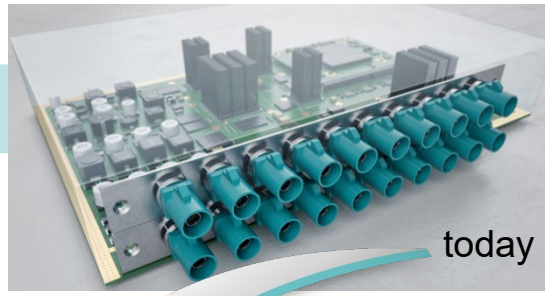
- Has drawbacks concerning complexity, weight, space consumption, field confectioning, physical flexibility, connector reliability, signal reliability
- Single Pair Ethernet is a means to improve electrical and mechanical properties of the PHY-layer (reliability, signalling performance, assembly automation …)

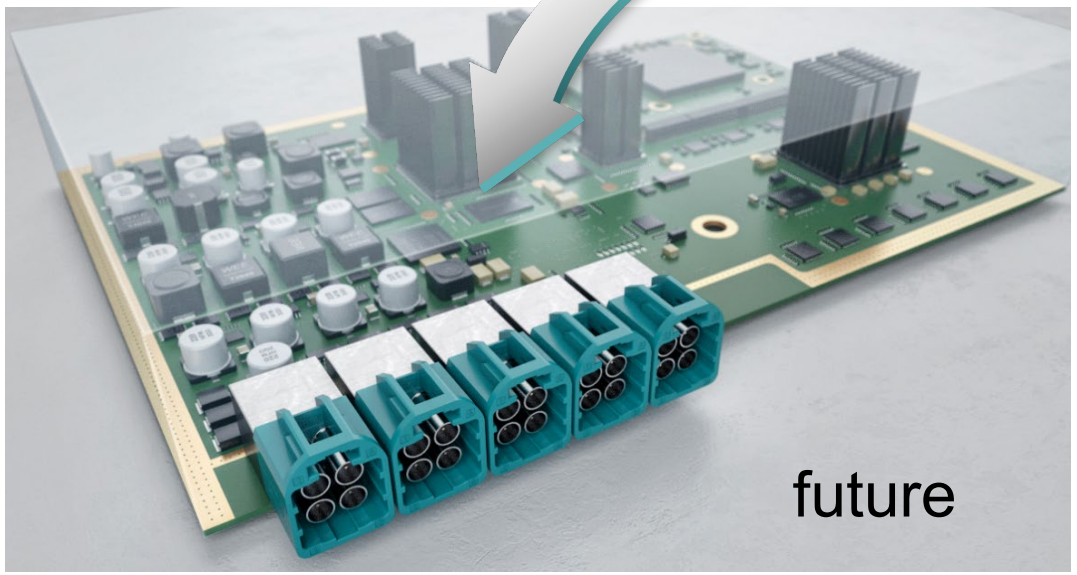
Motivation for Single Pair Ethernet

Miniaturization

- Miniaturization of the connector's footprint on interconnect panels is desired in future applications
- Miniaturization leads to limitations on the physical dimensions of the cables
- Connectors get smaller but cables should be larger for low attenuation -> Compromise to be found

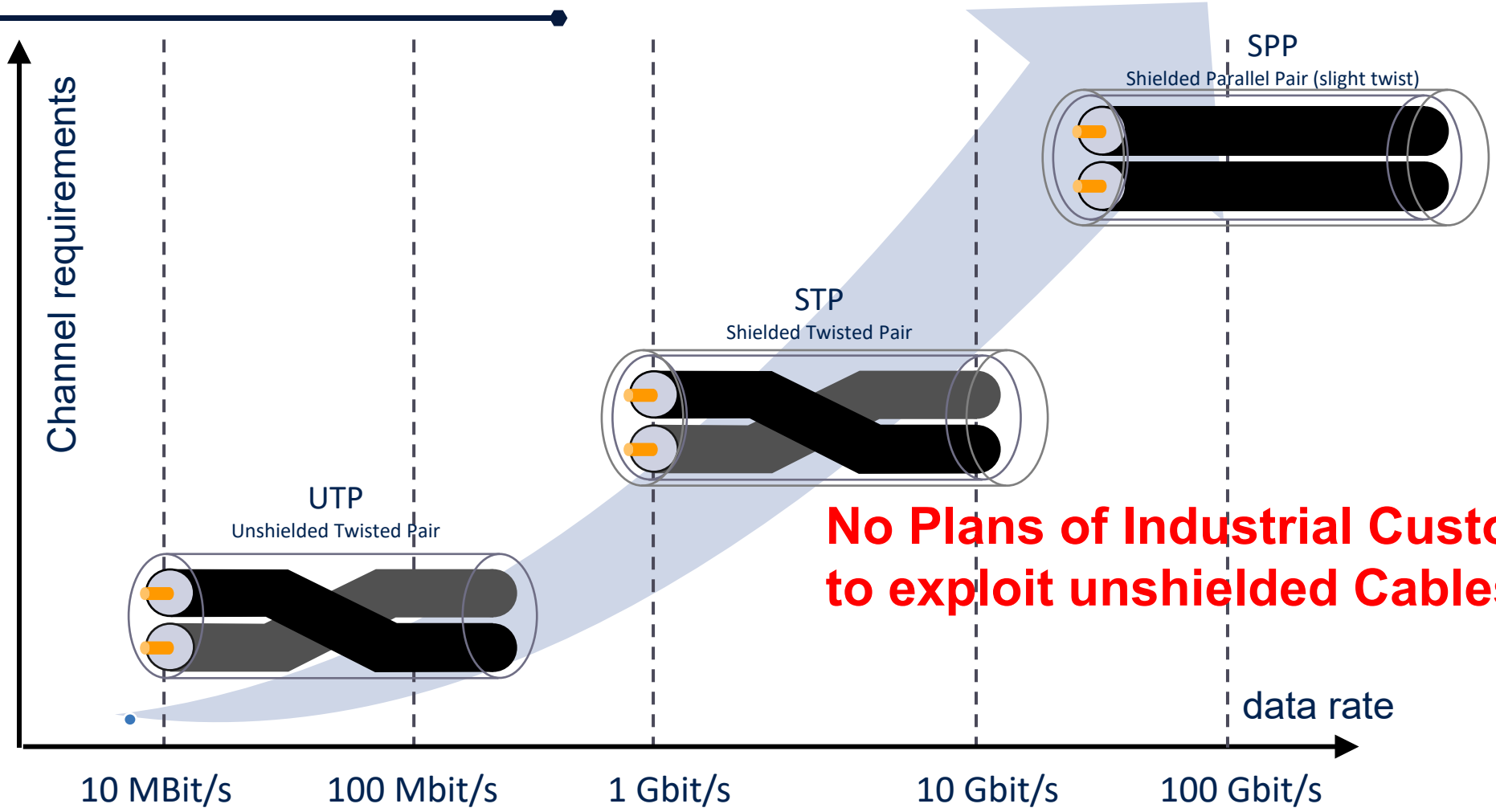
- Cables should target diameter < 5 mm for differential links





Cables for different data rates: *Industrial Applications*

Rosenberger develops automotive-grade RF and data cables in cooperation with leading cable manufacturers to provide up to 20 GHz of RF bandwidth for Automotive



No Plans of Industrial Customers to exploit unshielded Cables!

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Finalized IEEE-Standards for SPE

IEEE-Standard	Technical Comment
IEEE P802.3cg (10Base-T1); still in Draft Version	10 Mbit/s SPE, PAM-3?, 2.4V-Operation has 1000 m Reach, 1.0V-Operation has 15 m Reach
IEEE 802.3bw-2015 (100Base-T1); finalized	100 Mbit/s SPE, PAM-3, 4B/3B-coding Spec for reach up to 15 m is finalized; longer links to be specified in future releases; no physical reason, why 100 m-links should not work (consider prop.-delay-spec!)
IEEE 802.3bp-2016 (1000Base-T1); finalized	1000 Mbit/s SPE, PAM-3, 80B/81B-coding Spec is finalized; link segments type A (15 m, propagation delay < 94 ns) and type B (40 m, propagation delay < 234 ns) are specified 100 m-links not feasible with current technology;
IEEE 802.3bu-2016 (PoDL; Power over DataLines); finalized	Power over DataLines specified for 100Mbit/s- and 1000Mbit/s-Operation; Loop Resistance has to be very low depending on power class; power at device up to 50 W Additional ferrite components req'd

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Estimation of Req'd Wire CrossSection

SPE-Datarate as specified in IEEE	Length	Spec'd Frequency max. spec'd IL	Conductor CrossSection / sqmm @ Tamb = 85°C	AWG
10 Mbit/s	1000 m	20 MHz, 58.35 dB	0.792	18
10 Mbit/s	500 m	20 MHz, 58.35 dB	0.201	24
10 Mbit/s	100 m	20 MHz, 58.35 dB	0.0089	37
100 Mbit/s	15 m	66 MHz, 7.2 dB	0.0425	30
1000 Mbit/s	15 m	600 MHz, 15.88 dB	0.0904	27
1000 Mbit/s	40 m	600 MHz, 22.27 dB	0.292	22
1000 Mbit/s (not spec'd! Just for comparison!!)	100 m	600 MHz, 22.27 dB (40 m loss budget assumed. Propagation delay will not meet spec!)	1.69	14

Assumptions: Validity of scaling models; dielectric losses negligible

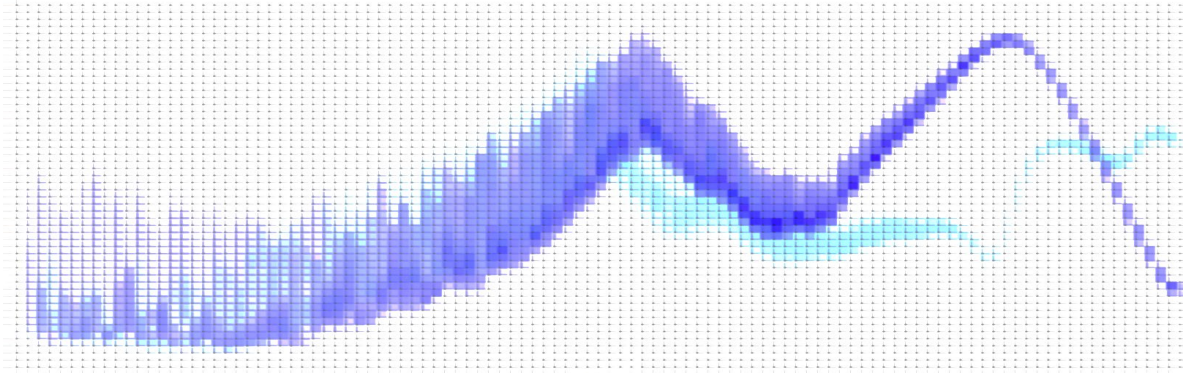
C EMC-Considerations

Why EMC takes a Major Role in the car

- EMC means: "*the ability of equipment or a system to function satisfactorily in its electromagnetic environment without introducing intolerable electromagnetic disturbances to anything in that environment*."
- "*The aim of EMC is to ensure the reliability and safety of all types of systems wherever they are used and exposed to electromagnetic environments. So EMC development is closely linked with the whole field of electrical and electronic engineering, including the design and testing of these systems*."

…found on the IEC Homepage

https://www.iec.ch/emc/explained/environment.htm



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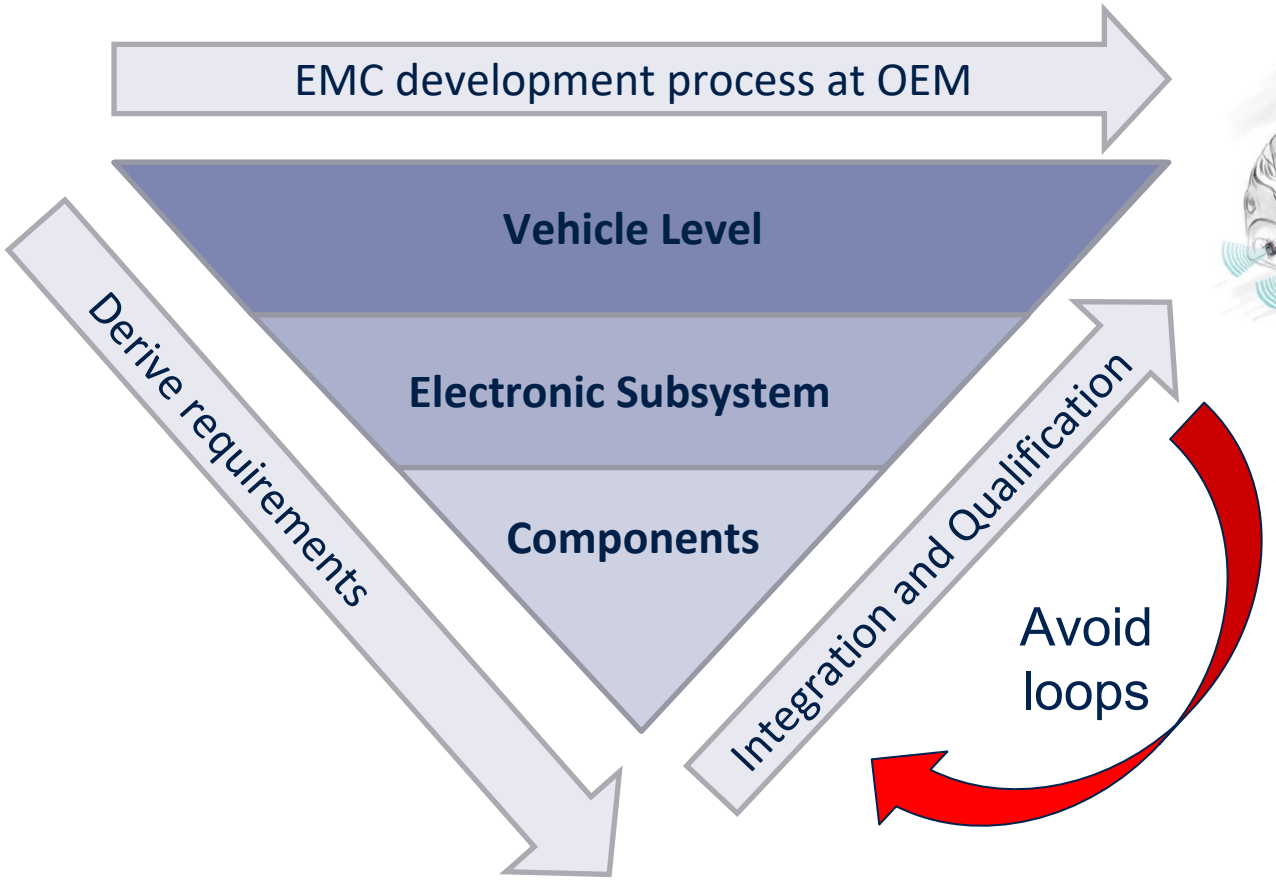
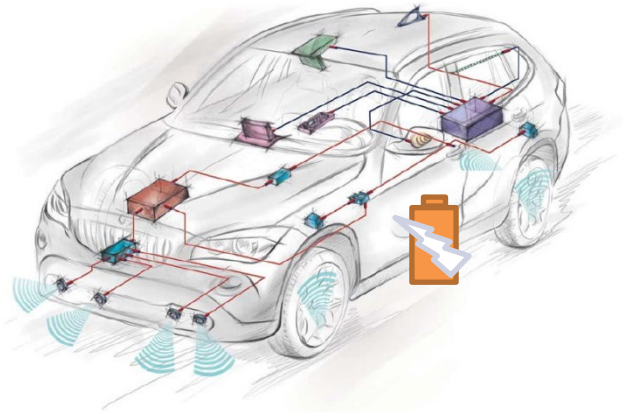
The V-Model in EMC-robust Design

Development Specification





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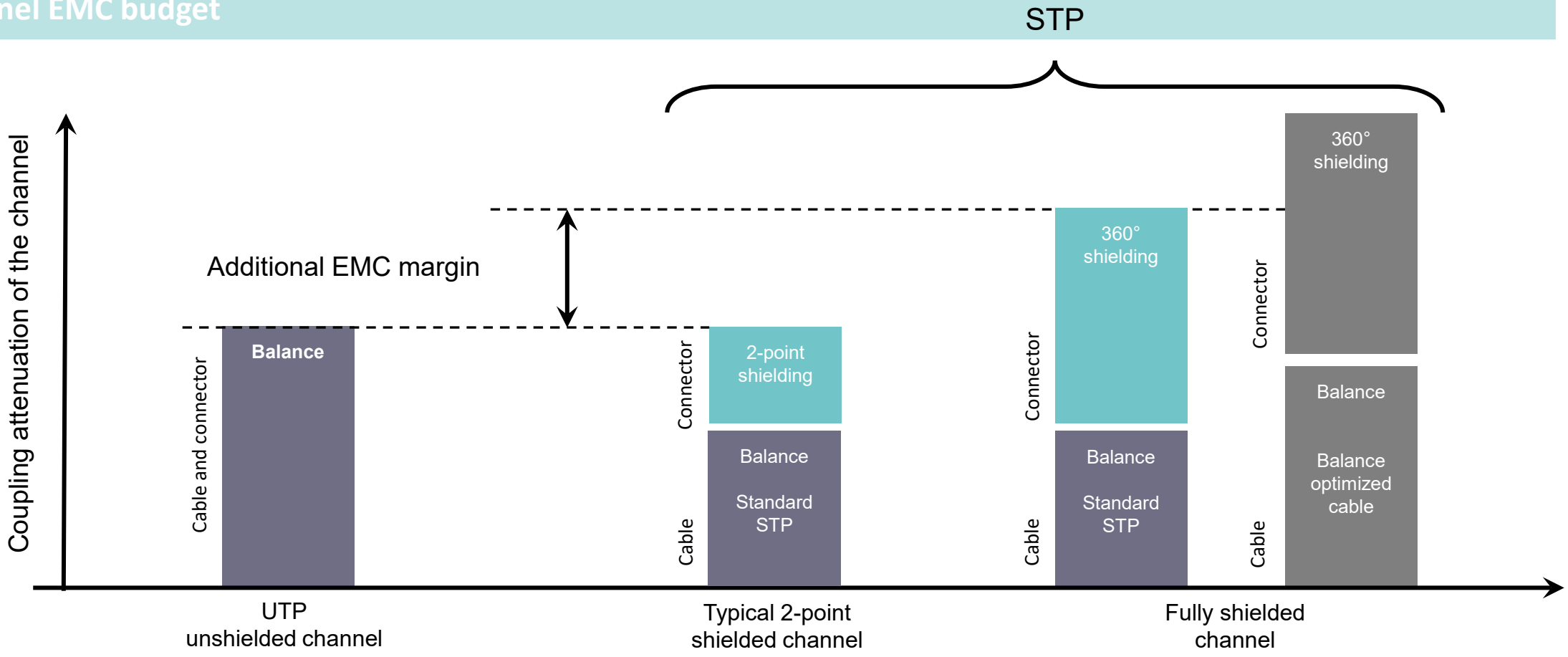
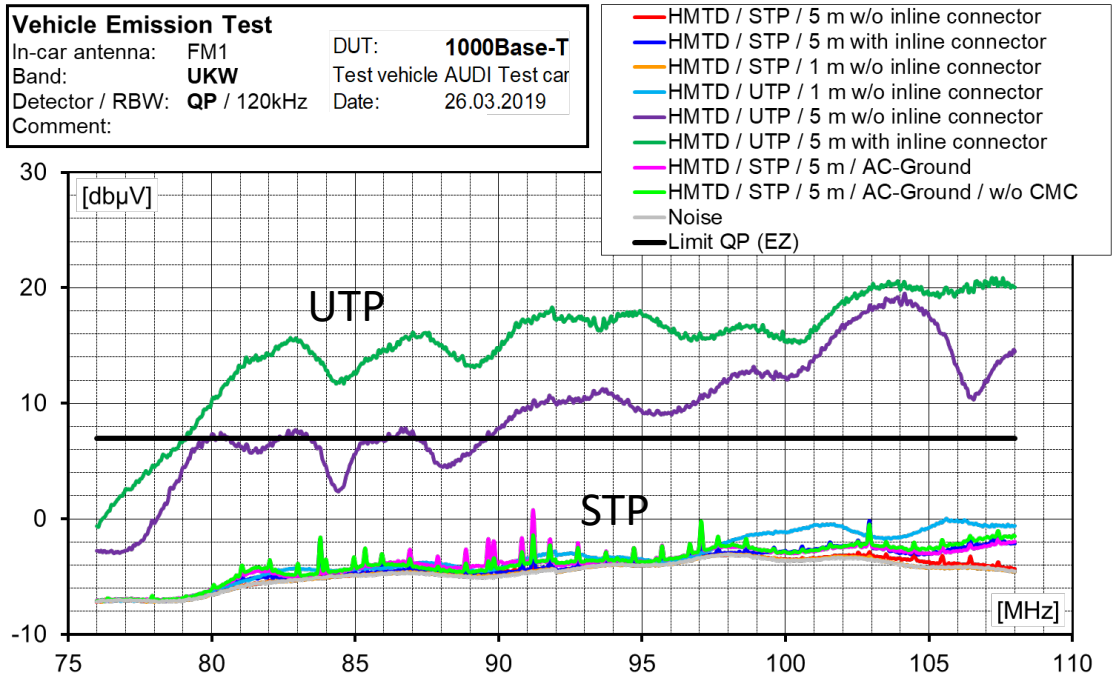
Automotive Ethernet Status of Implementation

Channel EMC budget

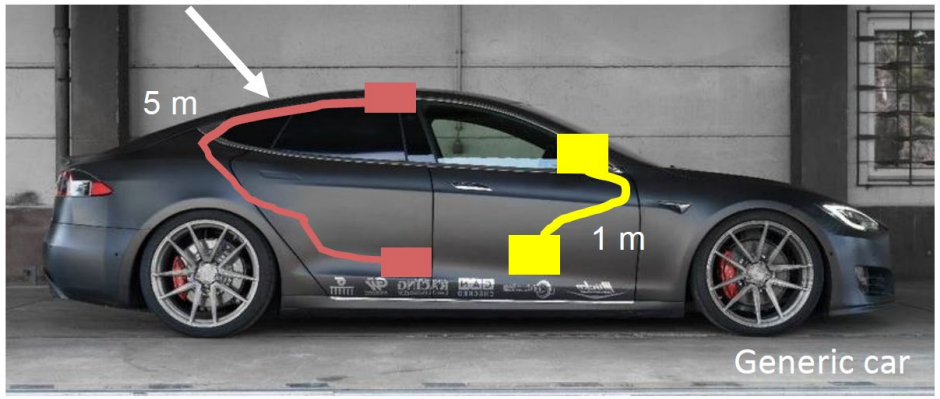


1000BASE-T1 Vehicle Measurement

Measurement results



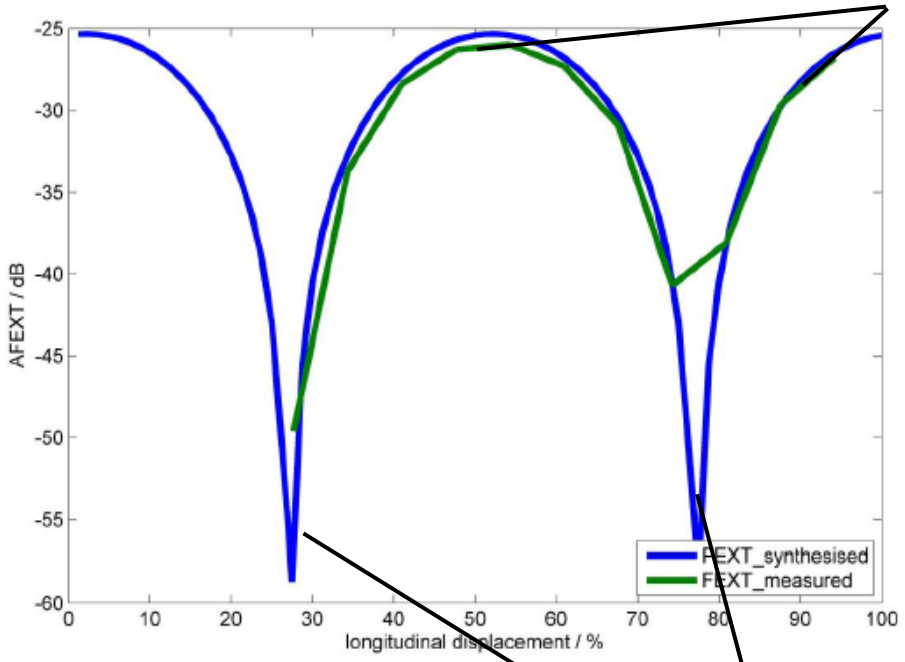
window integrated antenna

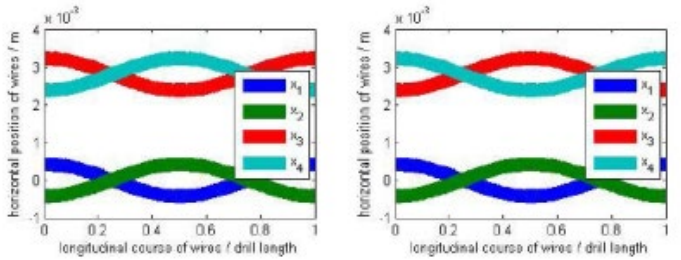


- H-MTD with UTP: 1 m link passes, 5 m link above the limit for emissions into antenna
- H-MTD with STP passes with margin (noise level)
- To implement UTP for 1000BASE-T1, the OEM should test EMC on vehicle level

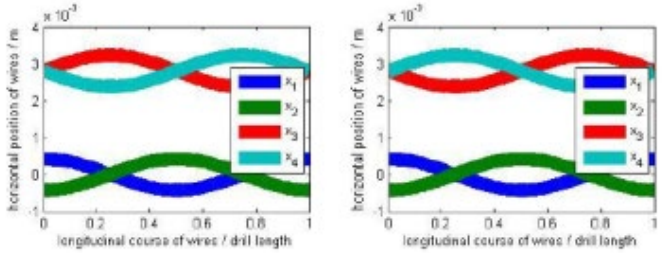
Crosstalk in Bundles

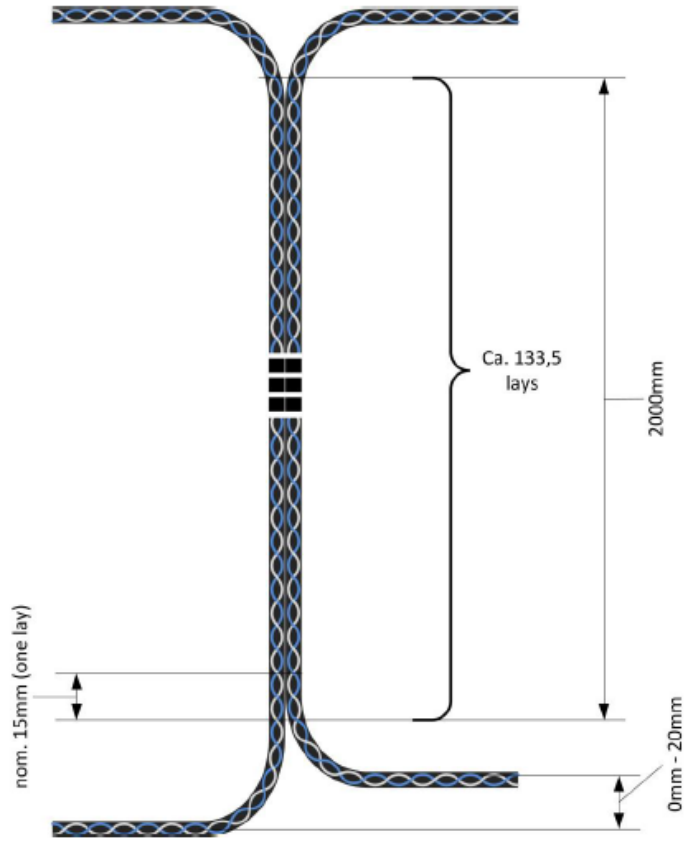
A general issue of UTP cables





- Crosstalk peak at same lay length of all cables
- Not covered by OPEN Alliance specs yet

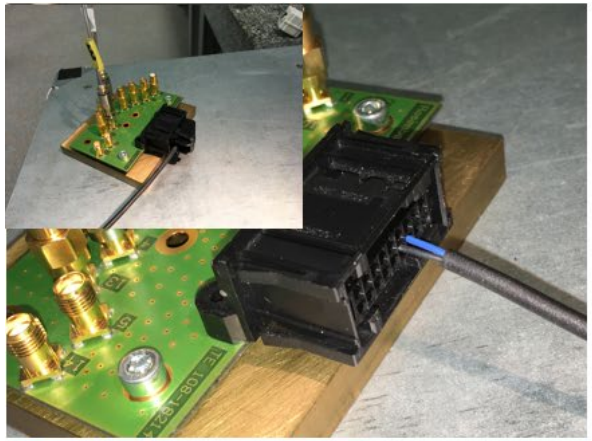




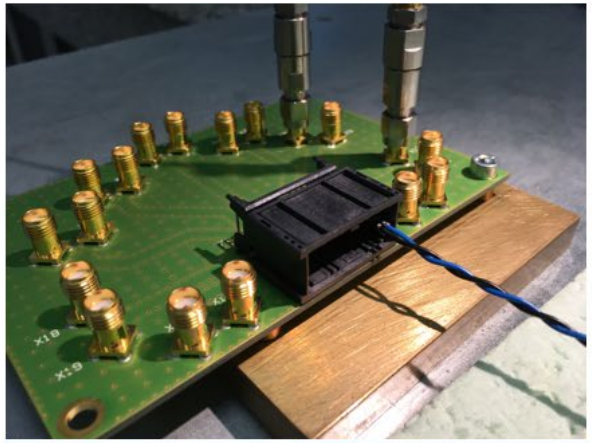
D

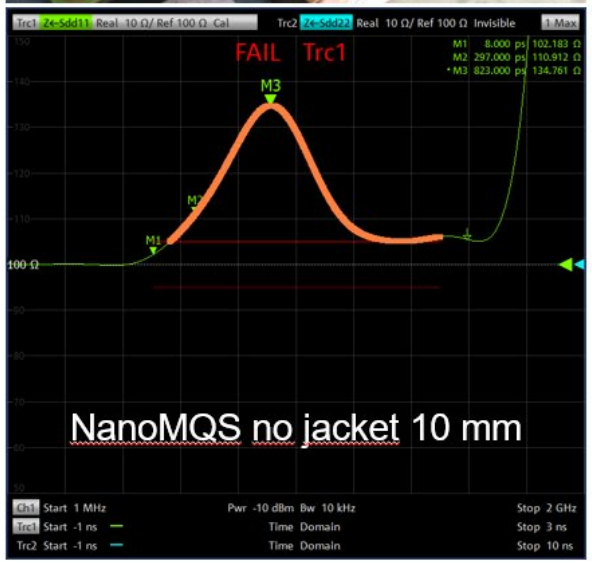
Lessons learned in Automotive Applications

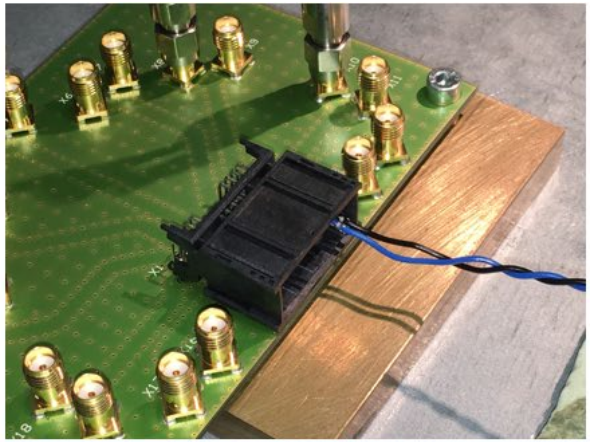
Untwist




FAIL
Trc1
M1
M2
M3
100 Ω
MQS jacket 10 mm untwist




FAIL
Trc1
M1
M2
M3
100 Ω
NanoMQS no jacket 10 mm




FAIL
Trc1
M1
M2
M3
100 Ω
NanoMQS no jacket 30 mm

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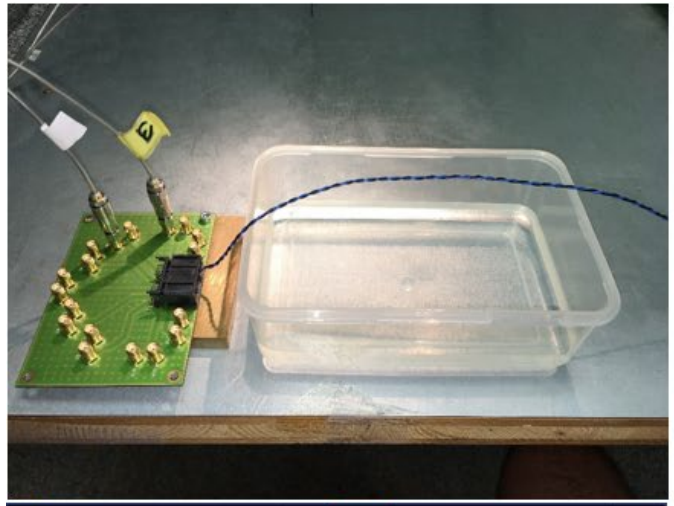
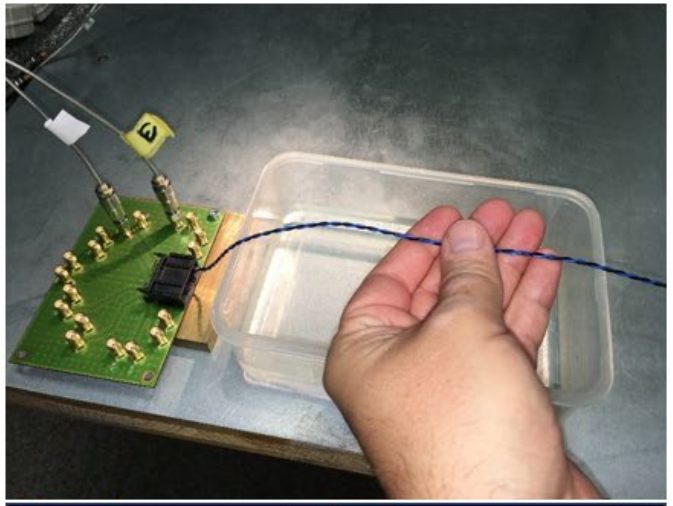
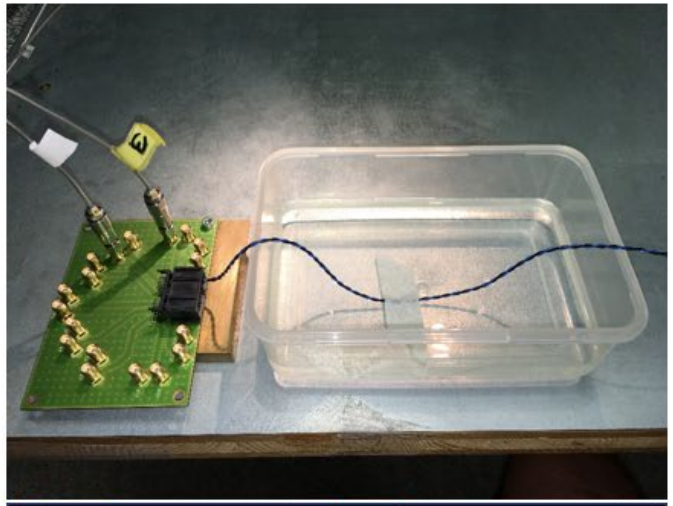
Exposure to water – Non-jacketed UTP



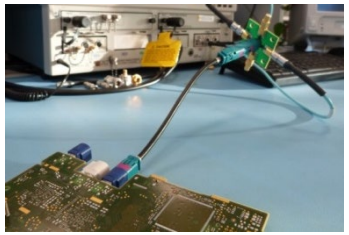


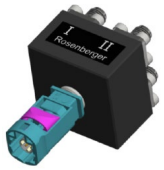


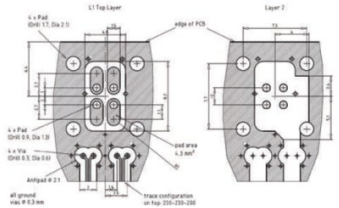
Automotive Ethernet

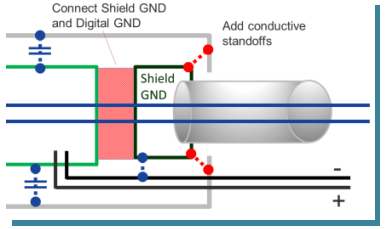
Design-In Support

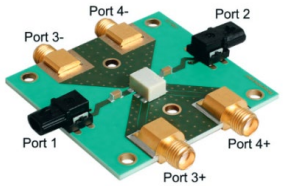
- Contribute in standardization
- Collaborate with PHY vendors
- Layout recommendations
- Signal path layout review
- EMC aspects of PCB grounding concepts
- Test adapters and break-out boards
- Measurement couplers for debugging in the car









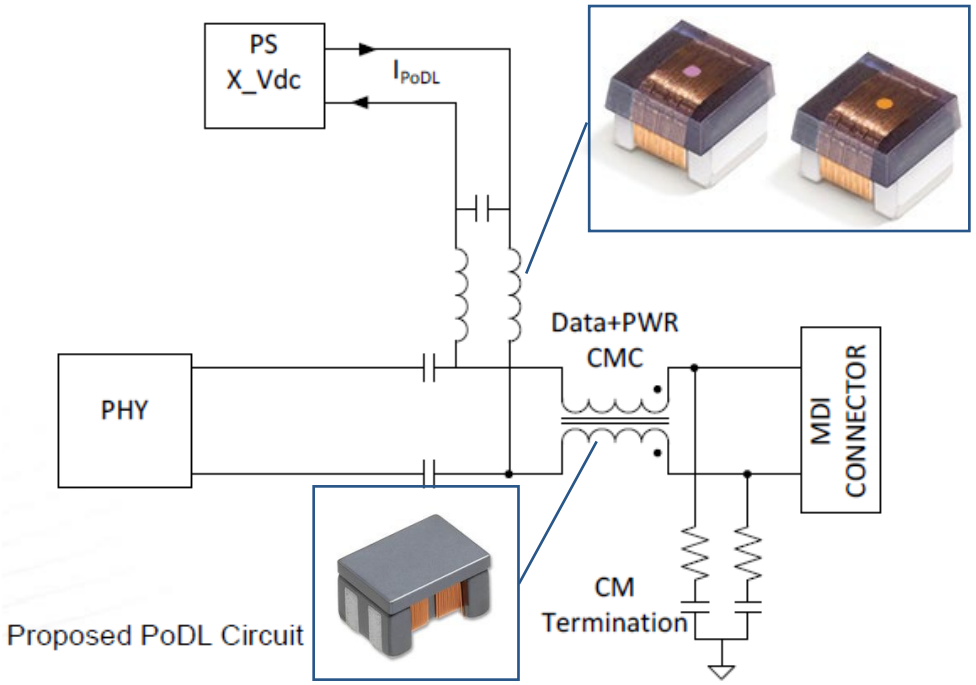


E

Power over Datalines (PoDL) reduces Harness Complexity

Power over Dataline (PoDL)

- Specified for SPE in IEEE 802.3bu
- Transmission of DC-power on a signal pair on top of the datastream is more difficult than if shield is used as DC-return (forward- reverse current act like a differential signal)
- Current rating is limited by the inductor‘s properties
  - RF-properties (physical size of the ferrite components!)
  - Symmetry
  - Wire dimensions
  - Ferrite core material (saturation effects!)
- DC resistance of the signal wires and thus voltage drop on the cable limit the possible cable length



Power over DataLines (PoDL); IEEE 802.3bu-2016

- Avoids ground loops, thus improving EMI-performance

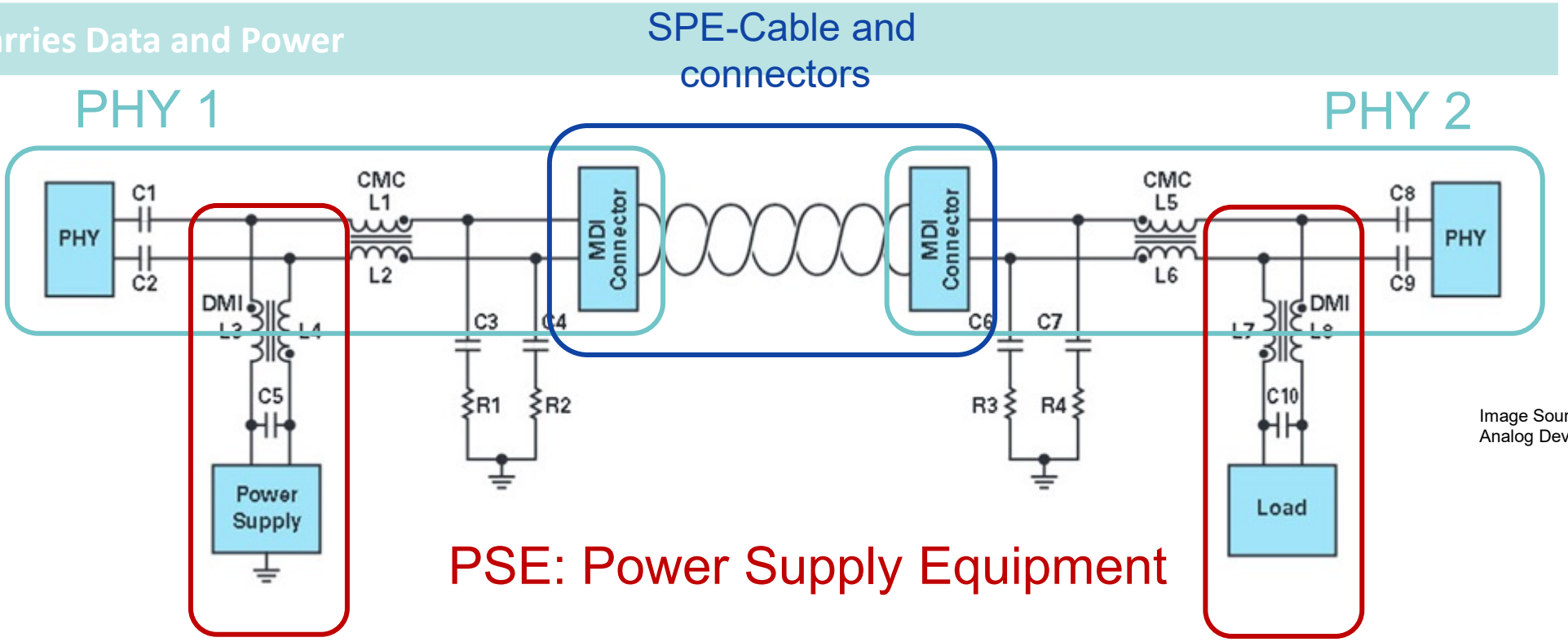


Image Source: Analog Devices

Transmission of data and energy on one cable;
no additional power cable is required! No inductive coupling loops!

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Power over DataLines (PoDL)

Summary of System Classes in IEEE 802.3bu-2016

System Class									
R_{Loop} loss 20%	I (5V)	I (12V)	II (12V)	II (24V)	III (24V)	III (48V)	IV (48V)	V (48V)	VI (Open)
*$V_{PSE(max)}$ (V)	5.5	14	14	28	28	56	56	56	-
*$V_{PSE(min)}$ (V)	4.75	9	9	18	18	36	36	36	-
$I_{PI(max)}$ (A)	0.53	0.28	0.69	0.35	0.69	0.35	0.87	2.08	-
**$R_{Loop(max)}$ (Ω)	1.8	6.5	2.6	10.4	5.2	20.7	8.3	3.5	-
***$P_{PD(max)}$ (W)	2	2	5	5	10	10	25	60	-
P_{PSE} (W)	2.5	2.5	6.25	6.25	12.5	12.5	31.25	75	-
$V_{PD(min)}$	3.8	7.2	7.2	14.4	14.4	28.8	28.8	28.8	-

*V_{PSE} is the open circuit voltage measured at the PSE PI.
**R_{Loop} is defined as the sum of the PSE source resistance and link segment round trip resistance.

***P_{PD} is measured at the PD PI.

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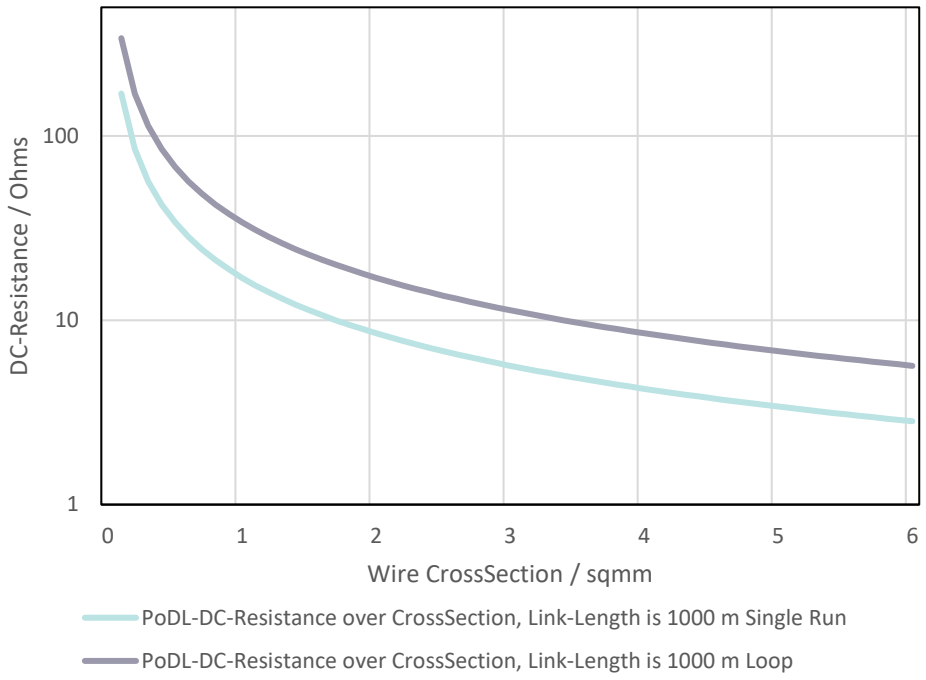
Power over DataLines (PoDL): 10Base-T1 over 1000 m

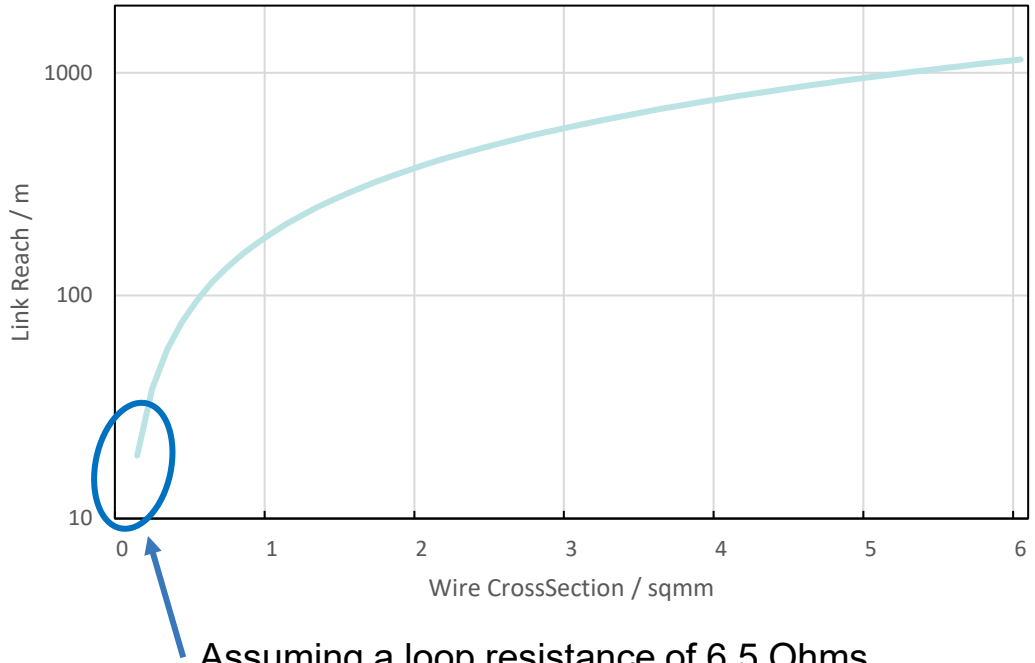
Reach according to IEEE-Specs at Room Temperature; Assessment based on Loop Resistance

Link Resistance over Wire-CrossSection



Cable dimensions get unrealistically large for 1000 m-links!

Link Reach over Wire-CrossSection



Assuming a loop resistance of 6.5 Ohms,
„Reasonable“ wire dimensions (< 0.35 sqmm)
are sufficient for 15 m- and 40 (100) m-links.

Thank You

Contact details

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