

# Robust Connectivity Solutions for Next-Generation Automotive Ethernet

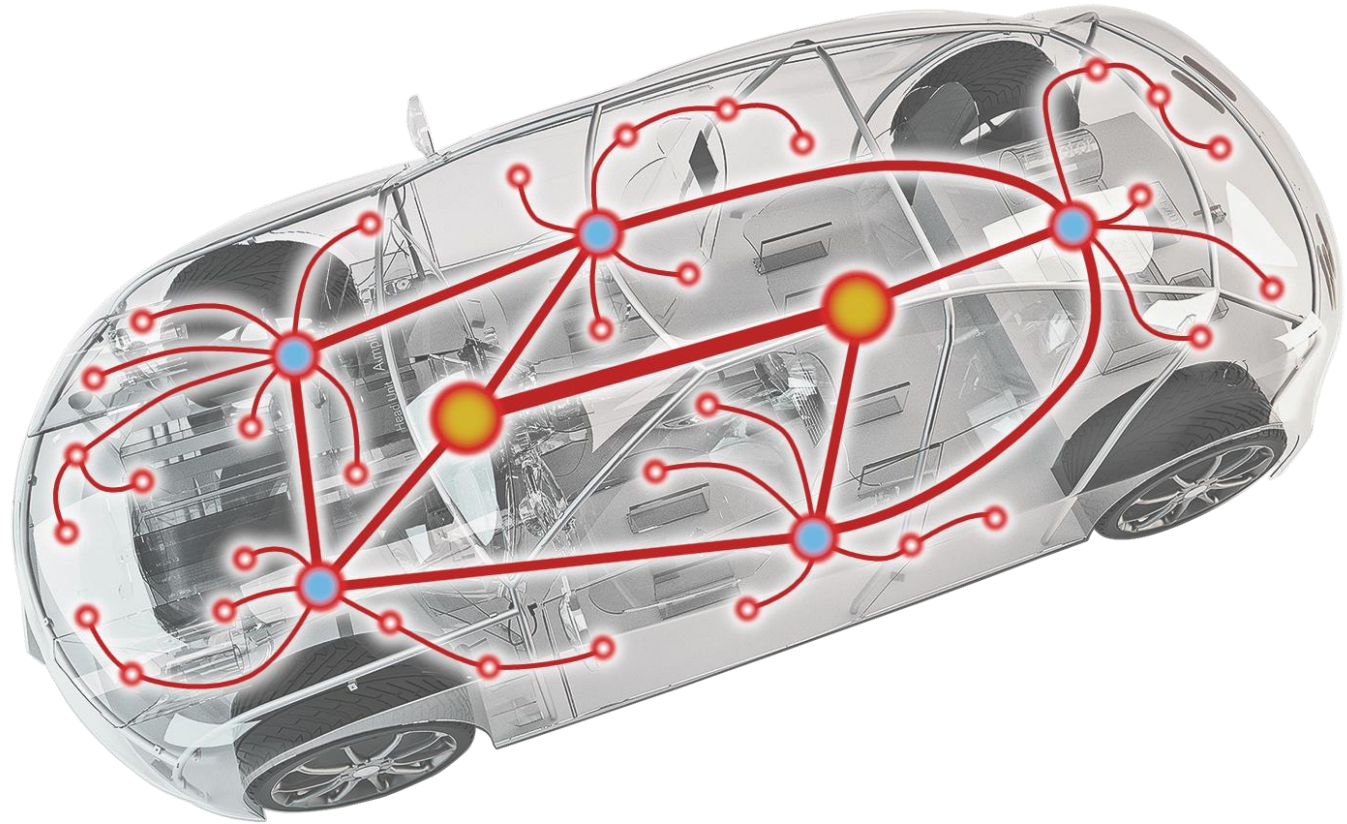
2019 IEEE SA Ethernet & IP @ Automotive Technology Day  
Bert Bergner, Eric DiBiaso (TE Connectivity)

# Enabling Technologies for Autonomous Driving

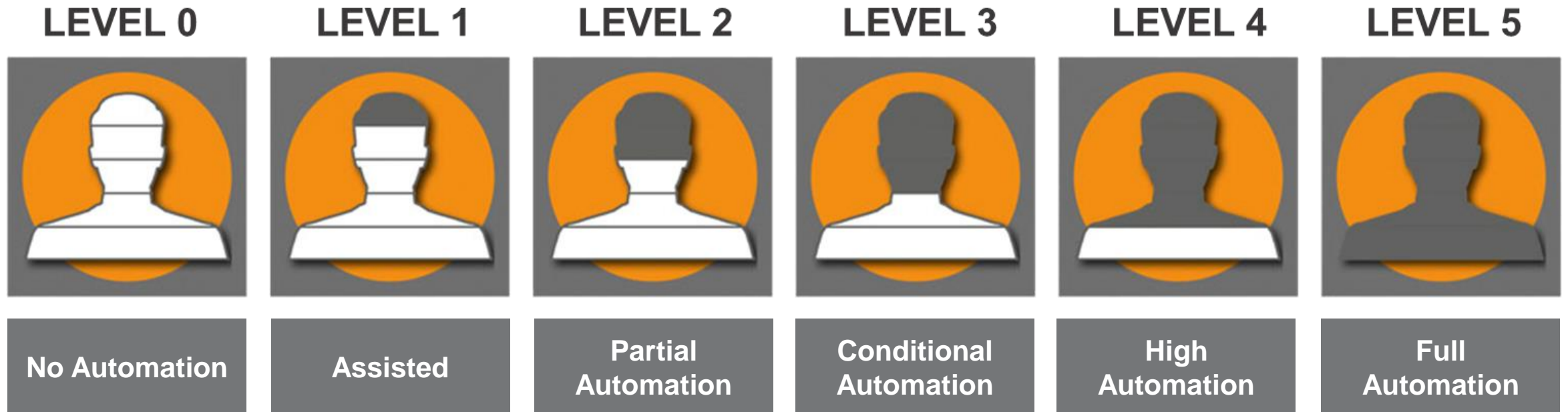
**SENSOR FUSION** multiple camera, radar, lidar and ultrasonic sensors

**NETWORK ARCHITECTURE** central computing, zonal data aggregation

**SAFETY** redundant and fault tolerant system design



# Evolution of Autonomy



Increasing Data Rate

“Drive by Data”

# Robust System Design – What does it mean?



Environmental  
Changes

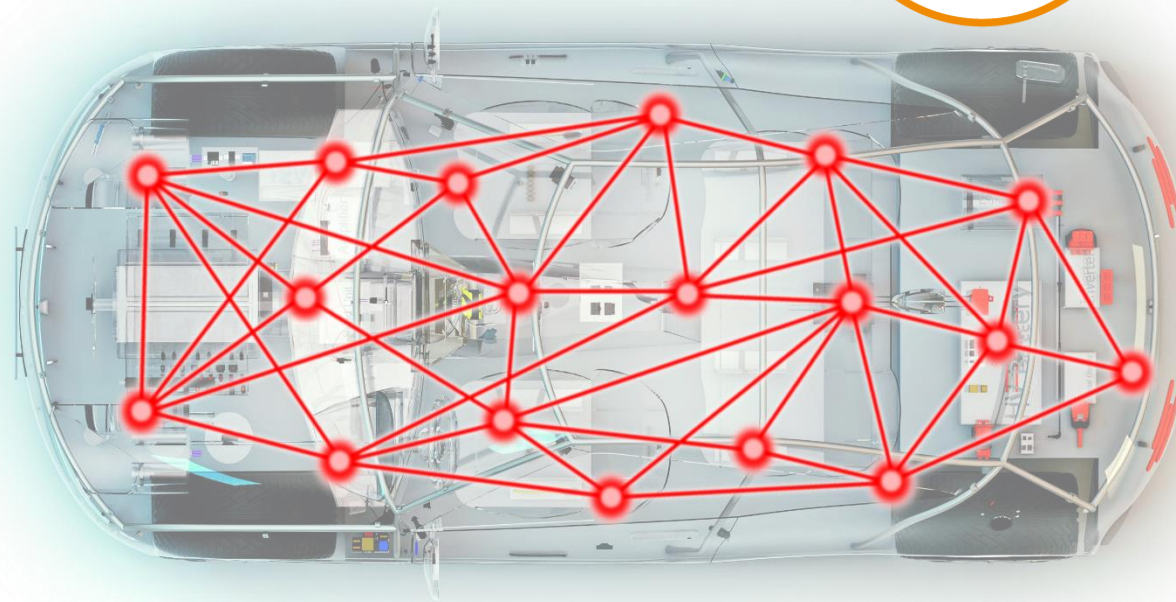
Process &  
Manufacturing  
Tolerances



Mechanical  
Stress



Material  
Variations



Electromagnetic  
Interference



Topology  
Variations

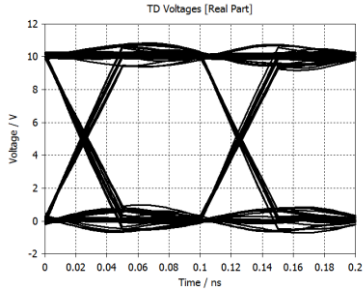
Aging





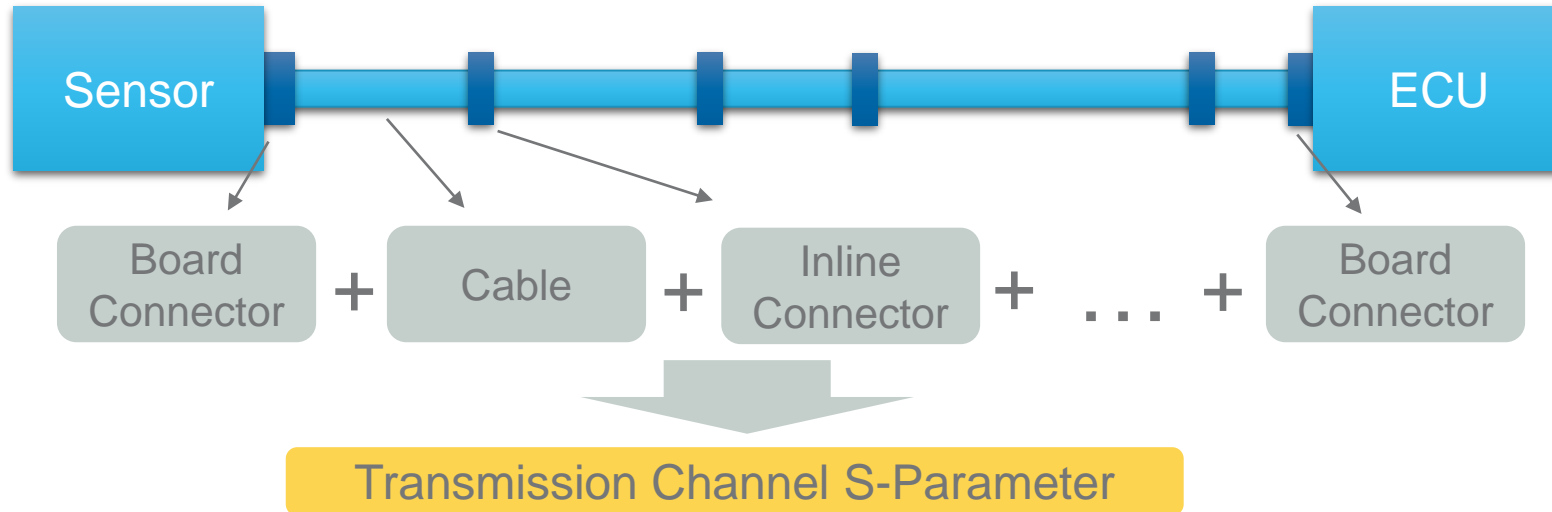
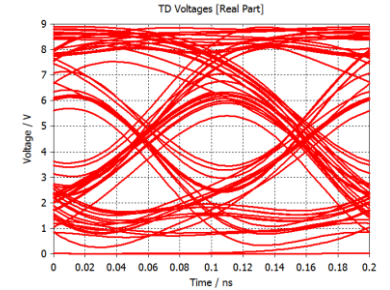
# Channel Performance Parameters

Transmitted Signal



Data Transmission

Received Signal



## Connector models:

- Based on measurements & simulations
- Connector types & pairing variants
- Mating tolerances
- Cable termination variation
- Geometric & material tolerances

## Cable models:

- Numeric models for cable types
- Parameters based on measurements
- Parameterization for:
  - Cable length
  - Impedance tolerance
  - Environmental changes & aging

# Connector Parameter Impact – Example

Geometric tolerances



Topology variations



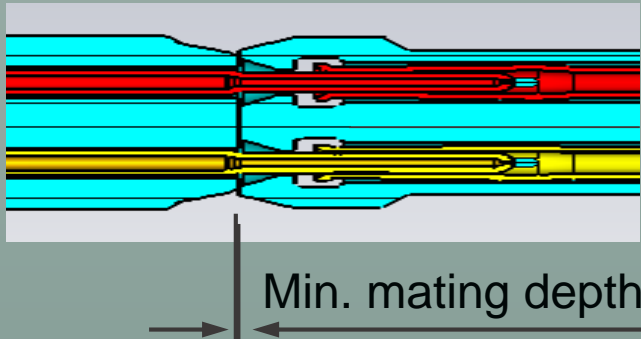
Environmental effects



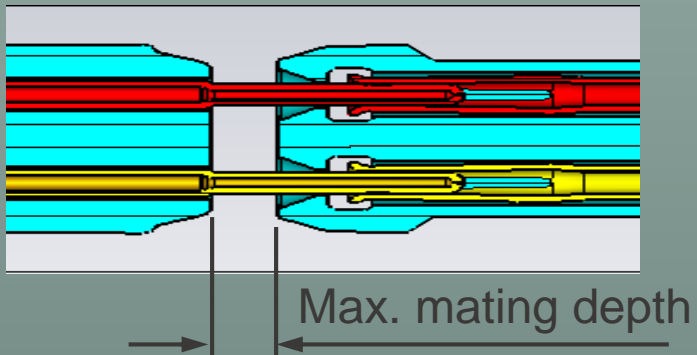
Material variations



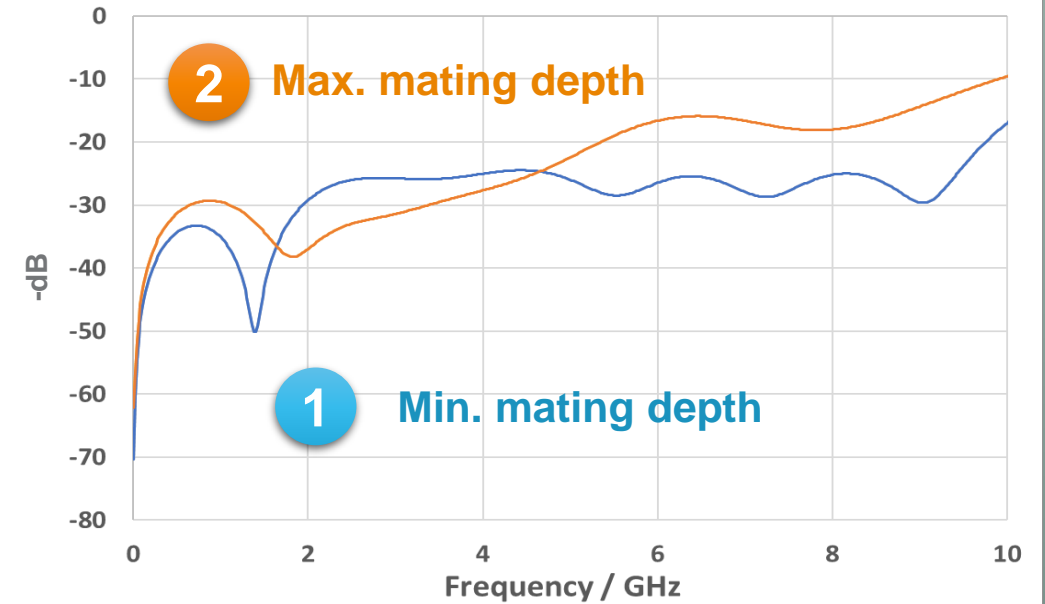
1



2



Mated Connector Return Loss



# Connector Parameter Impact – Example

Geometric tolerances



Topology variations



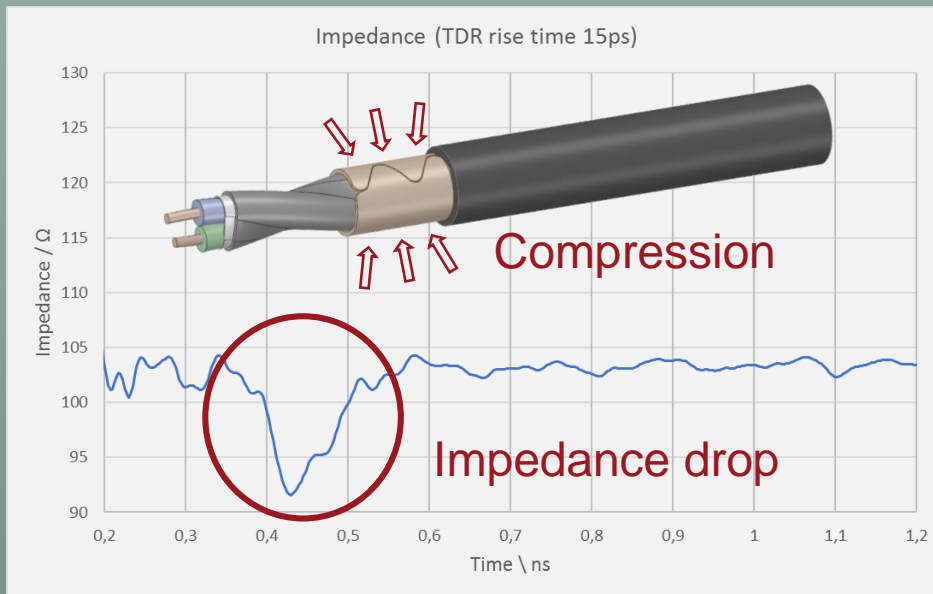
Environmental effects



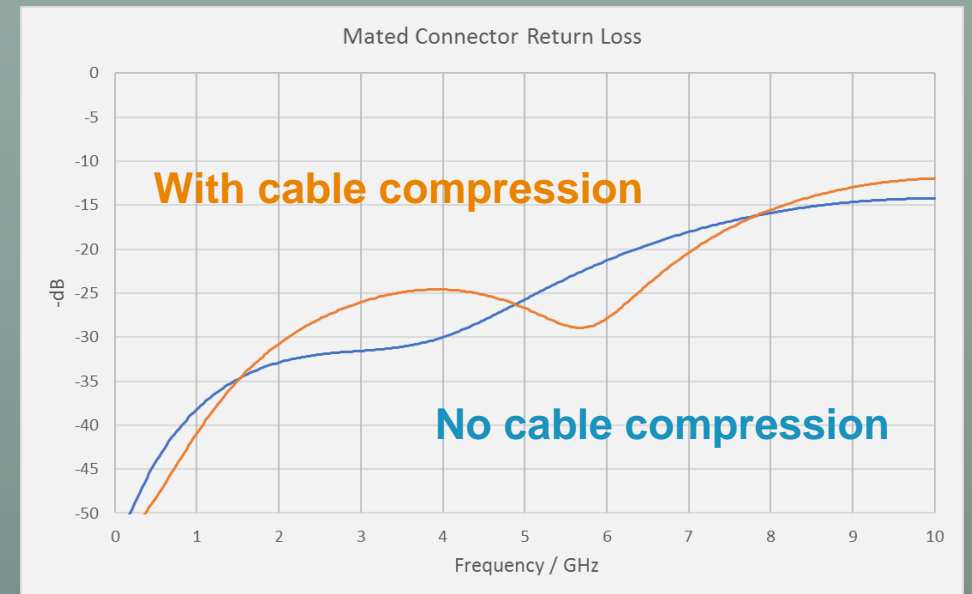
Material variations



## Cable compression in crimp zone



## Connector Performance



# Cable Parameter Impact – Example

Geometric tolerances



Topology variations



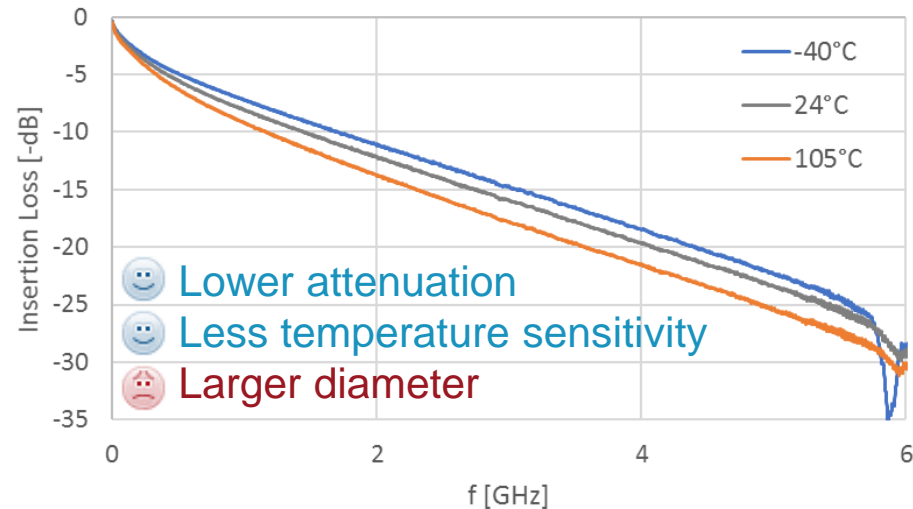
Environmental effects



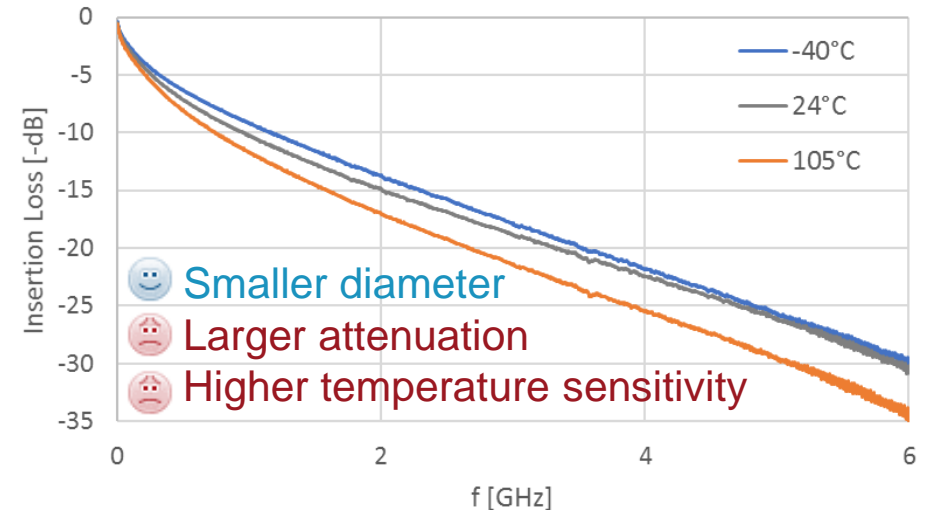
Material variations



STP Cable A - 10 m



STP Cable B - 10 m



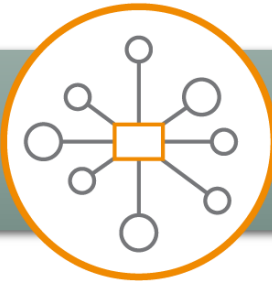


# Channel Analysis – Example

Geometric  
tolerances



Topology  
variations



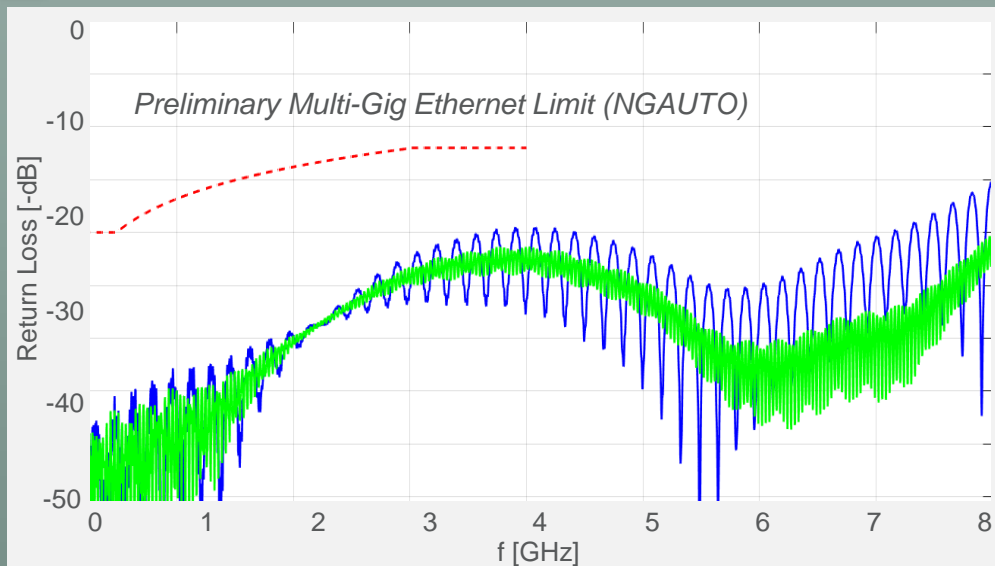
Environmental  
effects



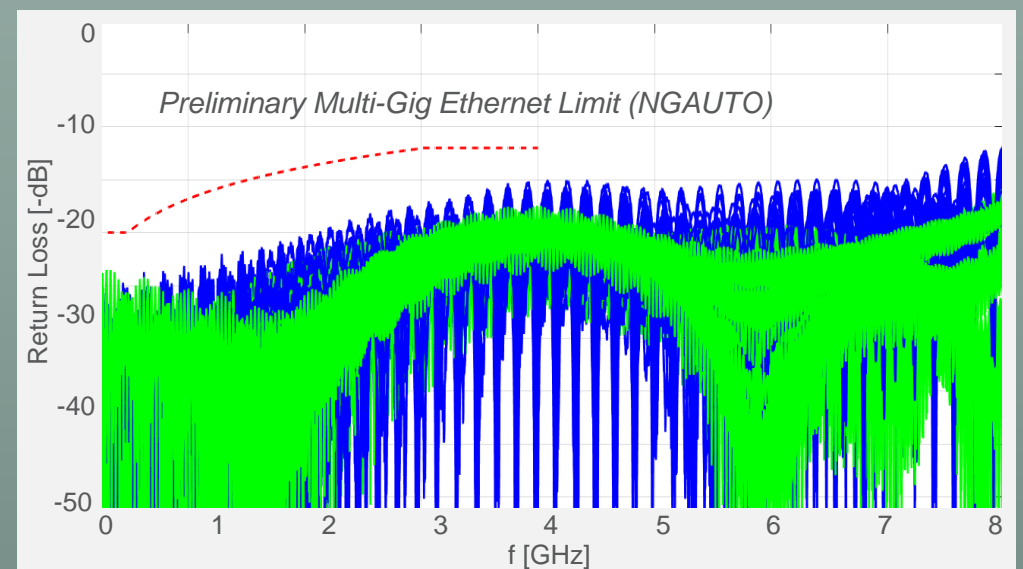
Material  
variations



## Single channel result



## Random parameter and topology variation



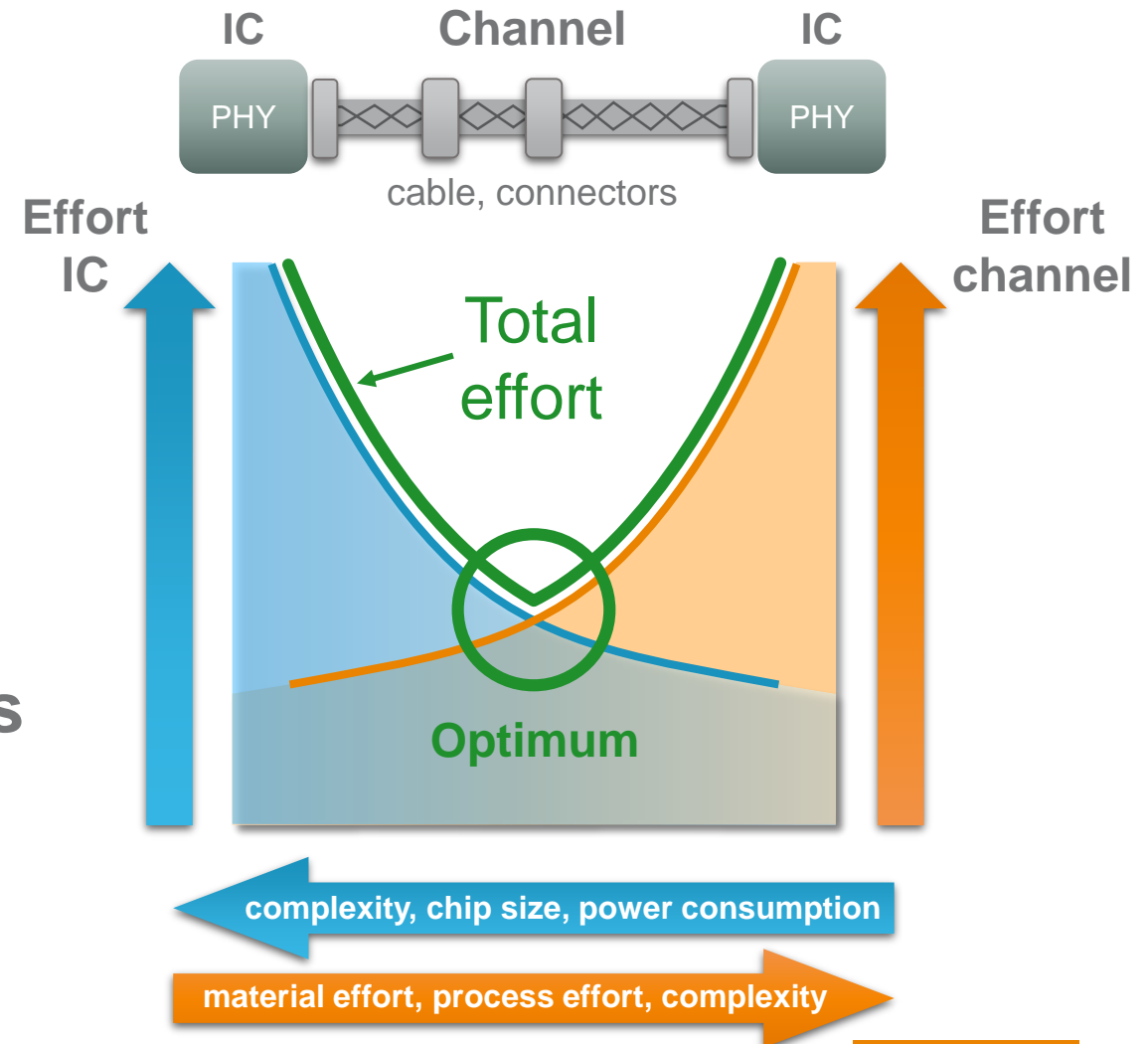
# Channel Analysis – Conclusion

- Robust system definition considering component tolerances and environmental changes
- Robust component design with low tolerance sensitivity of RF parameters
- Processes without degradation of RF parameters
- Engineered cable harnesses allowing economic implementation

# Data Capacity of Automotive Data Cabling

## How fast can we go?

- Identify physical limits
- Estimate maximum data rate
- Consider robust system design and automotive requirements
- Propose possible system solutions for data rates up to 25 Gbps



# Calculation of Achievable Data Rates

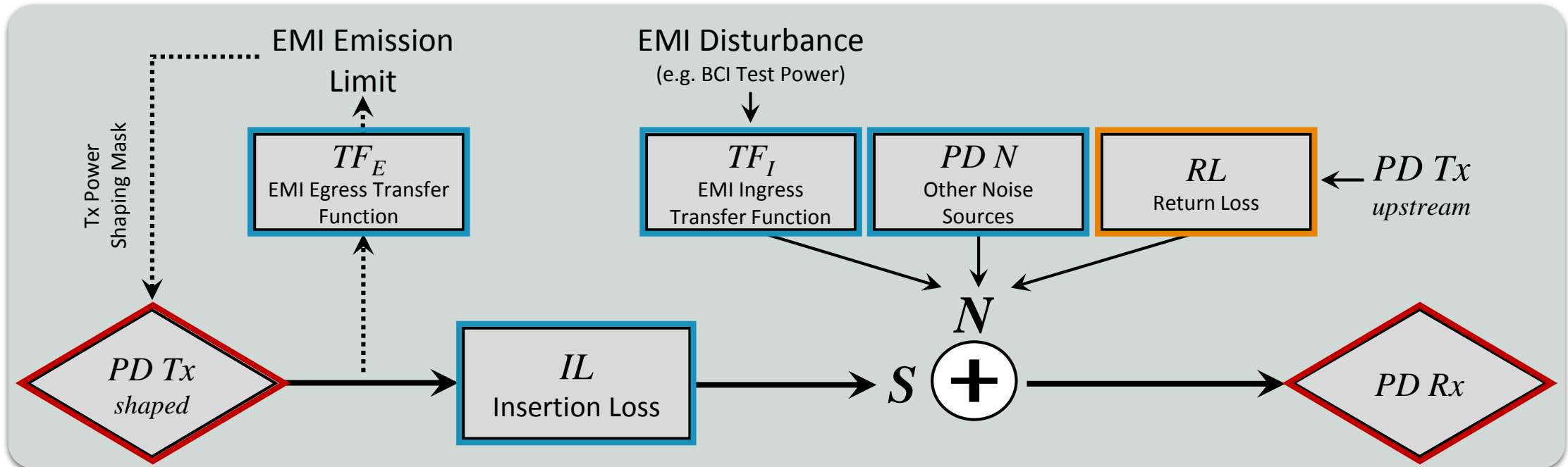
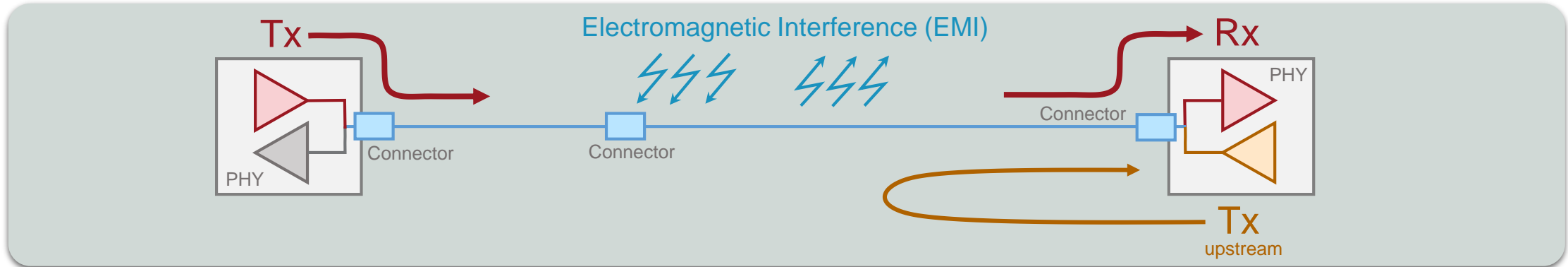
## Considerations:

- Baseband signaling on 0.14 mm<sup>2</sup> STP cabling
- Channel transmission parameter  
*Return Loss, Insertion Loss*
- Environmental degradation
- Electromagnetic emission limits
- Electromagnetic immunity
- PHY dependent transmission power limits, receiver noise, etc.

Shannon-Hartley theorem:  
(for White Gaussian Noise)

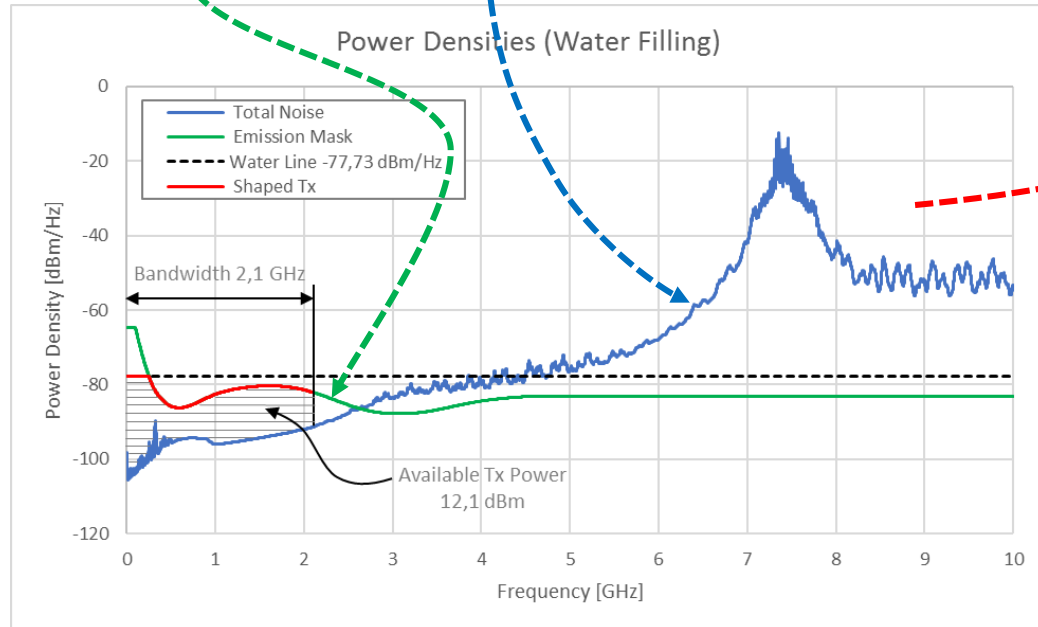
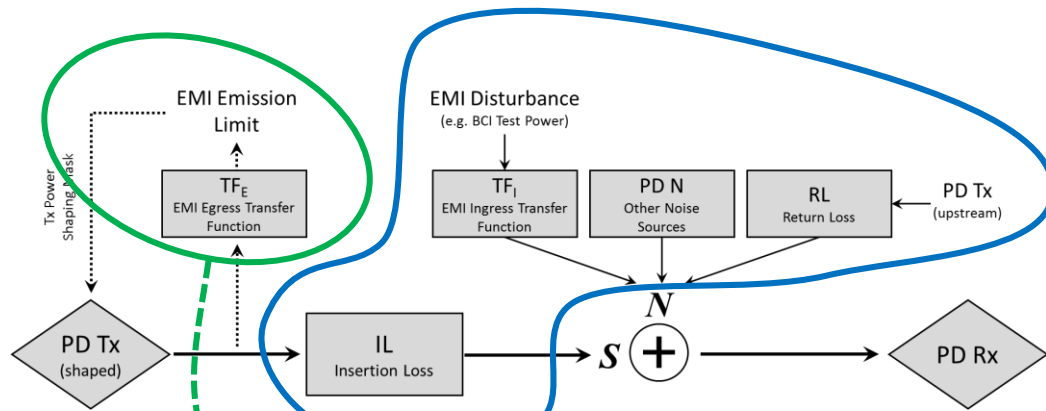
$$\text{Data Capacity} = \text{Bandwidth} \cdot \text{ld} \left( 1 + \frac{\text{Signal}}{\text{Noise}} \right)$$

# Channel Model Including EMI

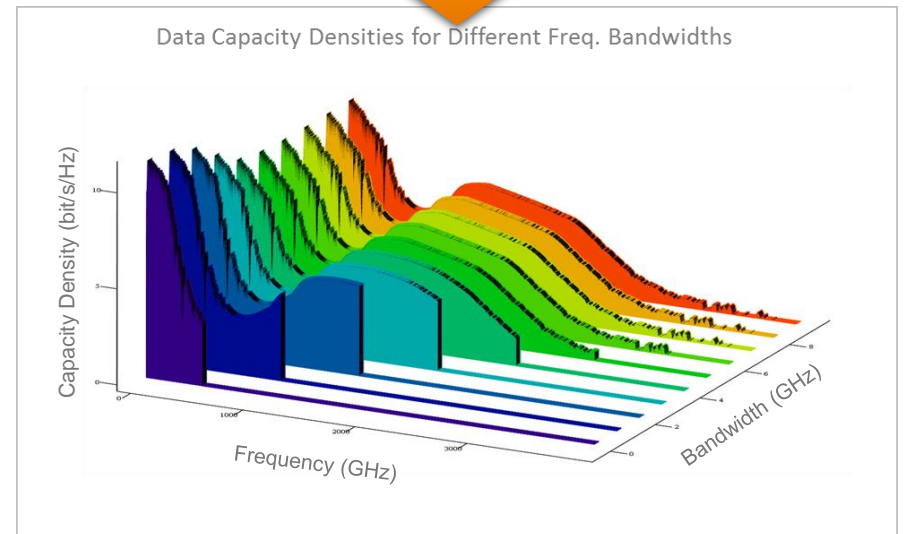
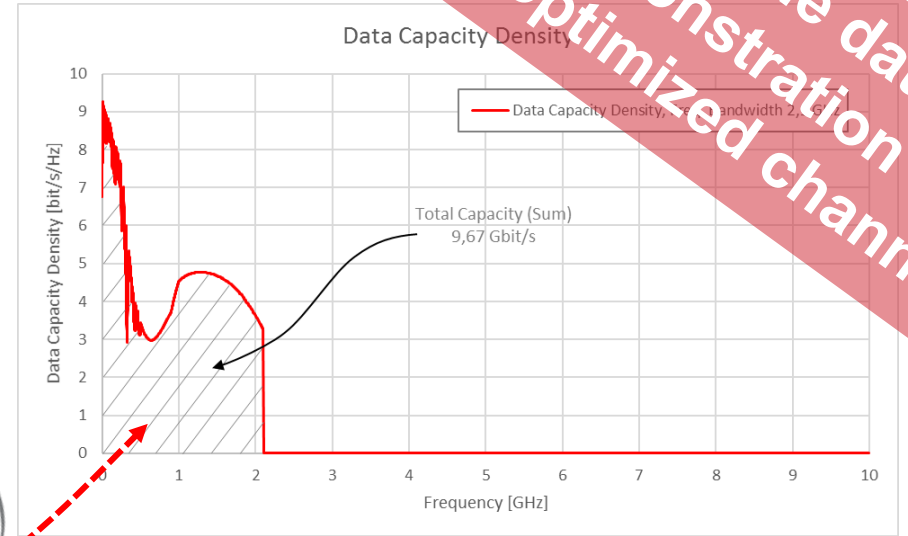




# Channel Capacity – Methodology

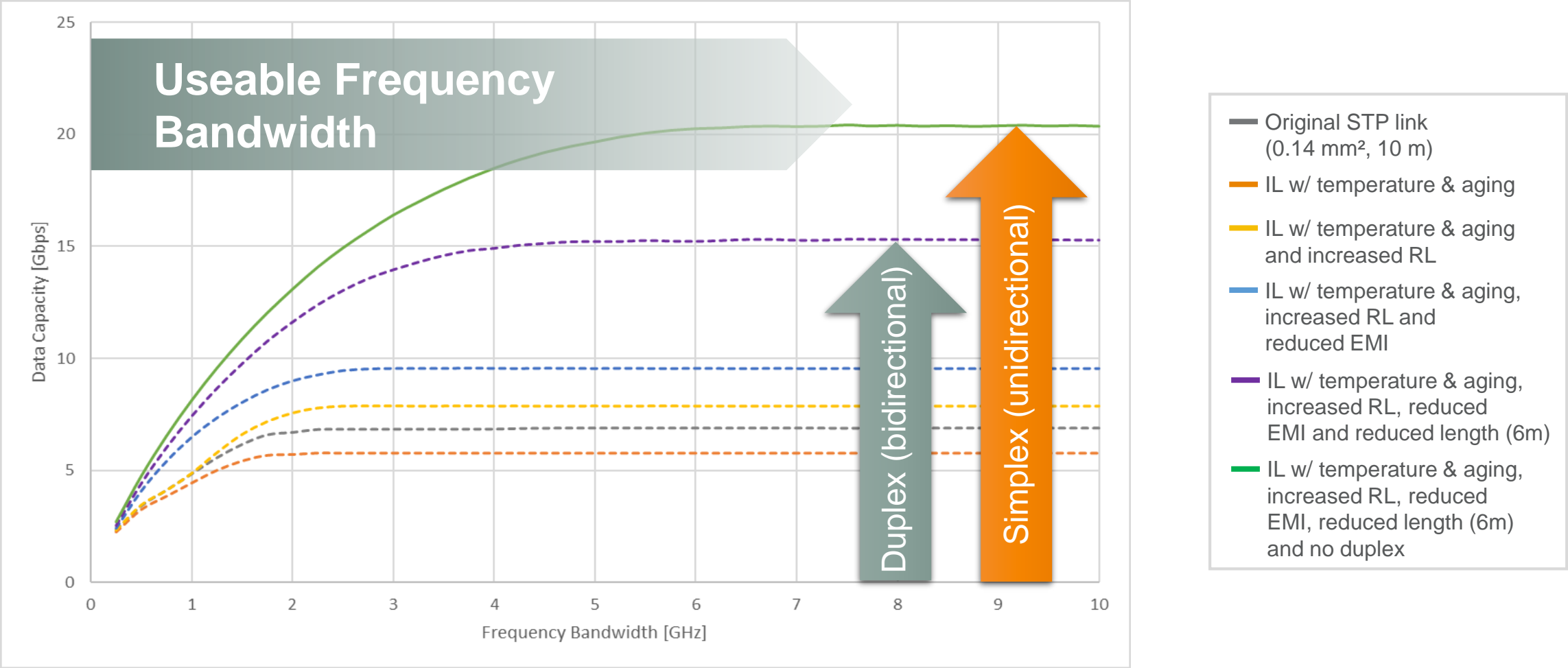


$$BW \cdot \log\left(1 + \frac{S}{N}\right)$$



Example data for demonstration – no optimized channel

# Channel Data Capacity Results



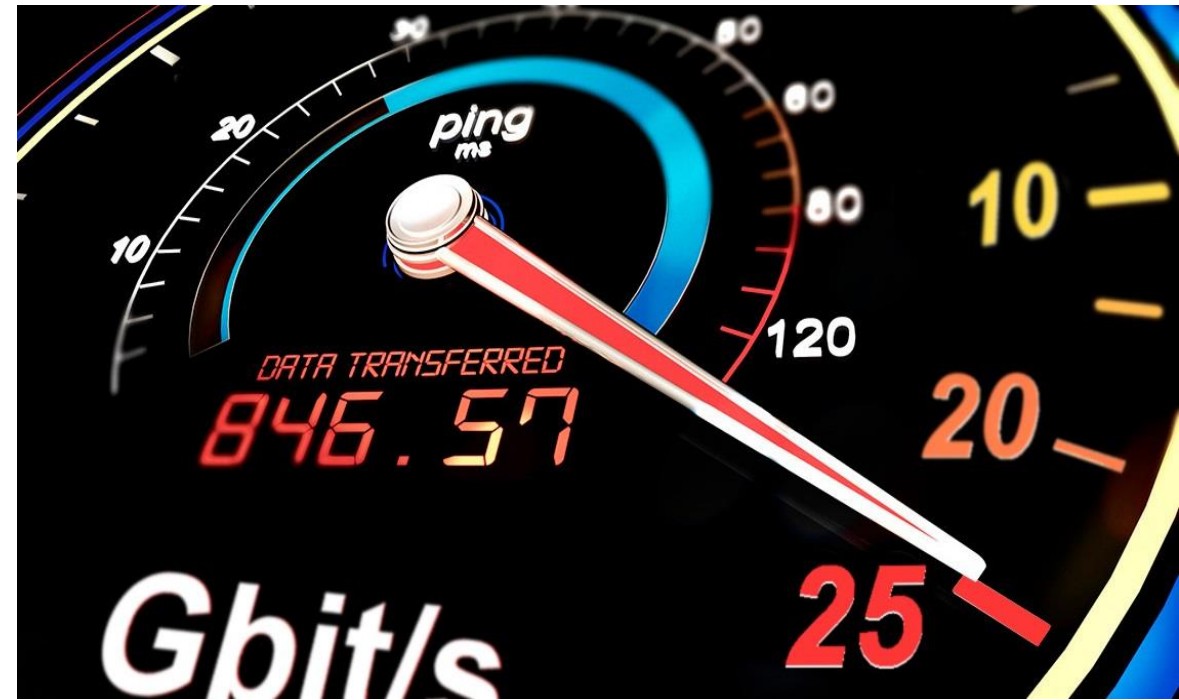
# Channel Capacity Analysis – Conclusions

- Data rates  $> 10$  Gbps possible on single shielded pair
- Insertion loss is primary limiting parameter
- Useable frequency bandwidth  $< 10$  GHz
- Improvements by increased return loss and shielding  
→ *appropriate connectors and cables*

# Channel Capacity Analysis

## Options for Robust 25+ Gbps Systems

- Tx and Rx on separate wire pairs  
→ *no single pair duplex*
- Decreased insertion loss  
→ *reduced length*  
→ *alternative media (e.g. coax)*
- Multiple number of Tx/Rx pairs  
→ *multi lane*





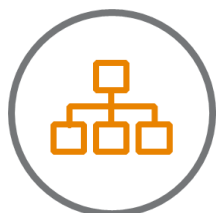
# Data Connectivity for Next-Generation Mobility



**High  
Performance**



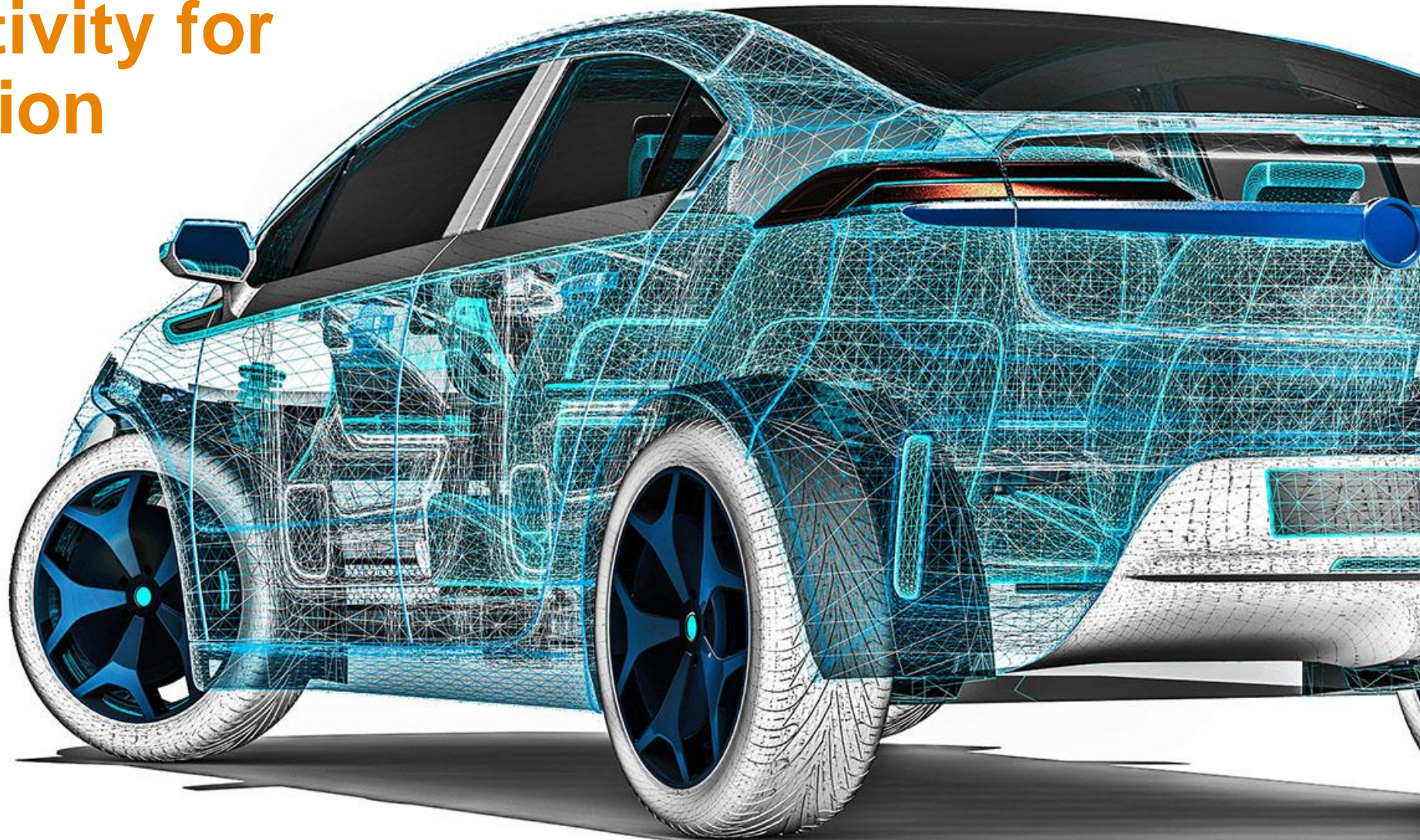
**RF and  
EMC Expertise**



**Ready for Next  
Generation  
Architectures**



**Automotive  
Robustness  
and Reliability**





# Thank You

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