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10BASE-T1S Link Segment Evaluation: Interconnect vs Cable

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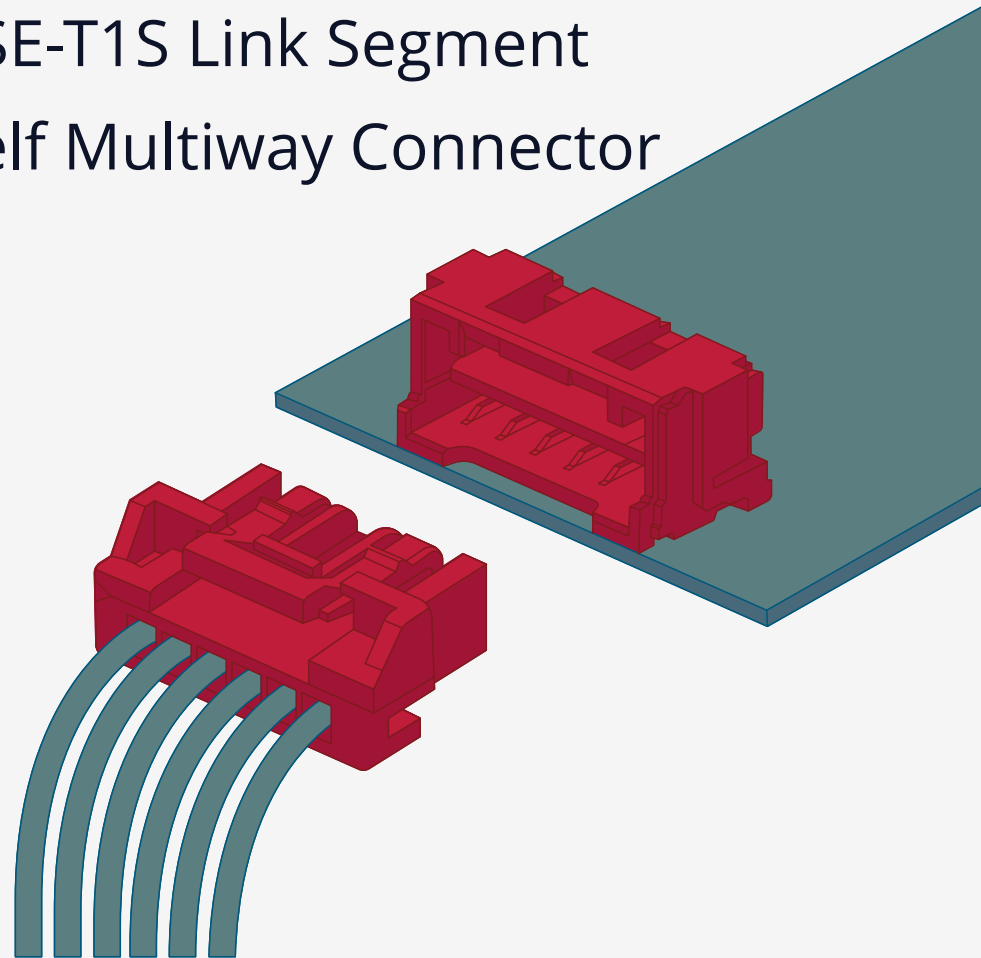
Agenda

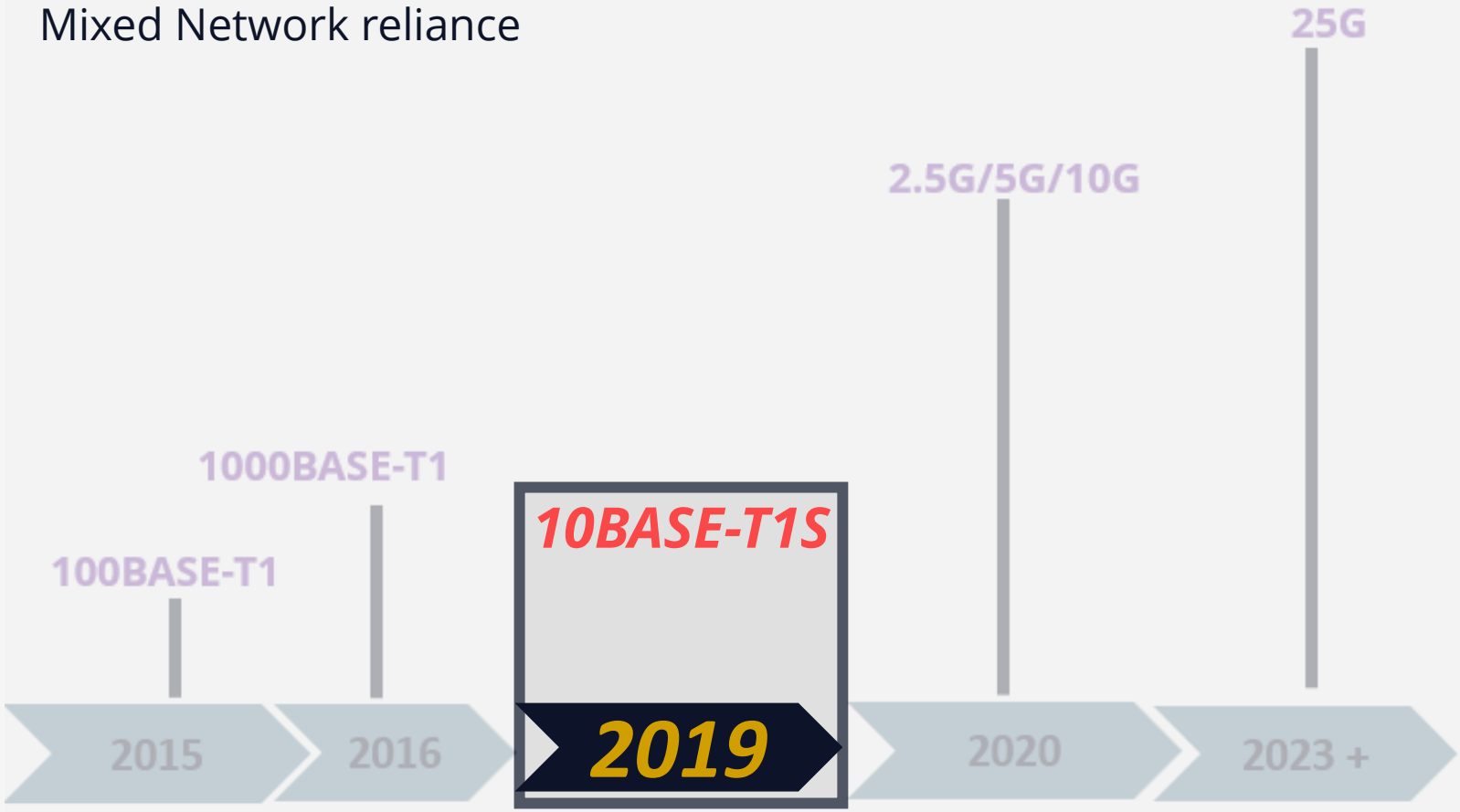
- Background
- Cable vs. Interconnect in 10BASE-T1S Link Segment
- Industry Challenge: Off-the-Shelf Multiway Connector Simulation
- Key Takeaways

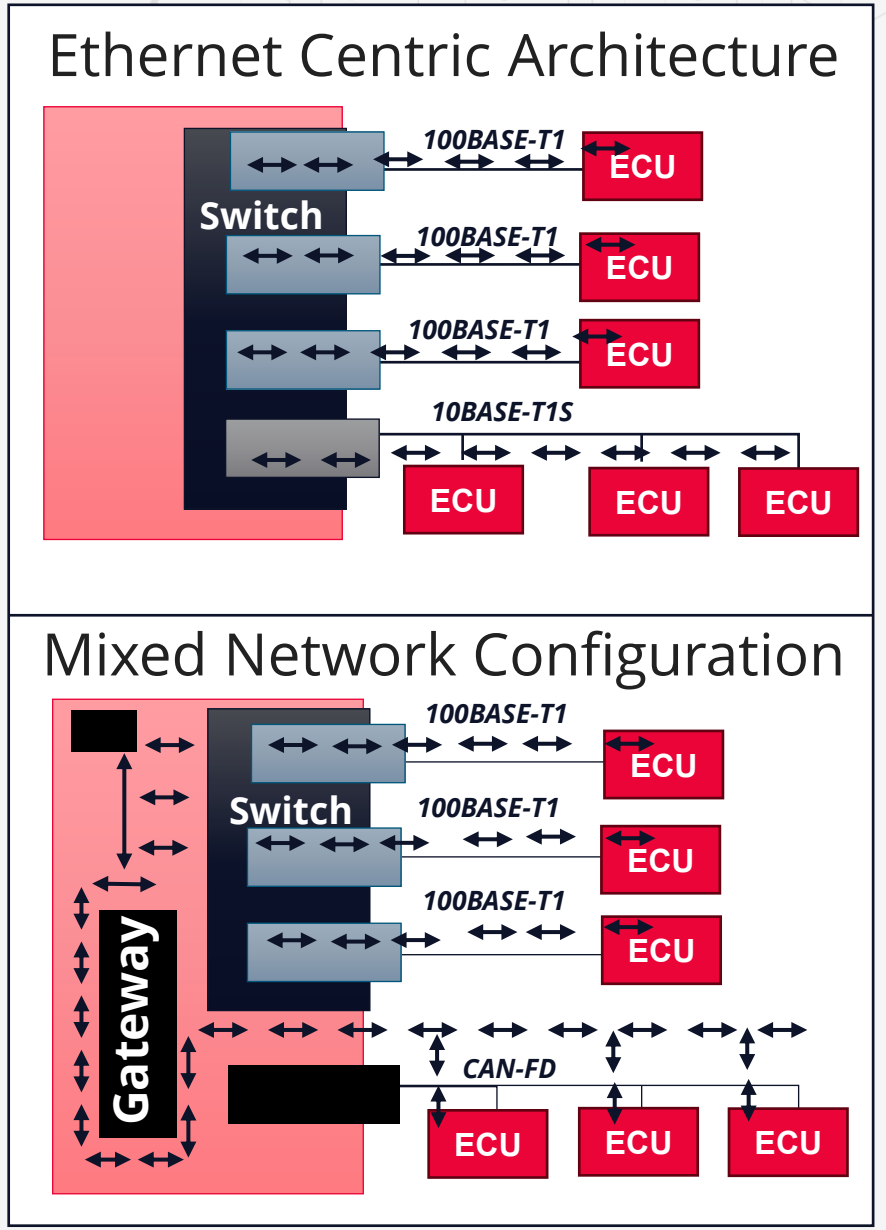


BACKGROUND

Simplifying Automotive Networking: 10BASE-T1S

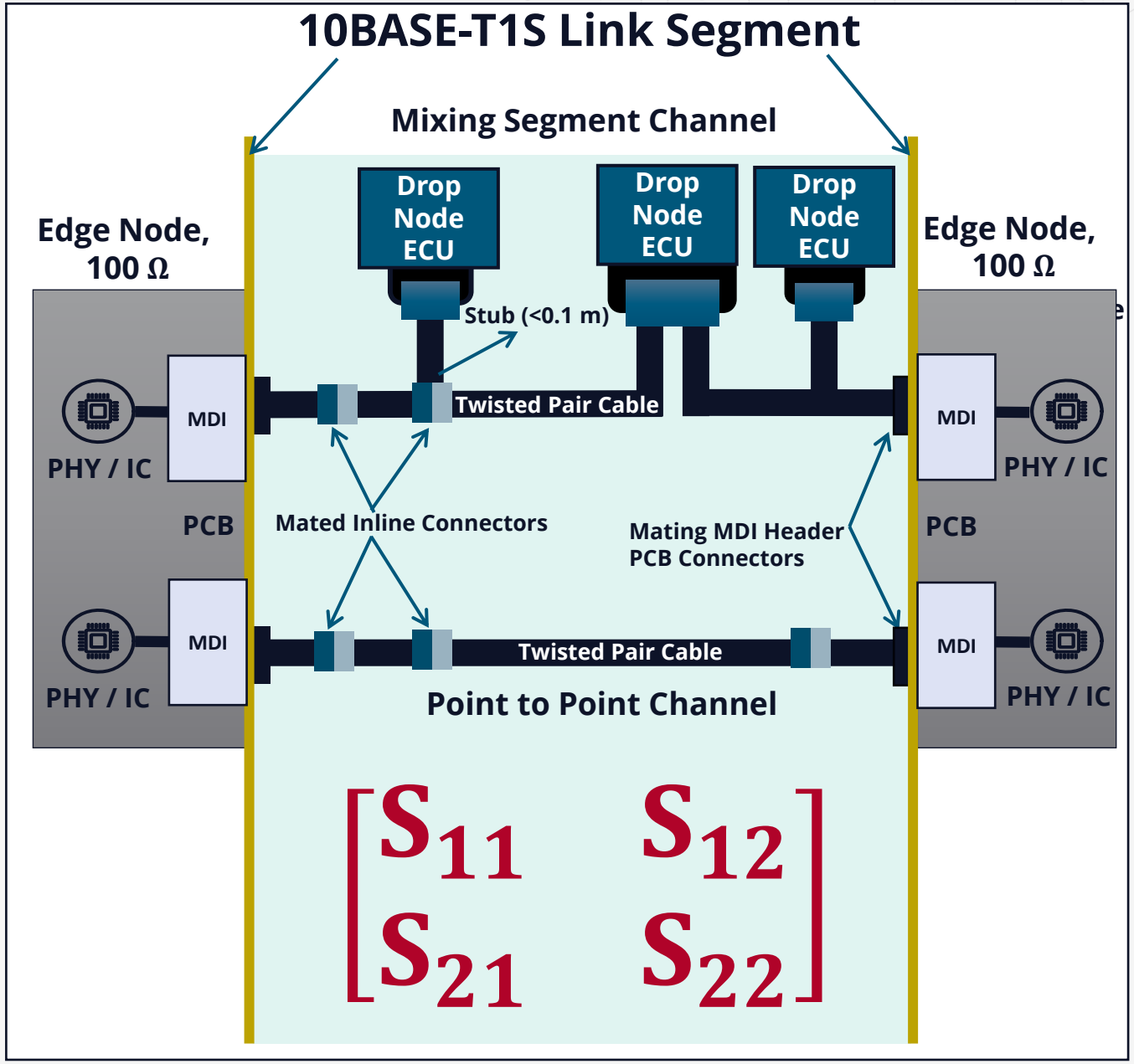
- Single pair UTP cabling, up to 25 m
- Simple topology / Multi-Drop architecture
- Lightweight alternative to CAN, reducing gateways and Mixed Network reliance





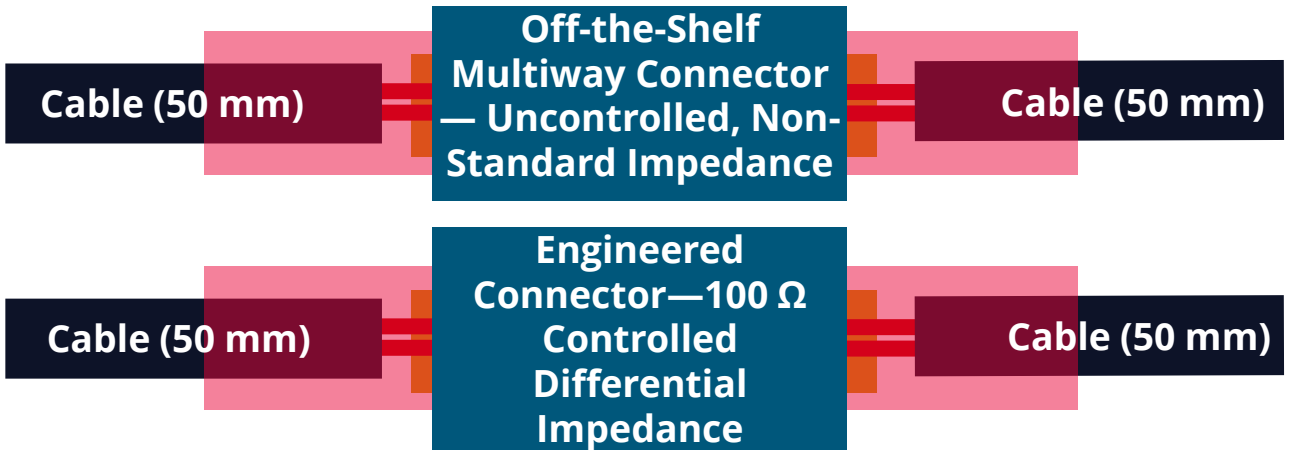
10BASE-T1S Physical Layer Connectivity Landscape

- **Ethernet Physical Channel key Components**
  - MDI (Medium Dependent Interface)
  - Link Segment (interconnects, cables and electrical compliance)
- **10BASE-T1S Channel Implementation**
  - Point-to-Point Channel (P2P-C), direct link between two nodes
  - Mixing Segment Channel (MS-C), multiple nodes sharing a single link segment
- **Performance Assessment**
  - S-parameters
  - Eye Diagram
  - PHY Test Modes

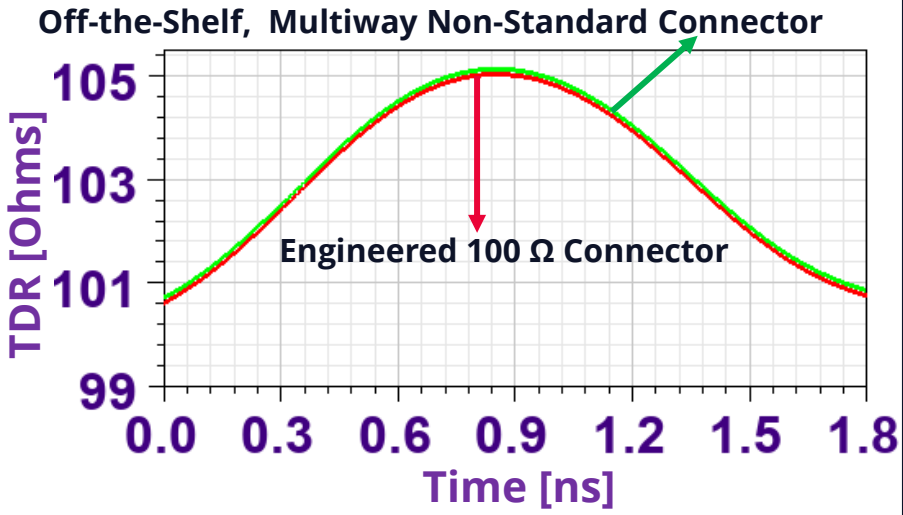


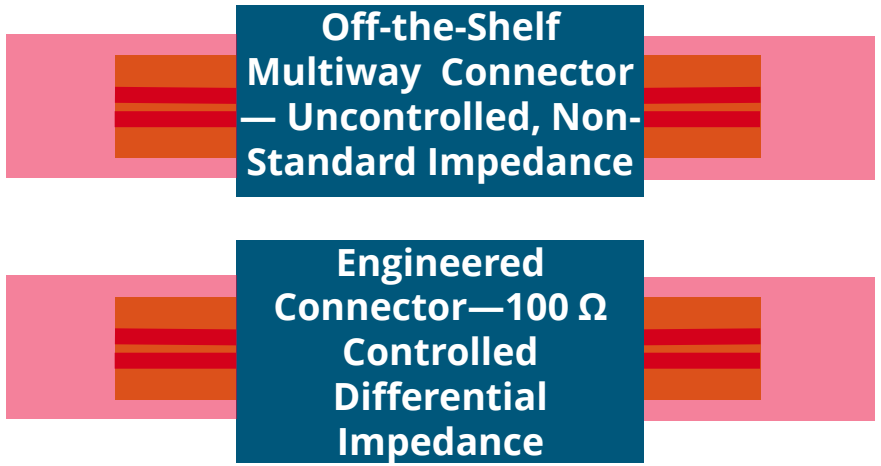
Interconnect Role in 10BASE-T1S Link Segment

Impact of Interconnect on 10BASE-T1S System Performance

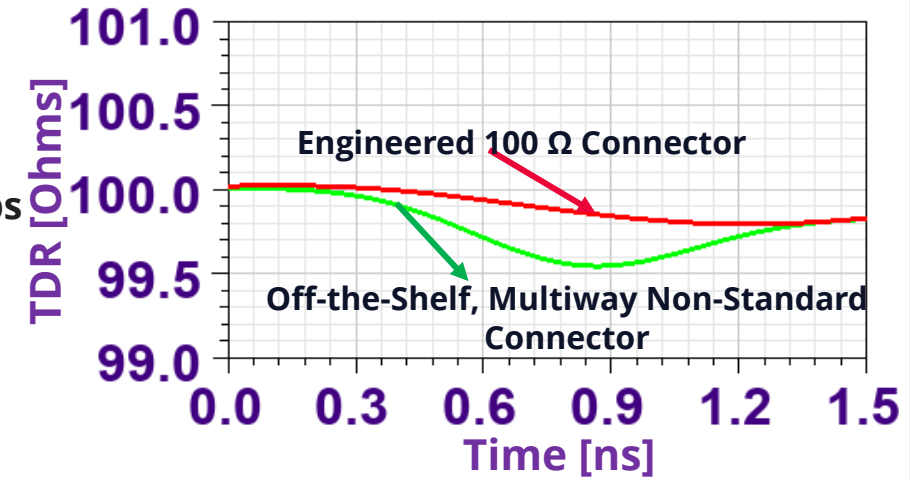


At 700 ps, the interconnect becomes electrically transparent to the system





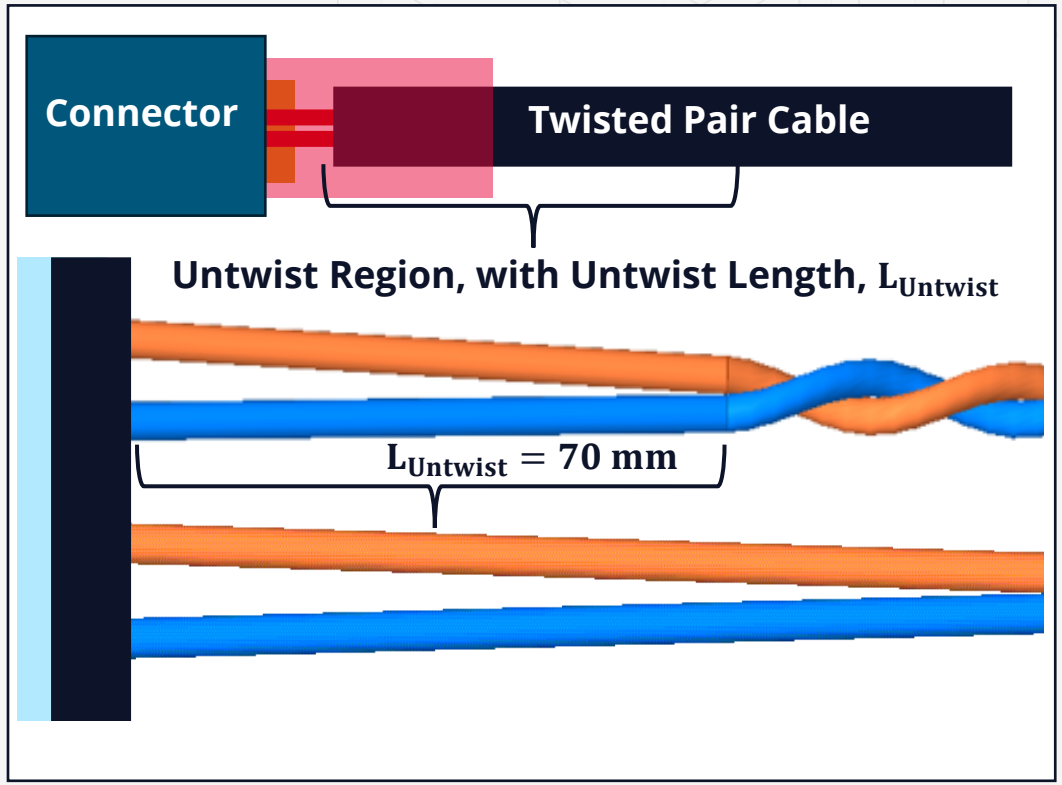
Connector response at 700 ps



What is critical in 10BASE-T1S link segment system?

Cable Role in 10BASE-T1S Link Segment

- **Link Segment Contributions:**
  - **Connectors**: Minimal electrical impact
  - **Cable:** Cable Management (Un-twist region / Impedance)
    - Cable dominates in MHz-frequency performance
    - **Minimize Untwist region for optimum performance**
      - Maintains impedance consistency
      - Improved S parameters: Return Loss, Mode conversion
      - EMI reduction
      - EM modeling simplification, Reduced simulation uncertainty

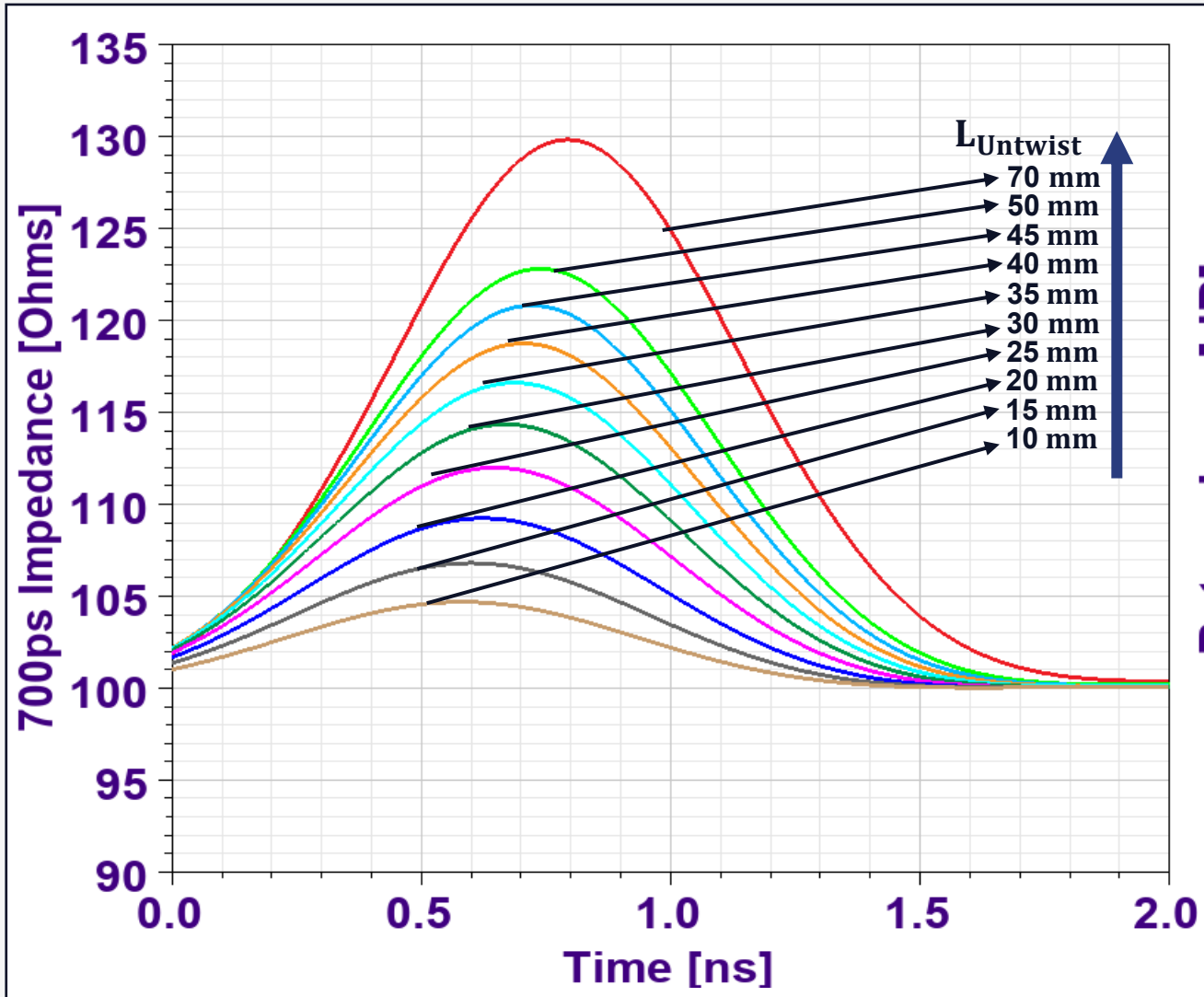


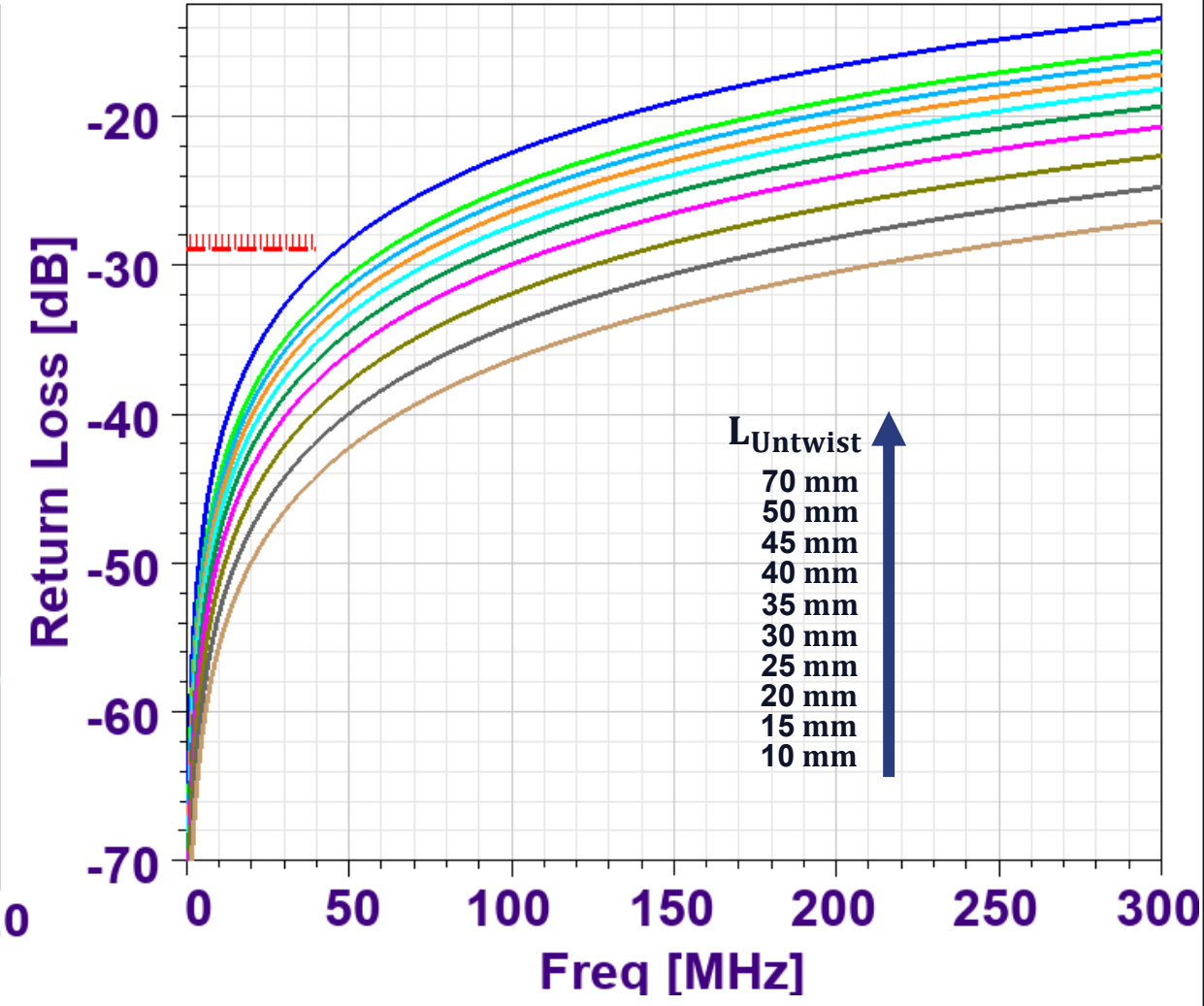
Demonstrating Varying Cable Untwist Length in Link Segment

Cable construction and Untwist length directly control 10BASE-T1S link segment performance

Cable Untwisting Dominance in 10BASE-T1S System

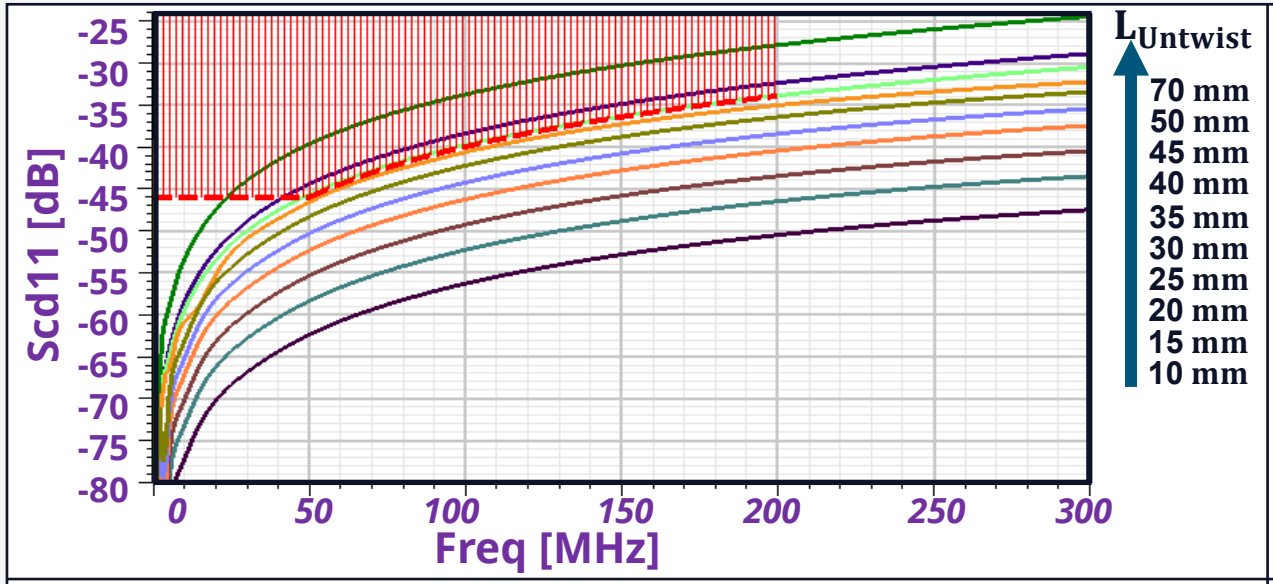
Impact of Cable Untwist on TDR and Return Loss

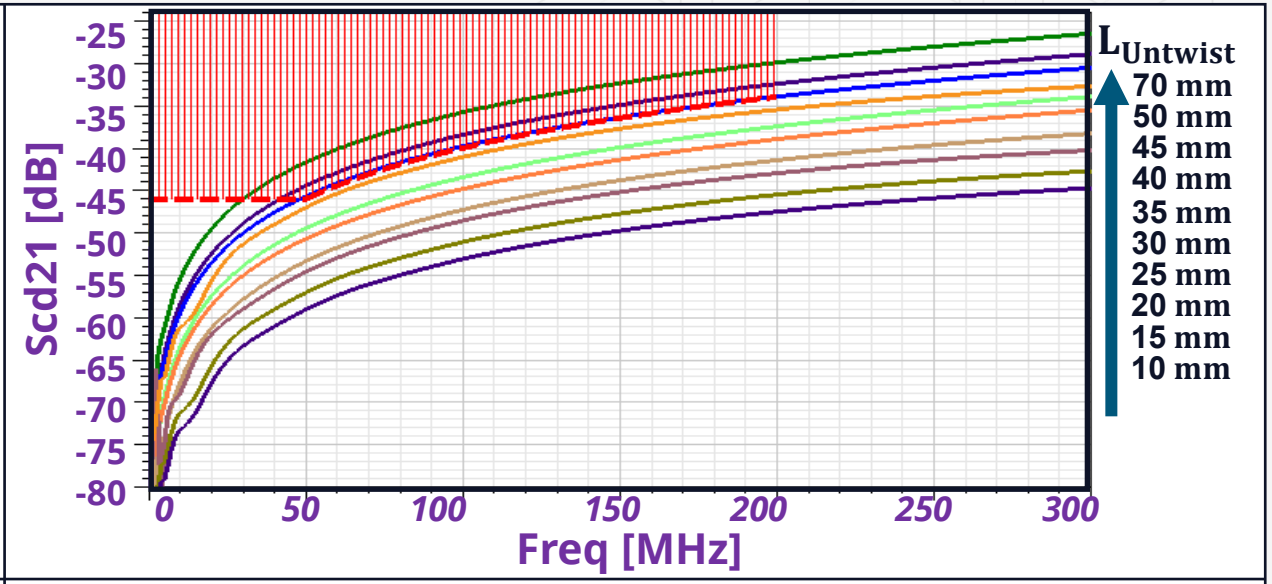


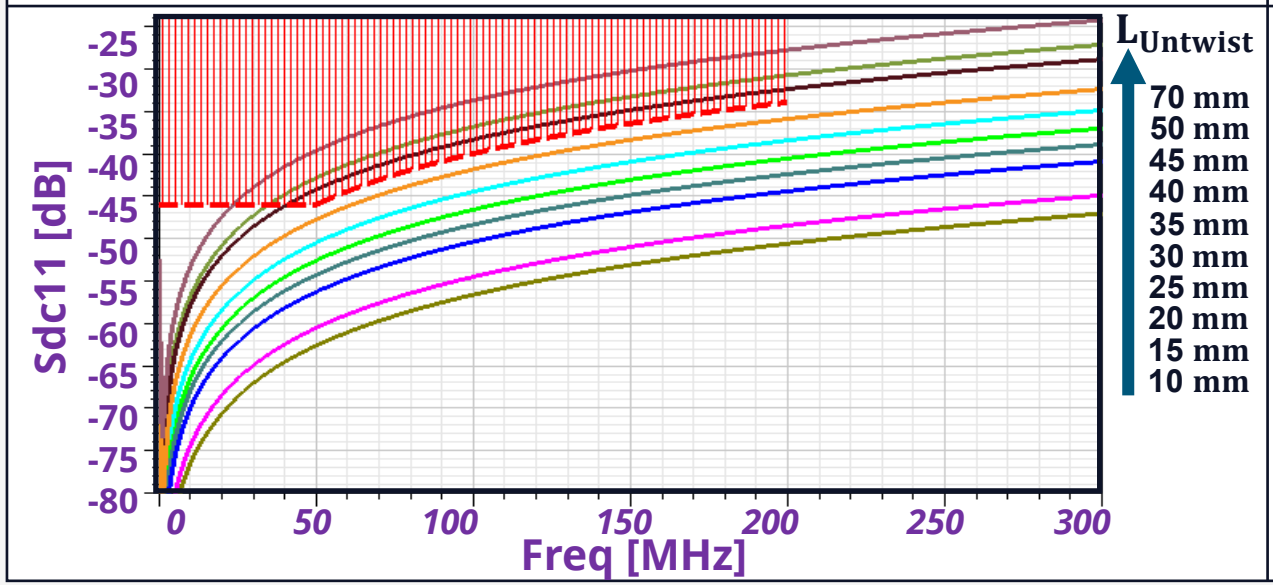


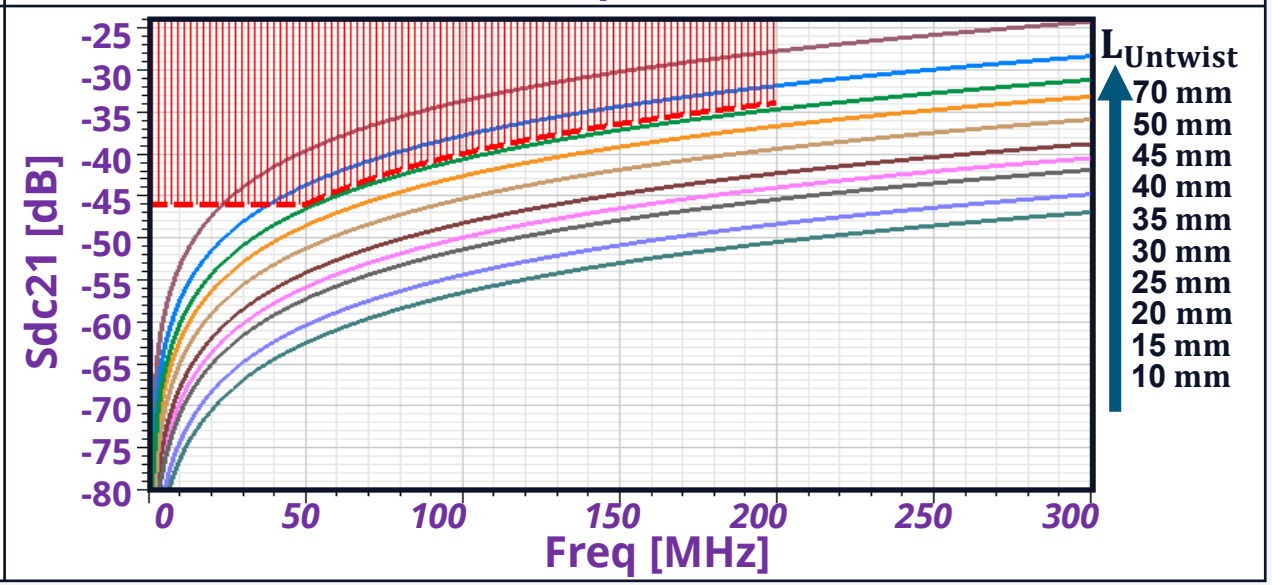
Cable Untwisting Dominance in 10BASE-T1S System

Impact of Cable Untwist on Mode Conversion



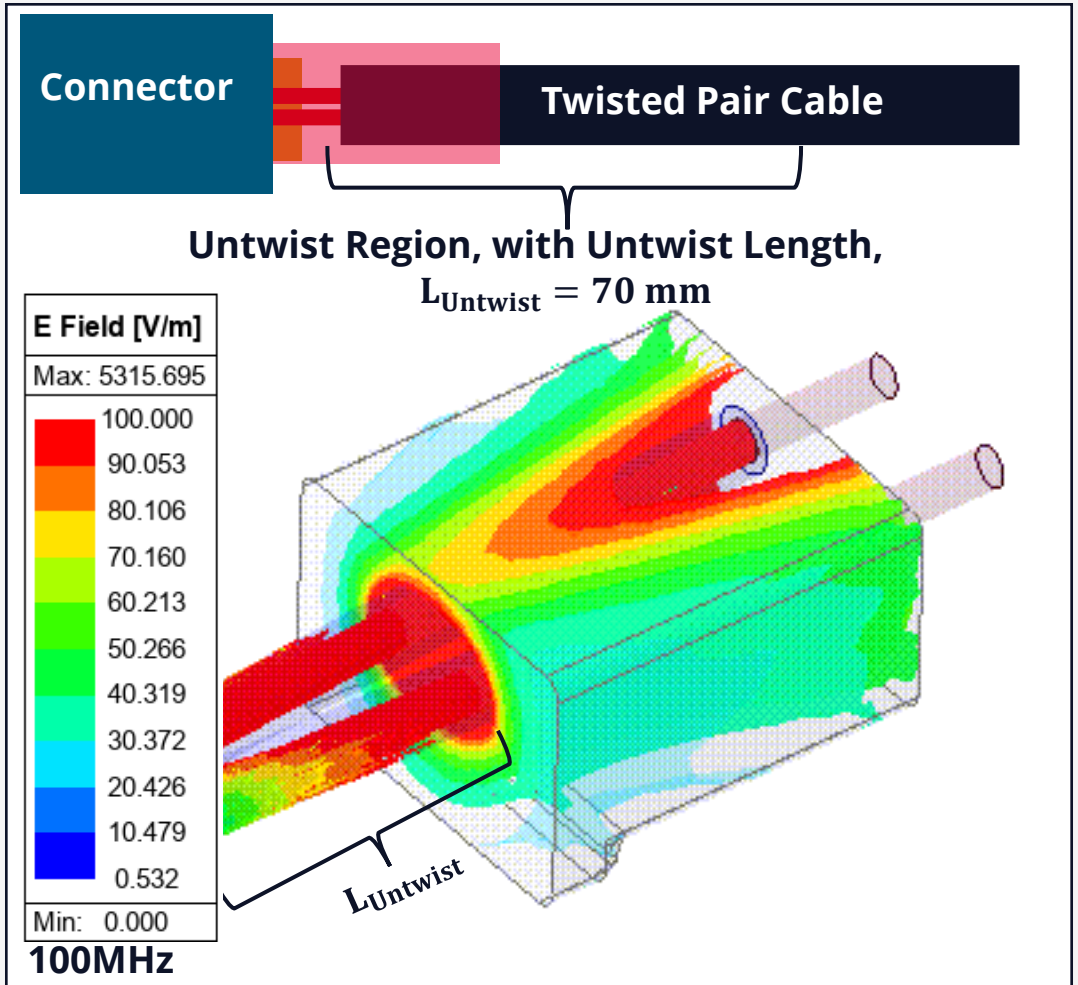




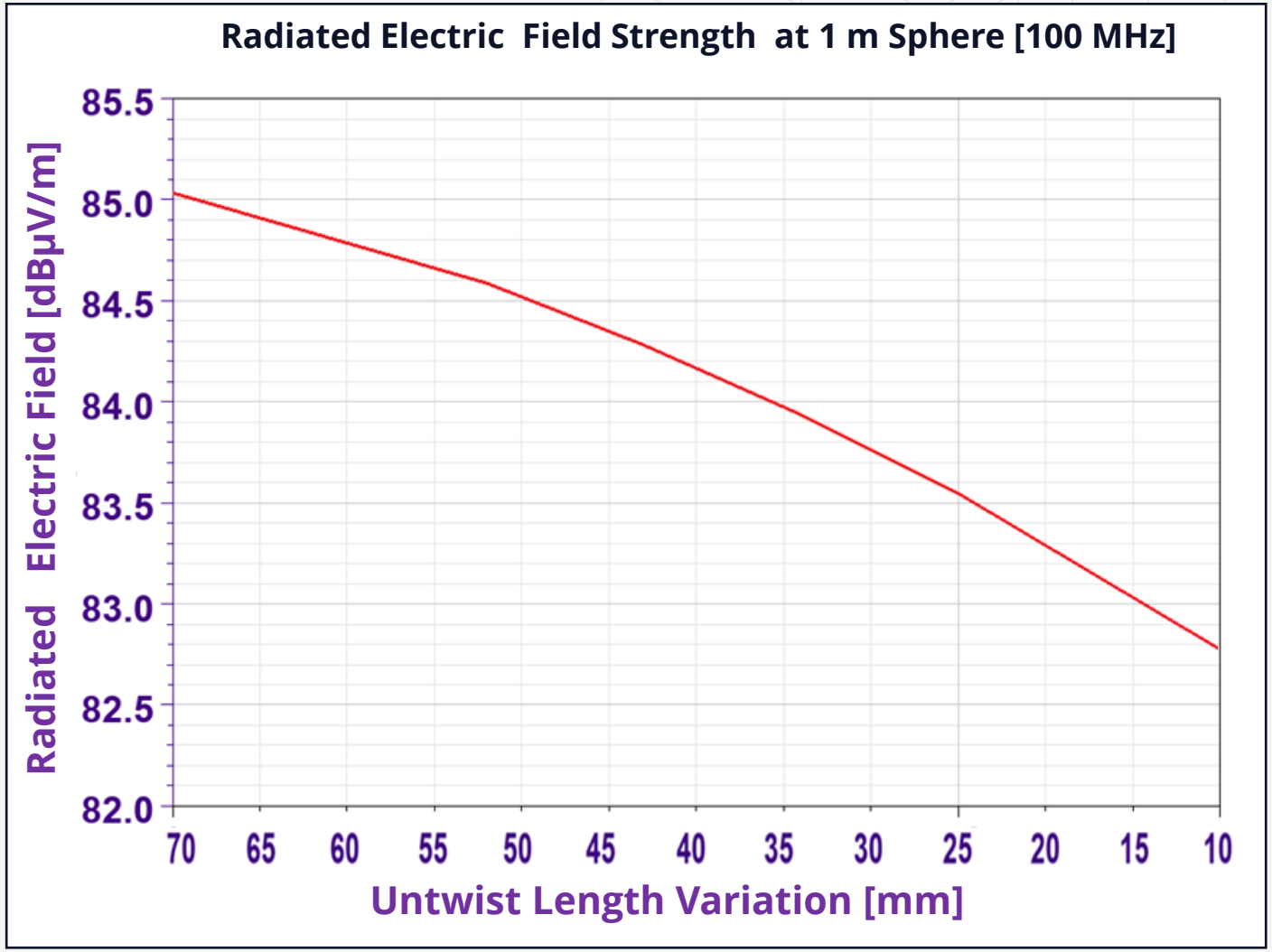


Cable Untwisting Dominance in 10BASE-T1S System

Impact of Cable Untwist on Radiated Electric Field



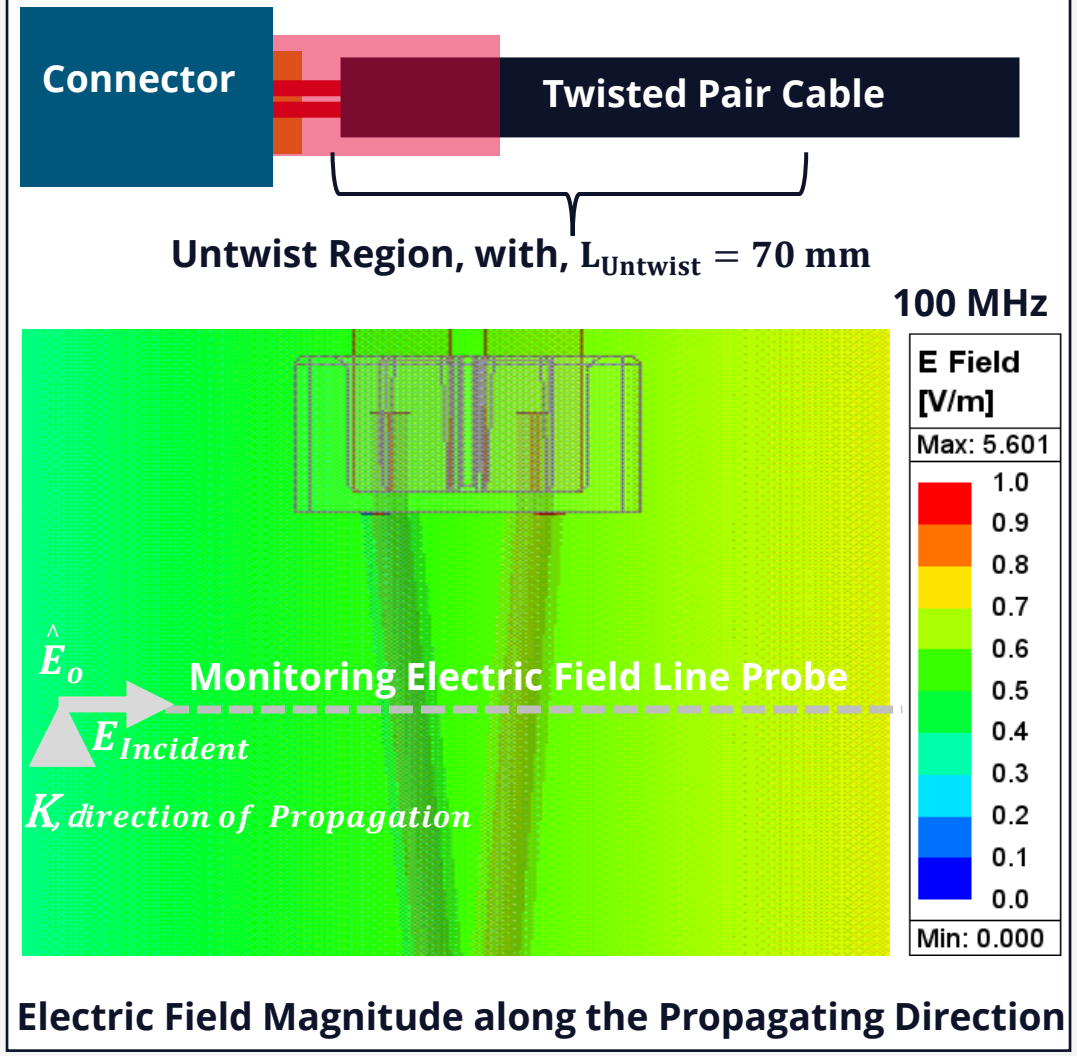
Electric Field Variation with Cable Untwisting



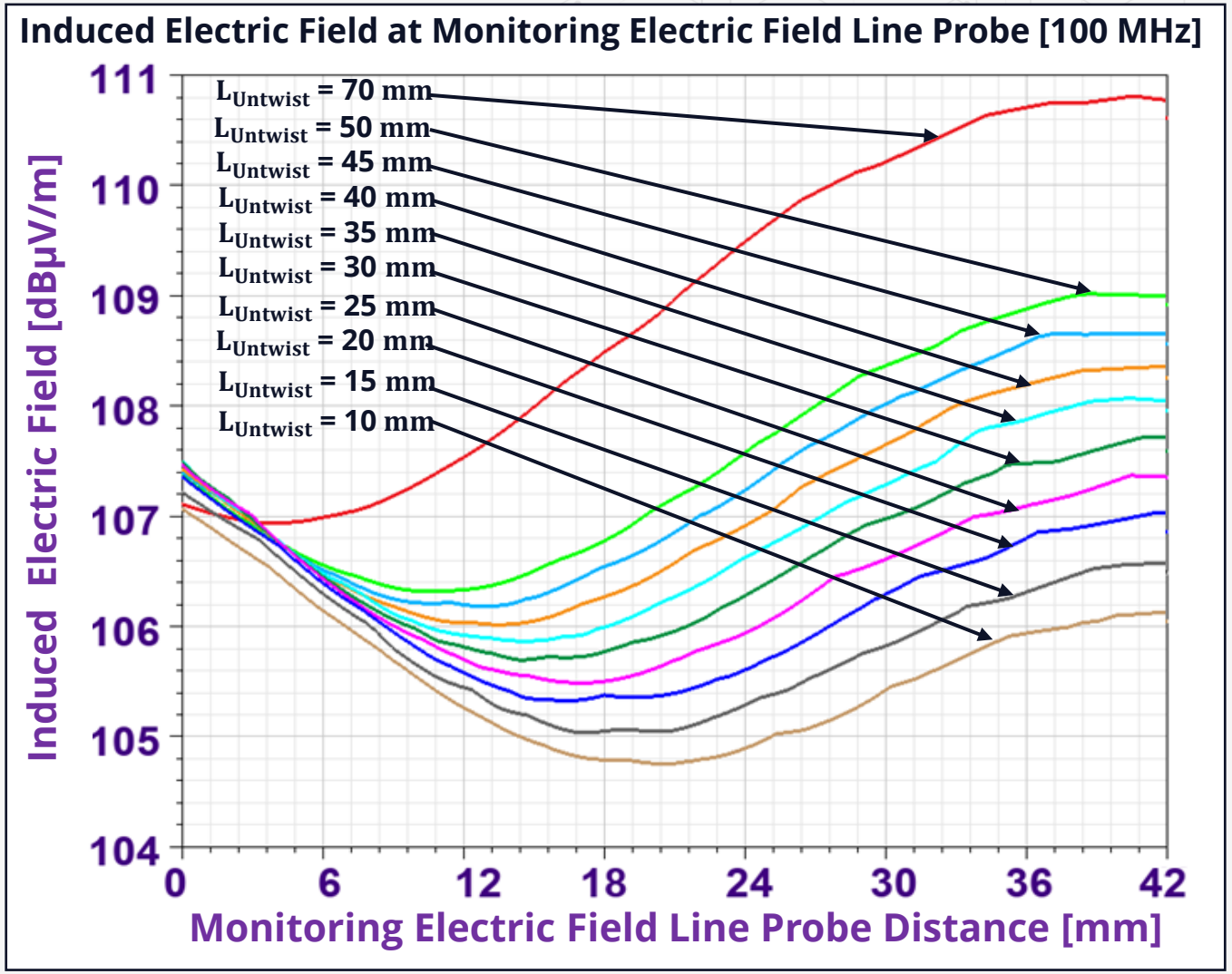
Uncontrolled cable Untwisting amplifies the radiated electric field, increasingly so with longer untwist lengths

Cable Untwisting Dominance in 10BASE-T1S System

Impact of Cable Untwist on Induced Electric Field



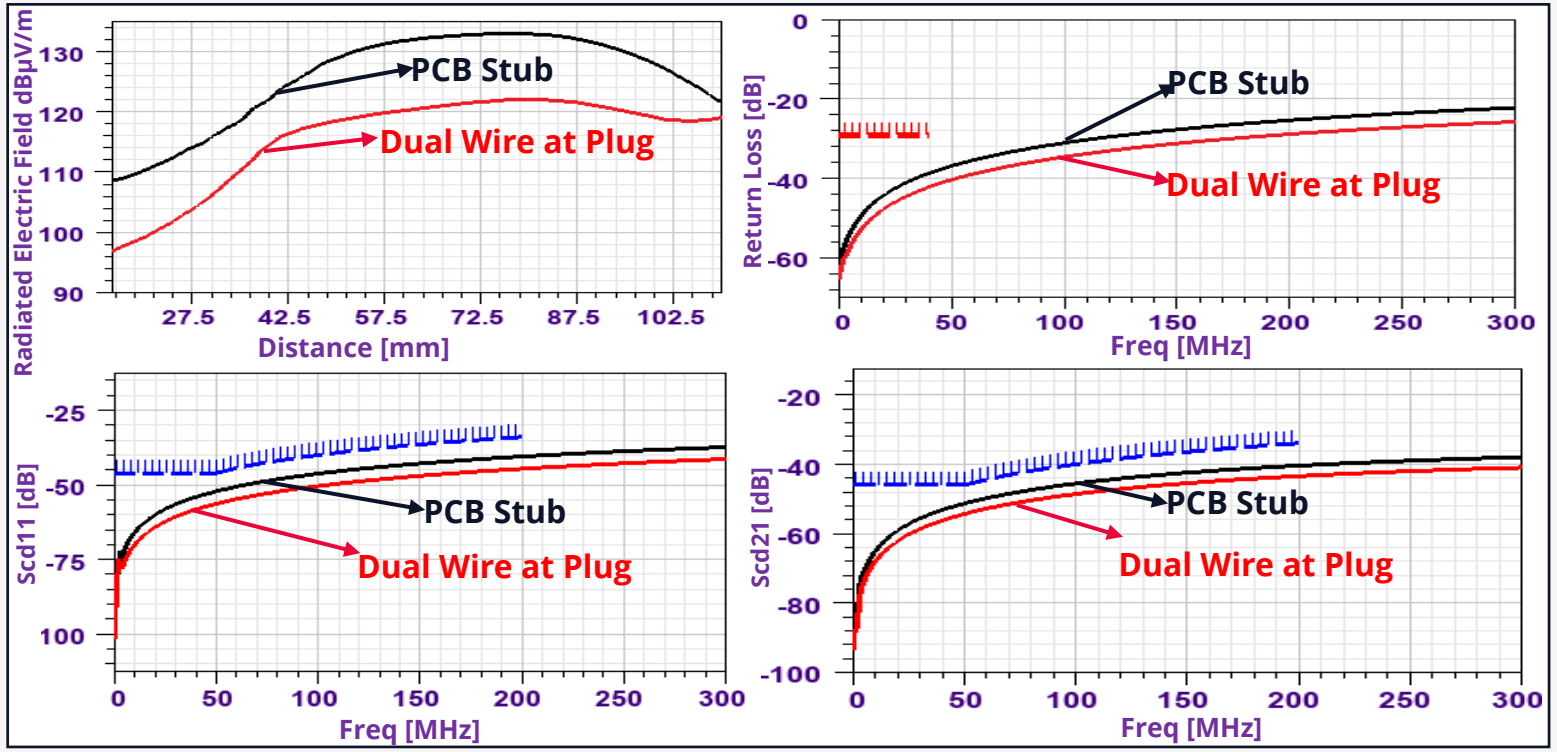
Electric Field Magnitude along the Propagating Direction

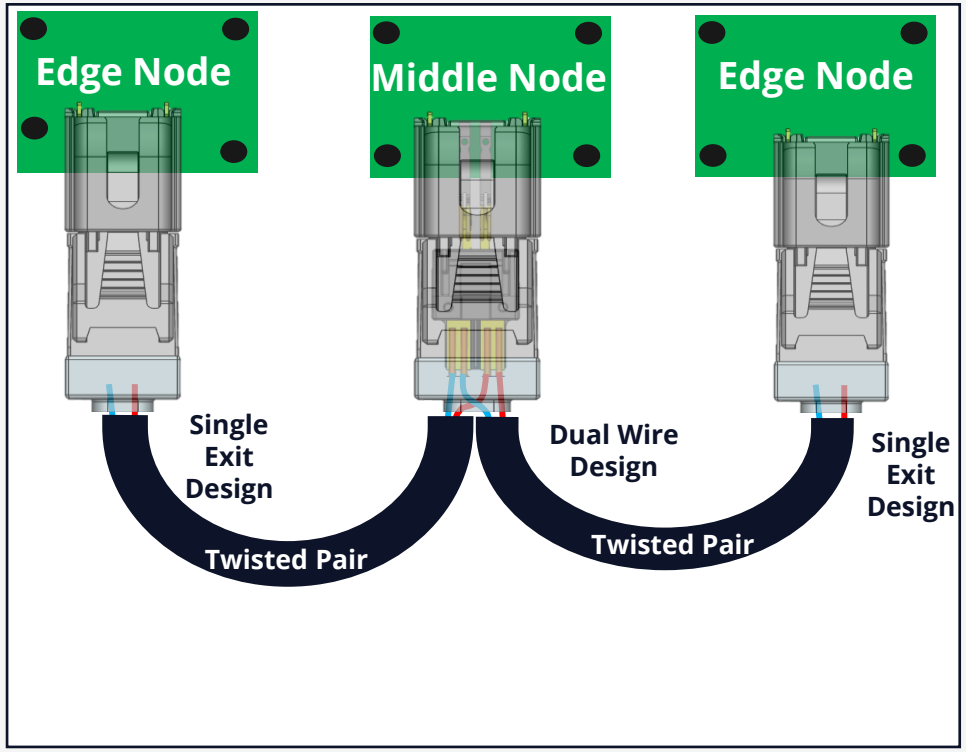


Uncontrolled cable Untwisting increases the induced electric field, increasingly so with longer Untwist lengths

Short on PCB vs Plug

- Both solutions are reliable and meet requirements; **dual wire at plug offers added advantages**:
  - More compact design with fewer connectors
  - Reduced stubs for improved signal integrity
  - Controlled untwisted region: Less EMI and mode conversion
  - Continuity is maintained even when some nodes malfunction





Dual wire (double soldering) ensures compact, crimp-free reliability, middle node continuity, improved EMI and Signal integrity, and scalable daisy-chain flexibility

What We've Covered so far

- **System-leve**l: Connector impact minimal; link segment performance dominated by cable quality
- **Uncontrolled Untwist**: Causes mode conversion and high EMI
- **10BASE-T1S**: Low frequency makes connector effects negligible; cable control remains critical (MHz range)
- **PCB Stub vs. Dual Wire Terminal:** Both solutions meet requirements, but the dual wire (soldered or crimped) **minimizes stubs, improves signal integrity**, and **offers additional advantages**
- **Next: Industry Challenge—**Simulating Off-the-Shelf Multiway connector with uncontrolled, non-standard impedance, supporting multiple 100 Ω standard CAN-style wirings and 10BASE-T1S channels

Cable Untwist control is critical for 10BASE-T1S—connector effects are minimal, but cable-driven mode conversion and EMI risks remain in the MHz range

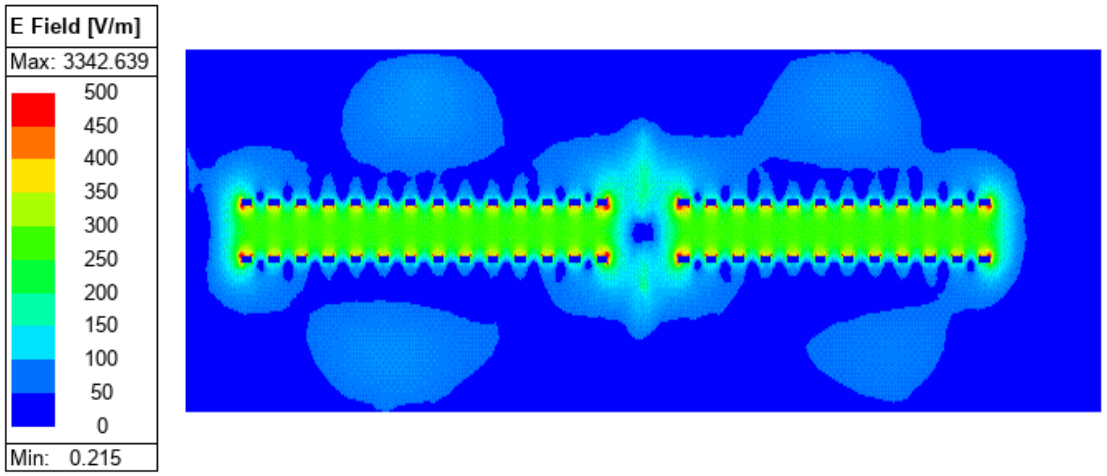
Industry Challenge: Off-the-Shelf Multiway Connector

Simulating Off-the-Shelf Multiway Connector with Unknown Impedance, Multiple 10BASE-T1S Channels with CAN-Style Wiring

- **Off-the-Shelf Multiway Connector-Induced Variables**
  - Off-the-Shelf, non-standard impedance connector
  - Localized impedance discontinuities, uncontrolled connector impedance
  - Complicate signal integrity modeling

- **EM Simulation Impact**
  - Unpredictable S-parameters
  - Ambiguous port references, limits ideal port setup
  - Degrades EM simulation-to-measurement correlation

Electric Field at Port Pin of an Off-the-Shelf Multi-Way Connector



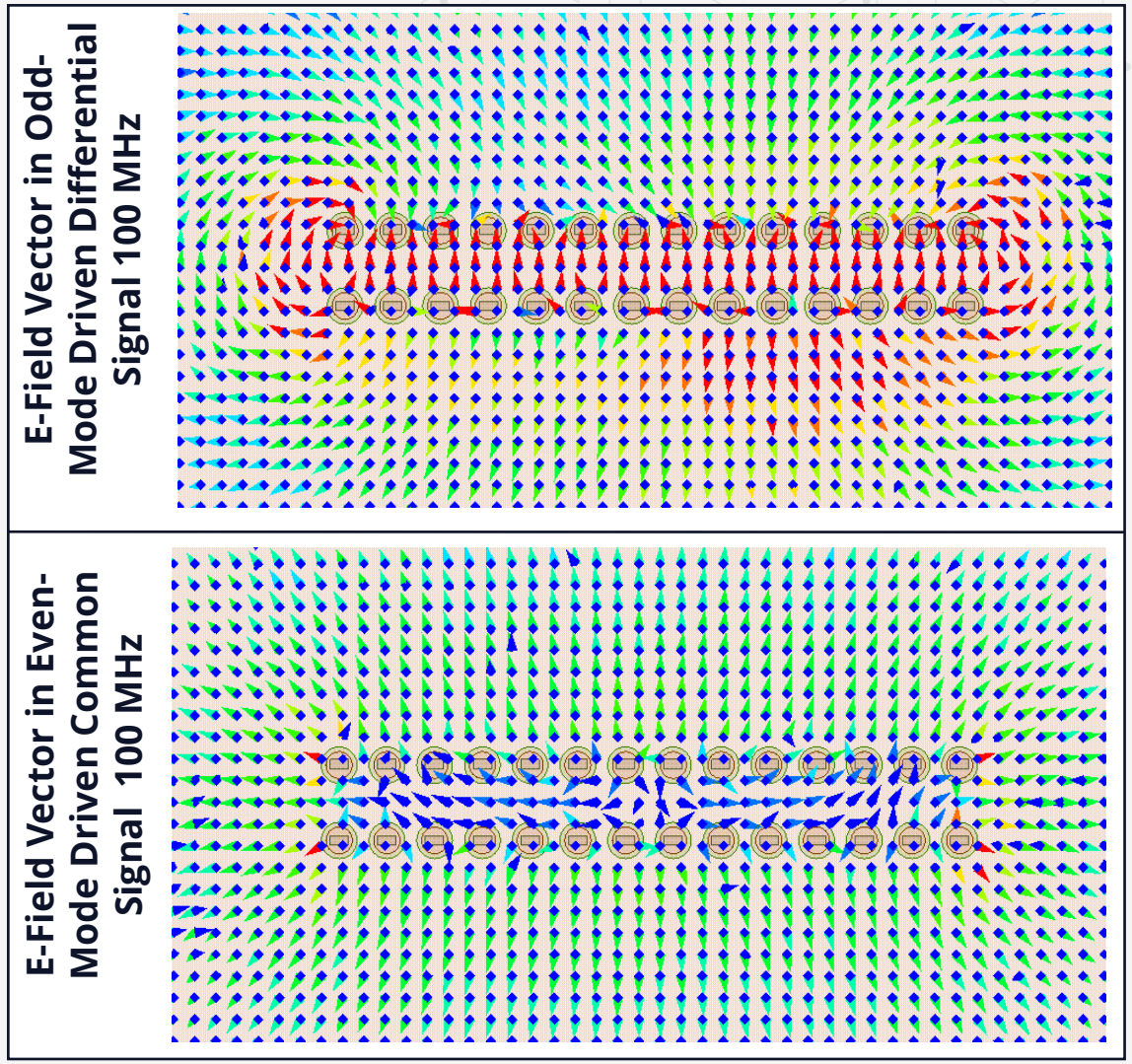
Connector and cable selection significantly impact 10BASE-T1S performance—Uncontrolled, non-standard connector impedance complicates simulation

Industry Challenge: Off-the-Shelf Multiway Connector

Simulating Off-the-Shelf Multiway Connector: Addressing Unknown Impedance Challenges

Key Considerations for Off-the Shelf Multiway Connector Simulation with Non-Ideal Port Conditions

- Port size optimization and field confinement
- Mode-matching accuracy
- Spurious mode excitation
- Boundary Field discontinuities
- Electromagnetic leakage
- Artificial reflections at port interfaces
- Mesh refinement demand
- Increased computational load
- S-parameter extraction sensitivity

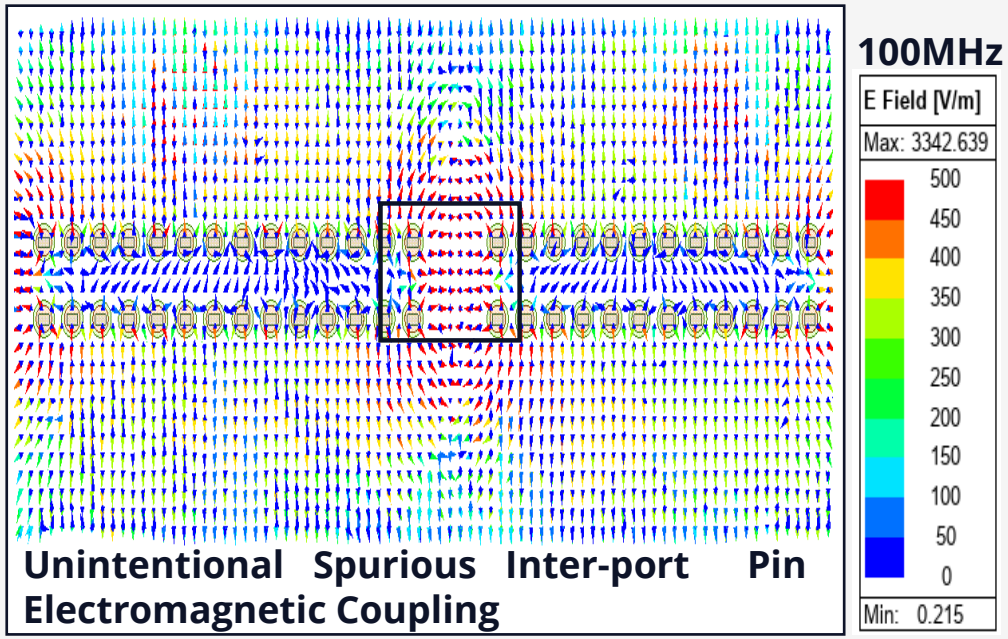


Non ideal ports face more challenges in Off-the-Shelf Multiway connector vs. Ideal Ports

Off-the-Shelf Connector Simulation: Non-Ideal Port Effects

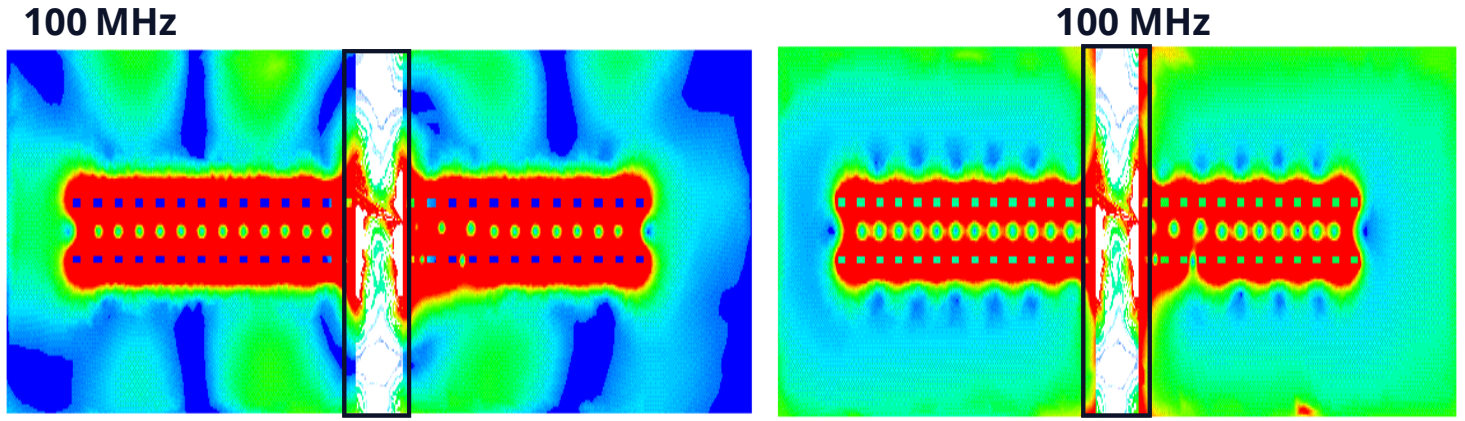
Simulation Artifacts : Reflections at Off-the-Shelf Multiway Connector Port Interface

- Two E-field plots highlight simulation artifacts that cause electromagnetic coupling between ports. These effects include edge discontinuities, leakage between signal pairs, cross-pair coupling, and unintended mode transformations

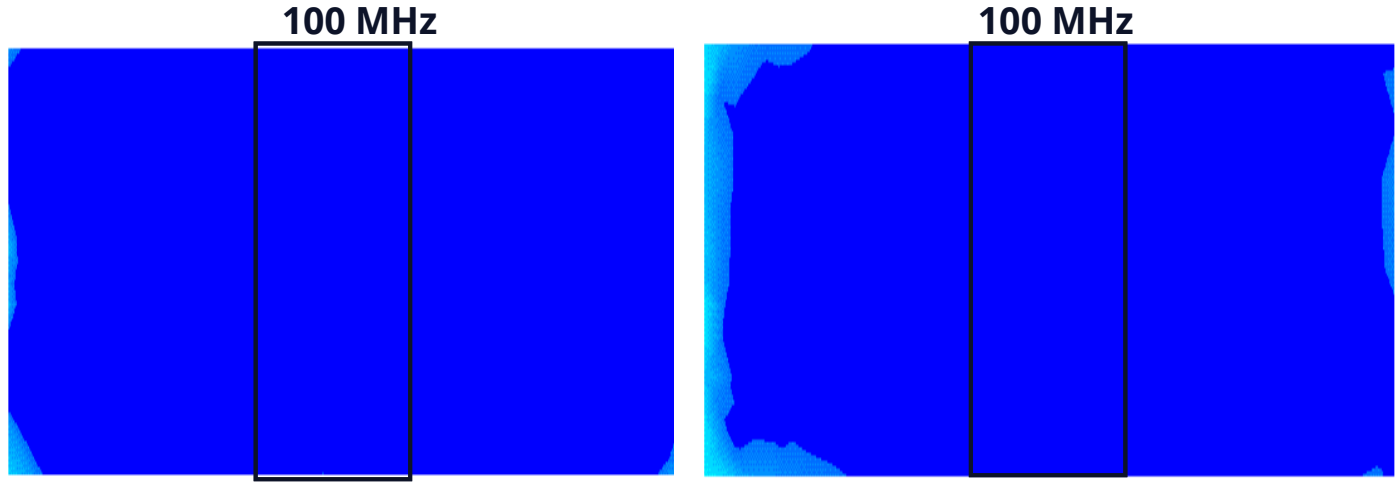


Unintentional Spurious Inter-port Pin Electromagnetic Coupling

Electric Field Leakage at Port Boundaries



Increasing Port Separation Effects Field Coupling between Channels



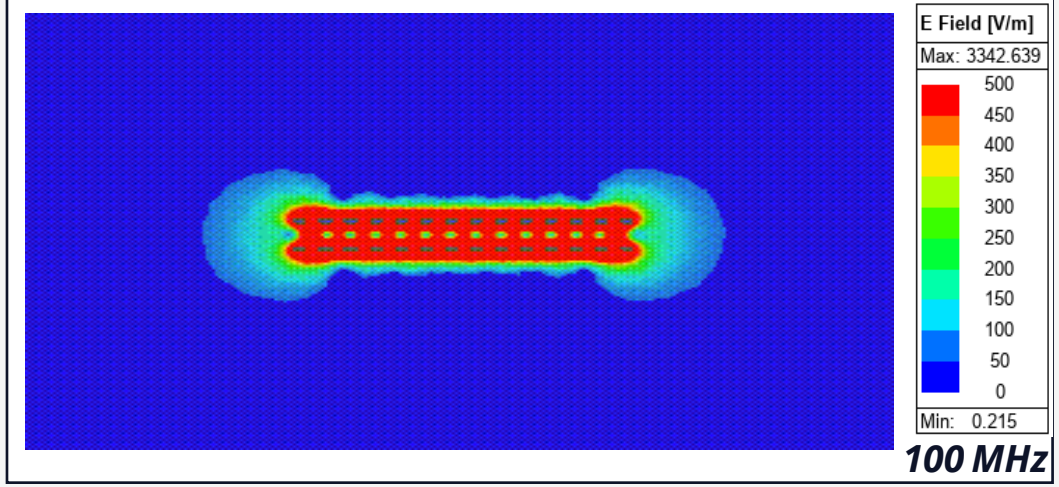
Subdividing wave ports causes artificial reflections, disrupts field uniformity, and leads to edge discontinuities, leakage, and unwanted coupling—reducing simulation accuracy

Off-the-Shelf Connector Simulation: Non-Ideal Port Effects

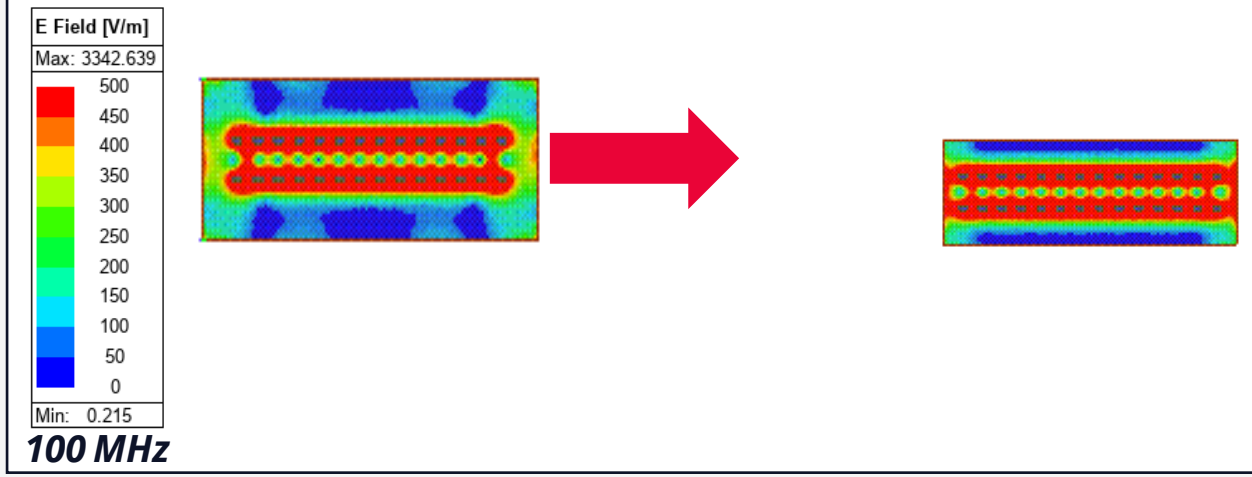
Simulation Artifacts: Port Size and Field Confinement

- **Improper Non-ideal Port Sizing**
  - Disrupts field confinement, and inaccurate fringing capture
  - Reduces accuracy of mode excitation
  - Can introduce unwanted higher-order spurious modes
  - Degrades simulation reliability

Suppress Non-physical Reflections, Fringing Leakage, and Spurious Inter-port Coupling by using a Single Contiguous Wave Port for all Signal Conductors



Dimension the Wave Port for Significant Field Attenuation to Ensure Field Confinement and Accurate Fringing Capture

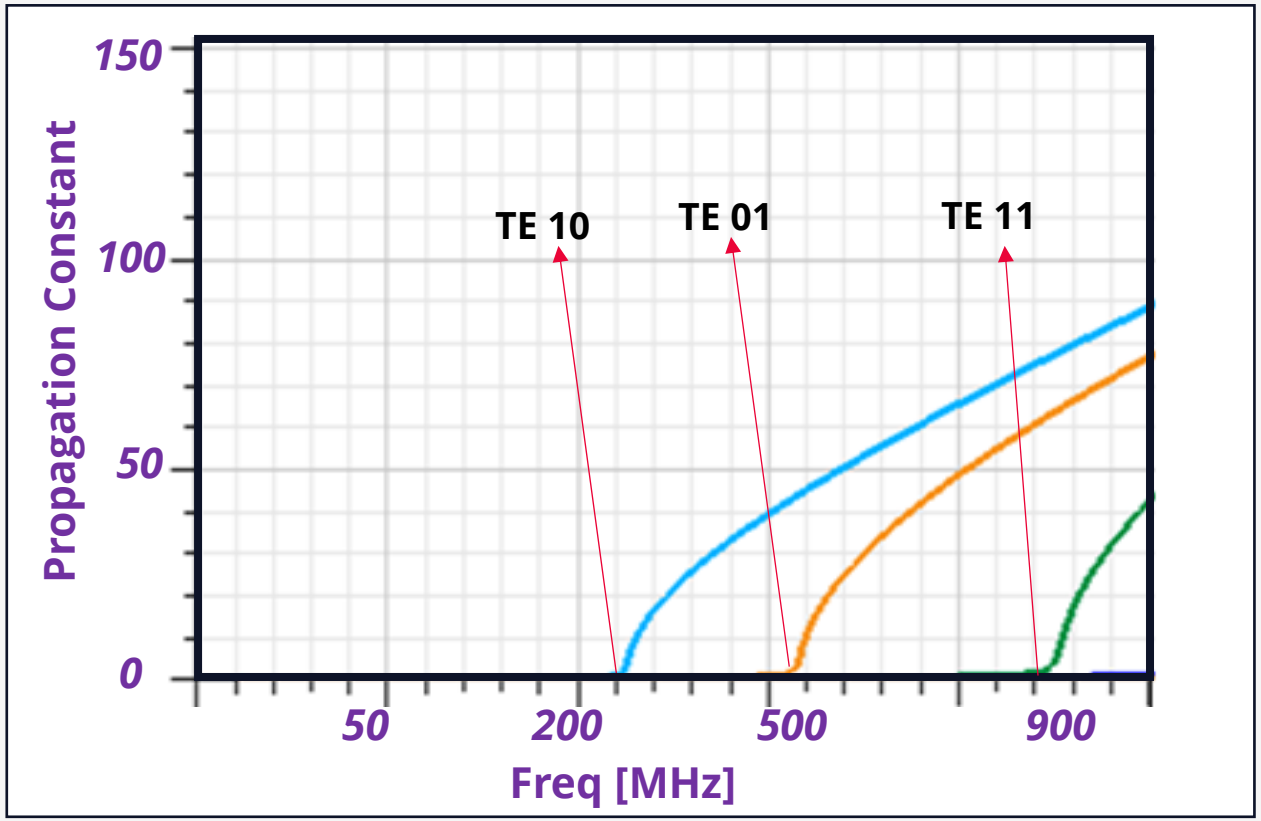


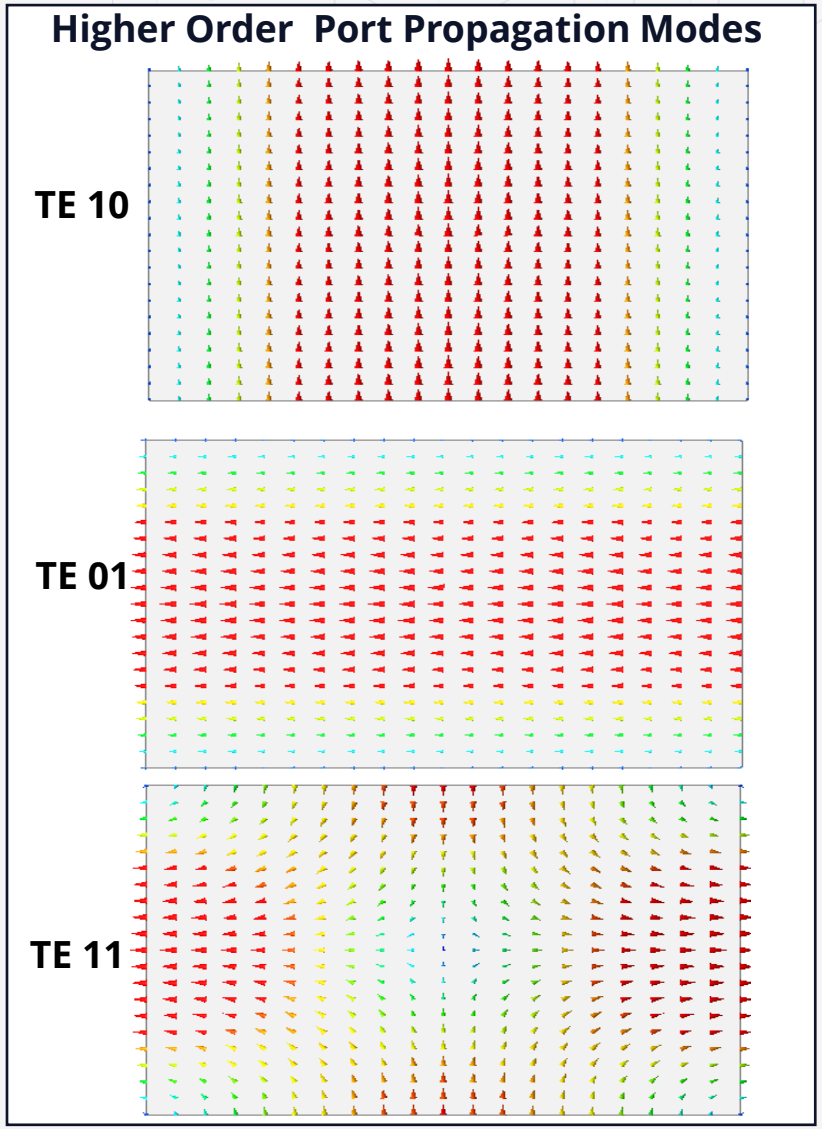
Improper wave port sizing compromises field confinement, introducing spurious higher-order modes and degrading simulation reliability

Off-the-Shelf Connector Simulation: Non-Ideal Port Effects

Simulation Artifacts : Spurious Excitation of Higher-order Electromagnetic Propagation Modes

- Spurious unintended activation of parasitic higher-order electromagnetic propagating modes due to suboptimal port sizing induces modal impurity and degrades simulation fidelity





Key Takeaways

- **Interconnect Signal Transparency:**
  - At 700 ps, interconnects appear electrically transparent especially when viewed at the system level but not for the cable itself
- **Cable Untwisting Effects:**
  - Untwisting degrades impedance control and increases mode conversion, impacting signal integrity and EMI
  - **Dual wire at plug** minimizes stubs, **improves signal integrity, and adds extra benefits**
- **Simulation Barriers:**
  - Off-the-Shelf Multiway connector with unknown impedance with standard CAN wiring make accurate modeling and reliable simulation with ideal ports difficult
  - Multiple 10BASE-T1S channels further increase complexity
  - Non-impedance-controlled interconnects are complex to simulate
- **Industry Open Question:**
  - Can 10BASE-T1S truly leverage legacy CAN wiring system ?

Questions?

Thank you for your attention. For more information and resources, please visit www.molex.com.

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