



Navigating EMC Challenges in Automotive Ethernet Communication: Strategies for Mode Conversion Mitigation

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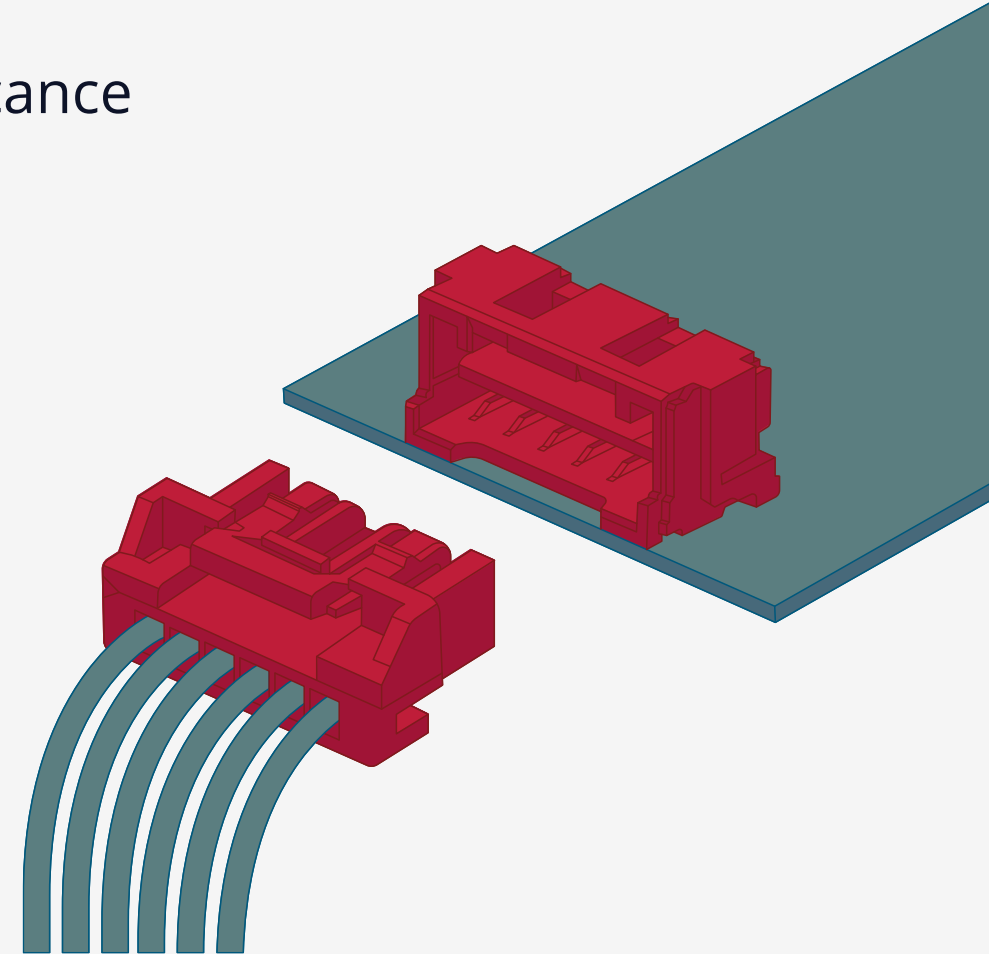
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Agenda

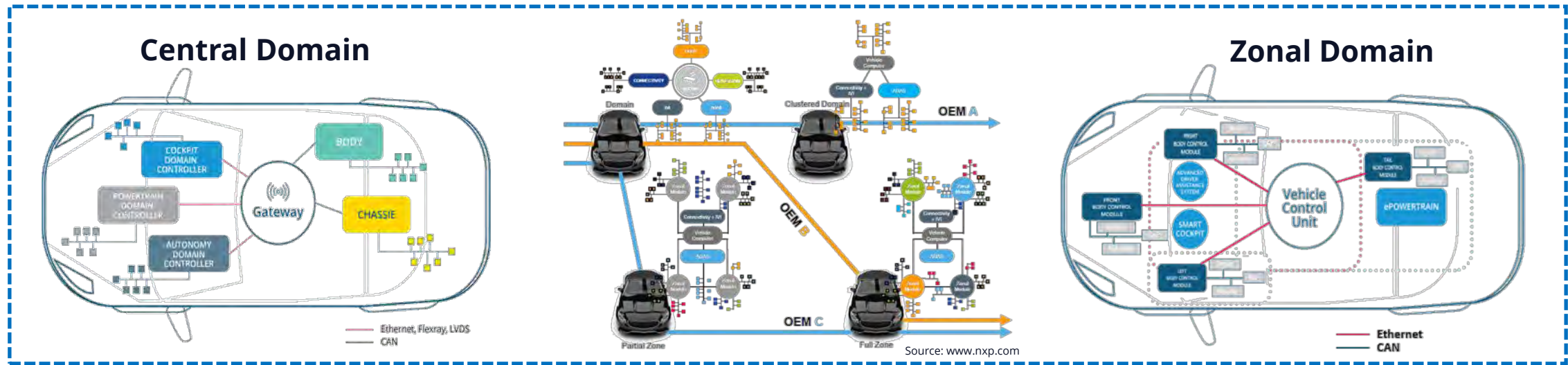
- Background
- Mode Conversion Significance
- Design Considerations
- Mitigation Scenarios
- Key Takeaways



Background

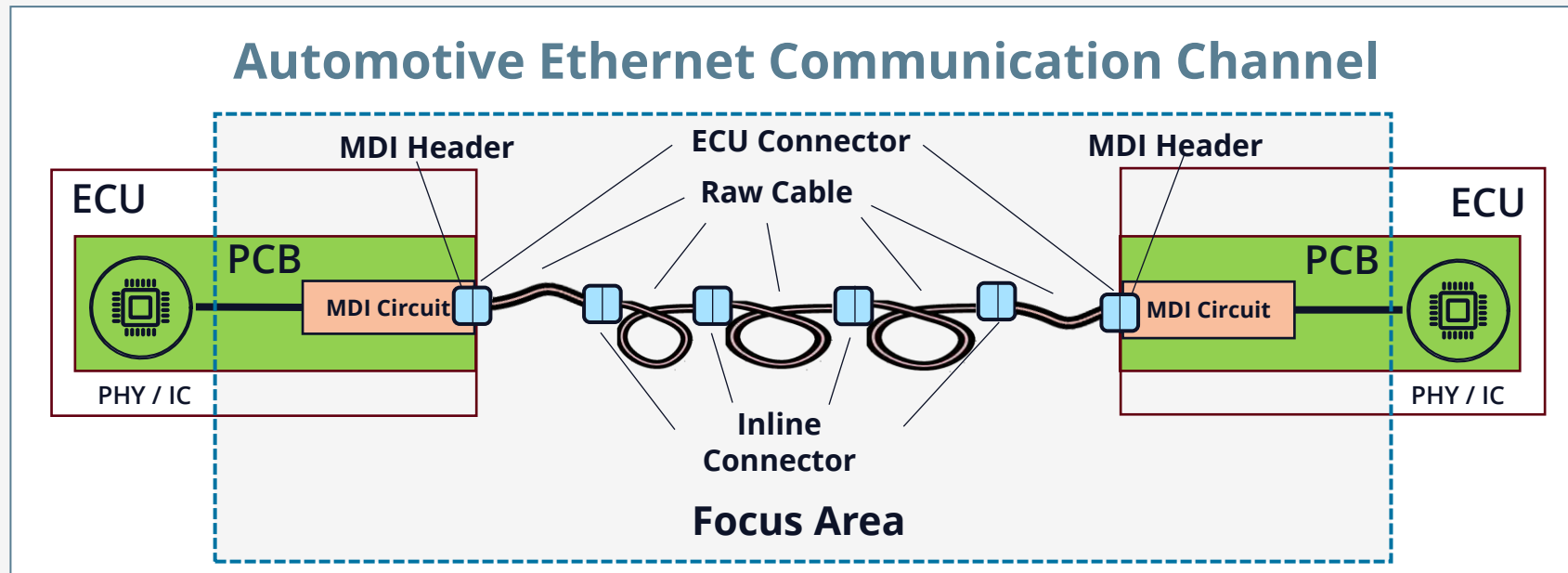
- Single Pair Ethernet enables in-vehicle networking for applications such as ADAS, infotainment, autonomous driving and V2X communication
- Implementing these new ethernet protocols into automotive applications is challenging because they must meet vehicle Electromagnetic Compatibility (EMC) requirements

Vehicle Architecture



Background

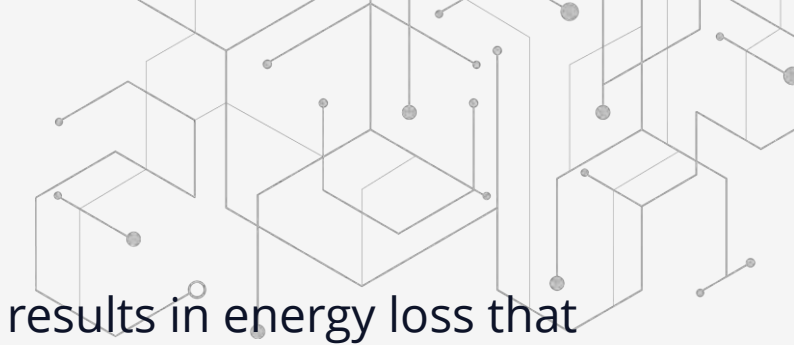
- Automotive Ethernet requires holistic, system-level operation, encompassing subsystems such as the MDI circuit, MDI header, and link segment, which include connectors and cables
- To predict system performance, we monitor S-parameters such as return loss, insertion loss, mode conversion and crosstalk
- Mode Conversion is an important S-parameter that can indicate impact on EMC / EMI
- Focus on key elements like the PCB, connectors, and raw cables, as mode conversion in any of these can impact EMC



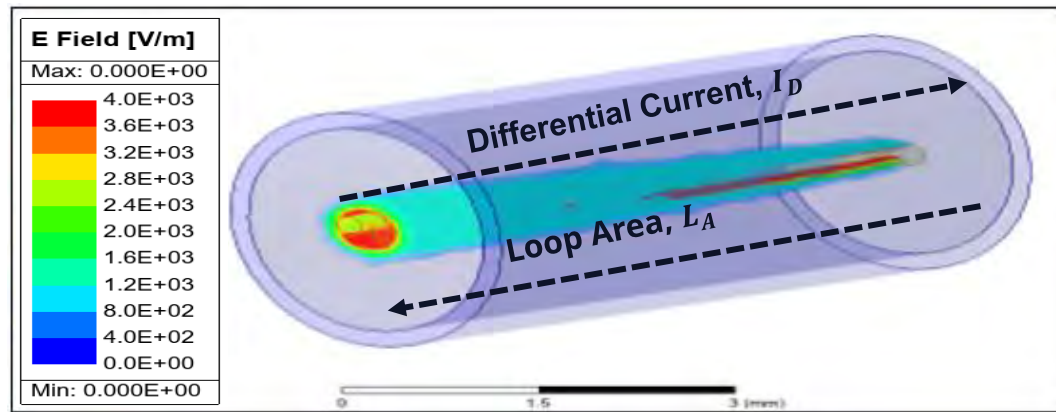
Mode Conversion Significance

What is Mode Conversion ?

- Transformation of differential signals to common signals, and vice versa, results in energy loss that impacts the Signal-to-Noise Ratio (SNR) of the system



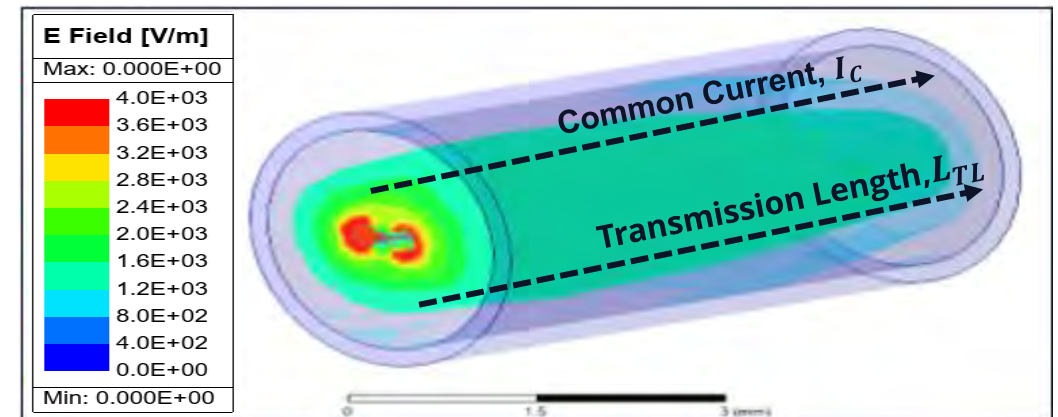
Differential Current



$E_{Radiated}$ related to the Differential current I_D can be approximated as:

$$E_{Radiated} = \frac{1.32 * 10^{-14} * L_A * I_D * f^2}{d}$$

Common Current



$E_{Radiated}$ related to the Common Mode current I_C can be approximated as:

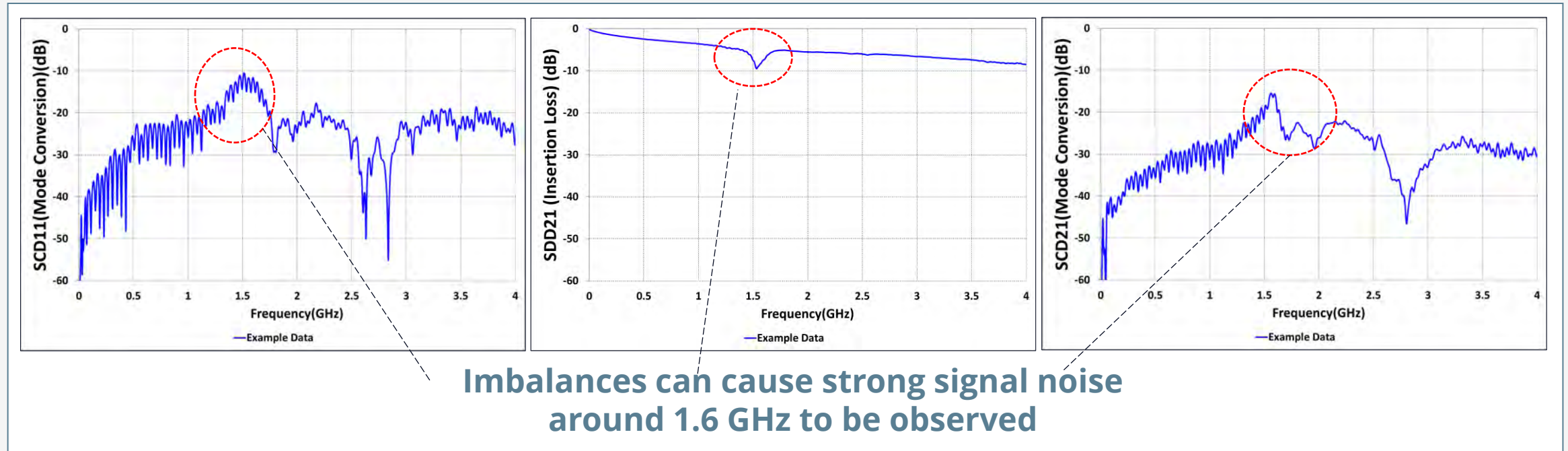
$$E_{Radiated} = \frac{1.257 * 10^{-6} * I_C * f * L_{TL}}{d}$$

In this context, L_A represents the area of the current loop, while L_{TL} denotes the transmission length. The variable f indicates the frequency of the currents, which are presumed to maintain a uniform magnitude and phase owing to the electrically short length, with measuring points being at far field with distance d .

Reducing common-mode currents can lower unwanted radiated emissions

Mode Conversion Significance in EMC

- EMC issues can lead to problems like GPS signal interruptions, infotainment interference, ECU disruptions, and ADAS failures
- S-Parameter data can demonstrate how system imbalances lead to mode conversion, impacting signal integrity and SNR, and can lead to EMC challenges



SCD11 – Transverse Conversion Loss (differential mode to common mode return loss)
SCD21 - Transverse Conversion Transmission Loss (differential mode to common mode insertion loss)

Design Considerations

Essential Ethernet Component Examination

PCB Optimization

- Ensure symmetry across signal pairs to avoid mode conversion

Connector Layout

- Ensure that pins in a multipin connector are properly terminated
- Improper pin termination can cause undesired behaviors impacting the system performance

Raw Cable Consistency

- For twisted pair cables, improper construction can impact performance, and asymmetries can lead to mode conversion



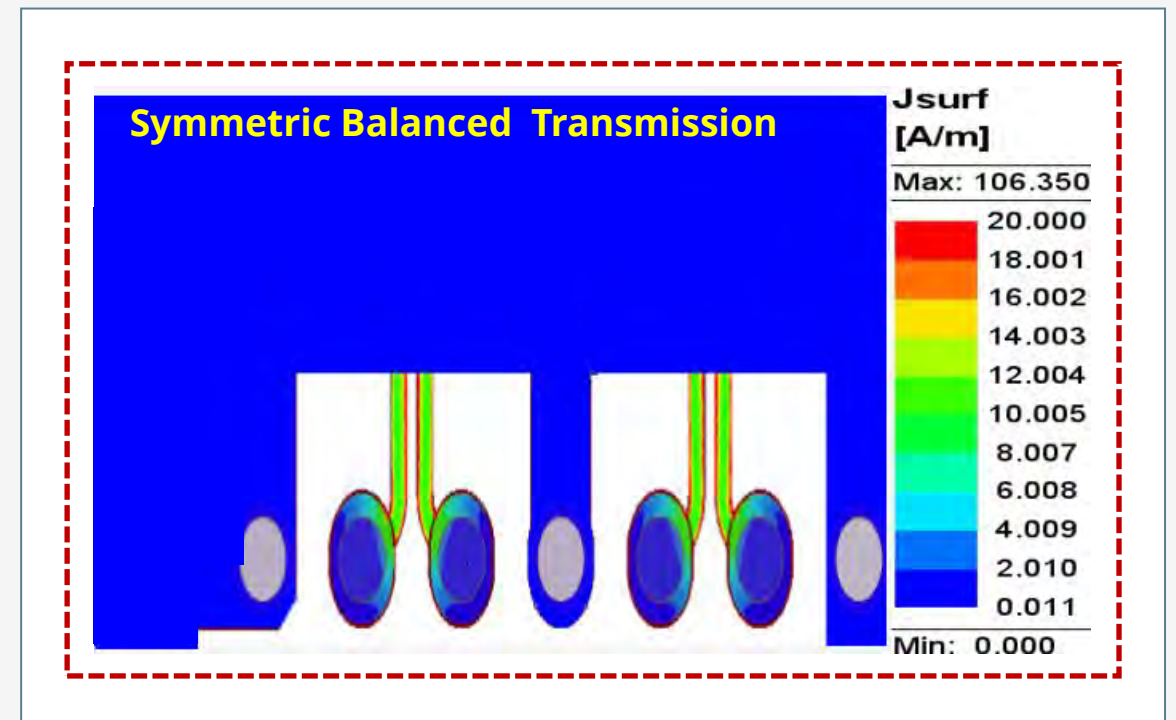
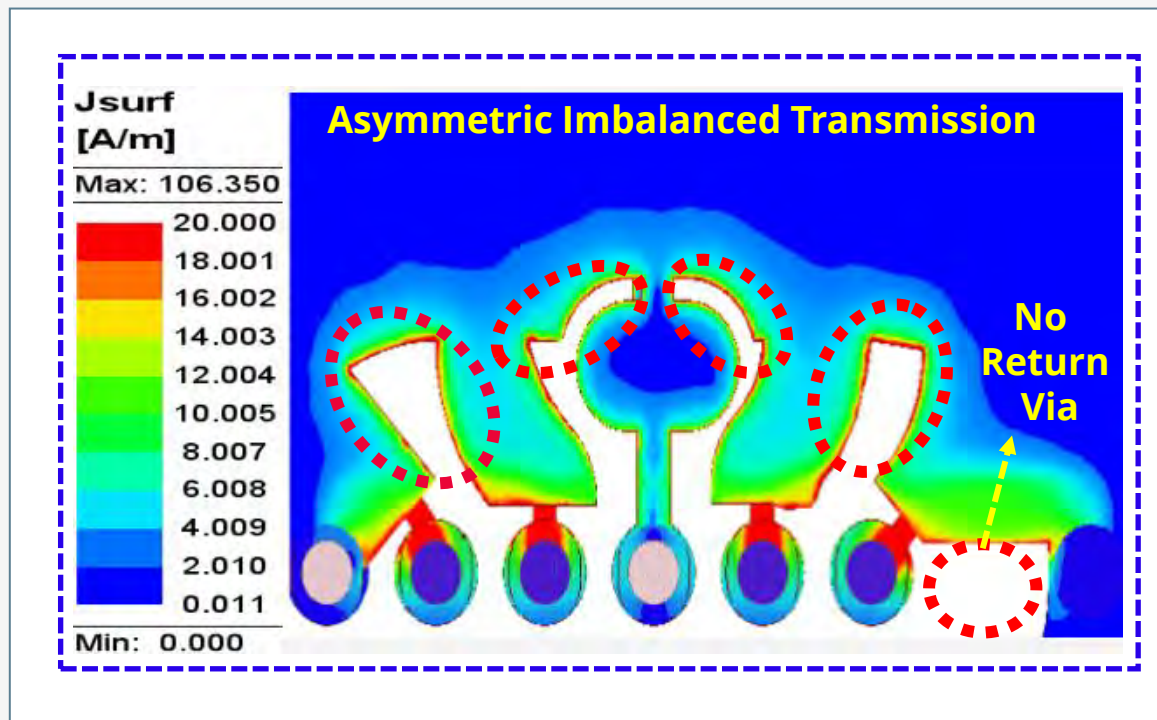
Careful consideration of key factors can minimize unwanted mode conversion across the system

PCB Mitigation Scenario

Controlling the Asymmetric Current Paths

- Asymmetry in the P-N differential pair enlarges the current loop, causing intra-pair skew
- This conversion of differential signals to common signals can lead to radiation

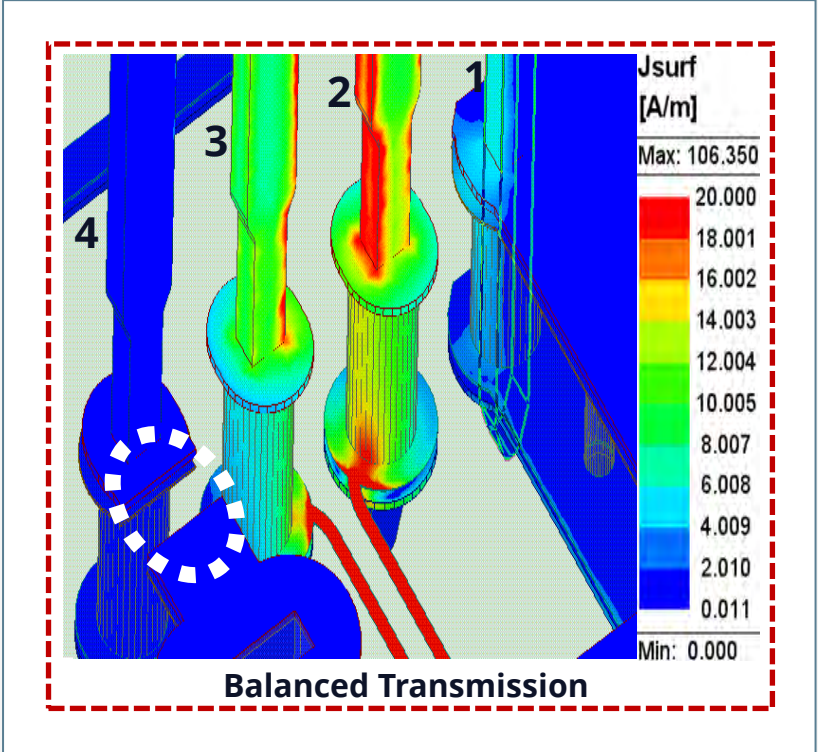
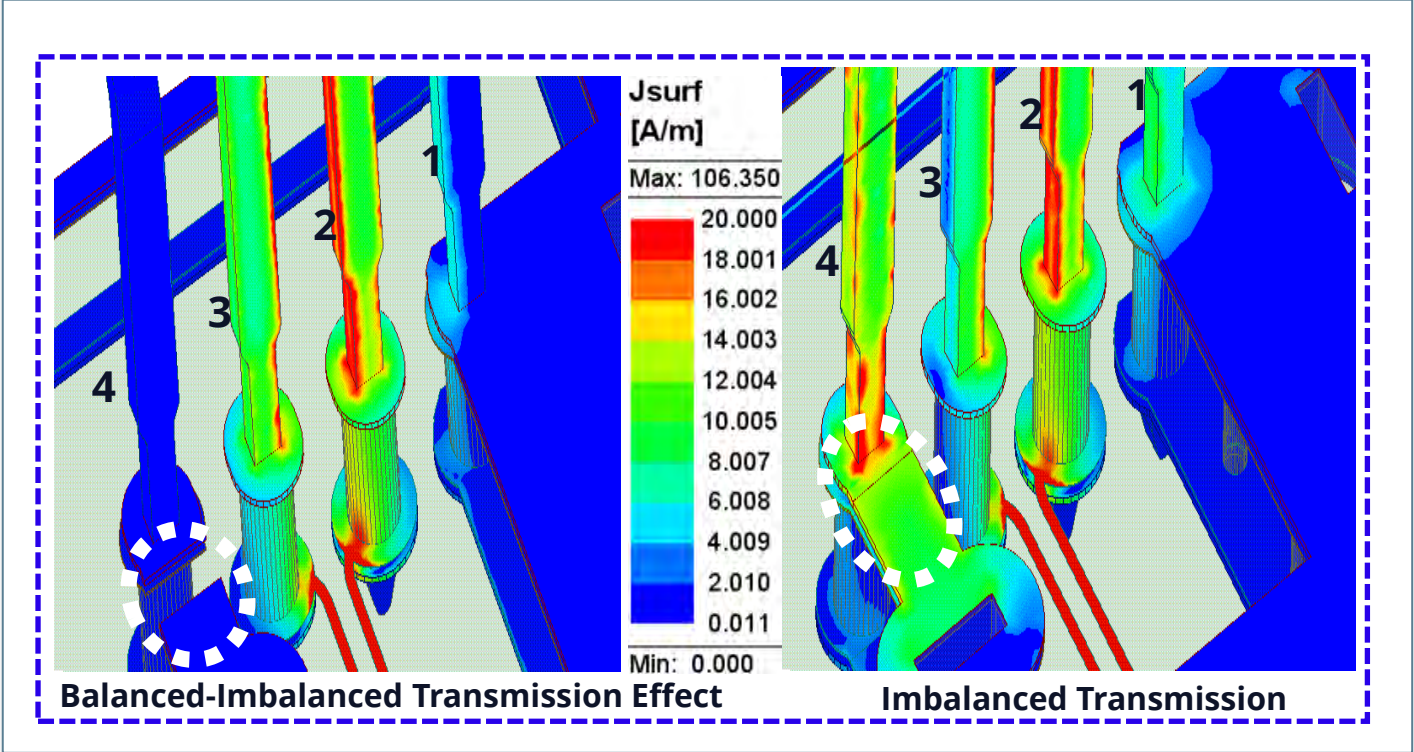
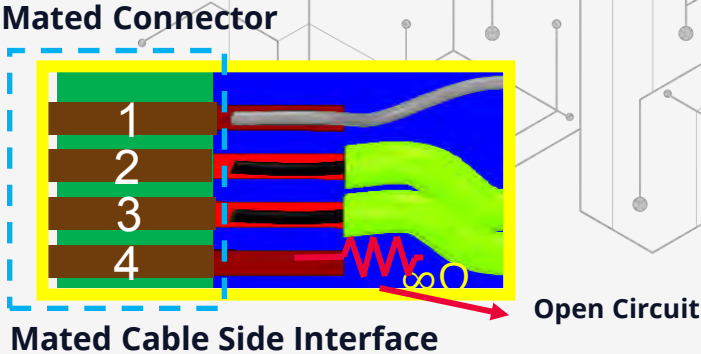
J_{surf} - Surface Current Density



Connector Mitigation Scenario

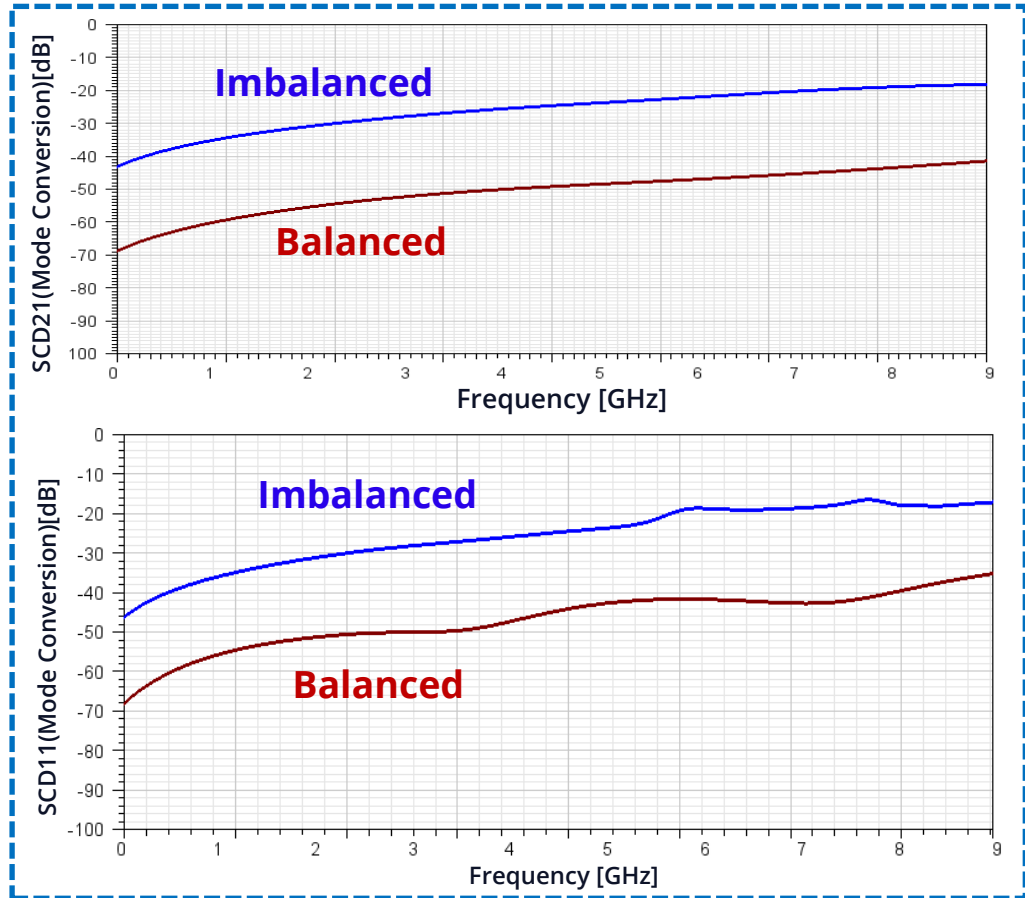
Balanced Current Flow Control

- Controlling the asymmetry of comprehensive current flow across the entire transmission pathway

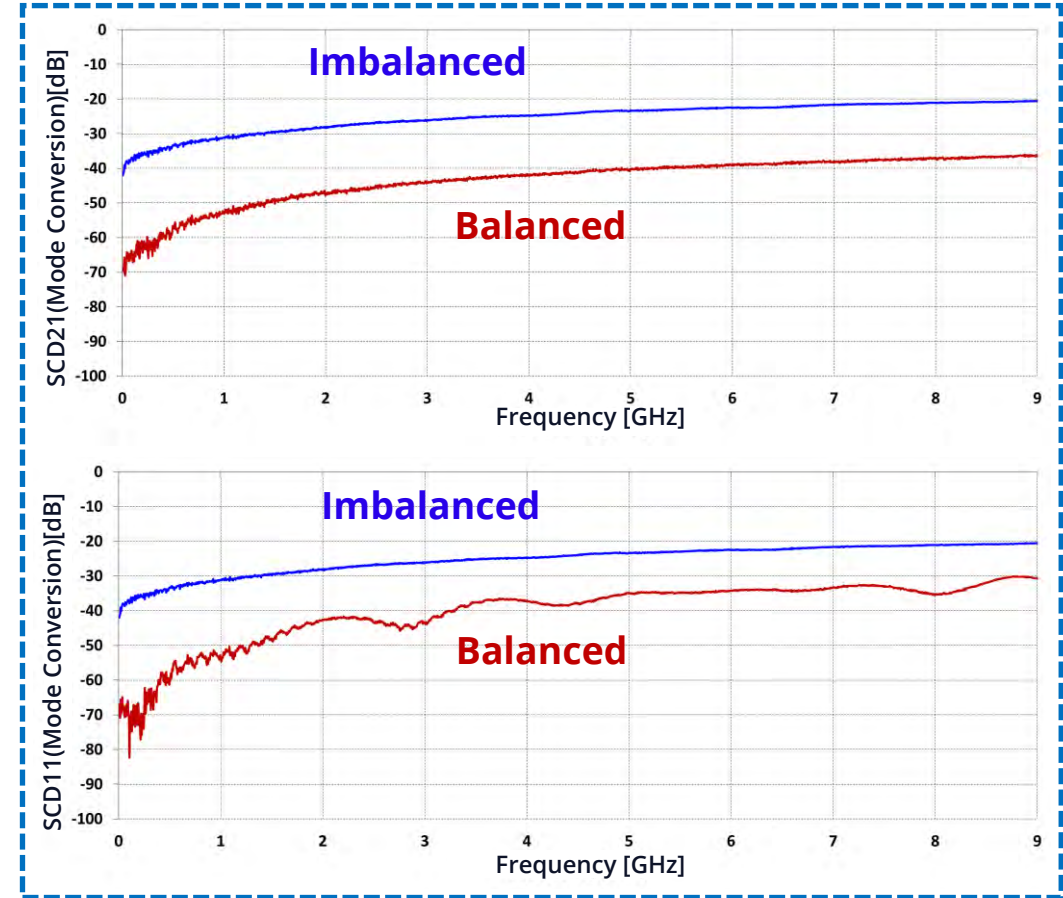


PCB Mitigation Scenario: Results

SIMULATION



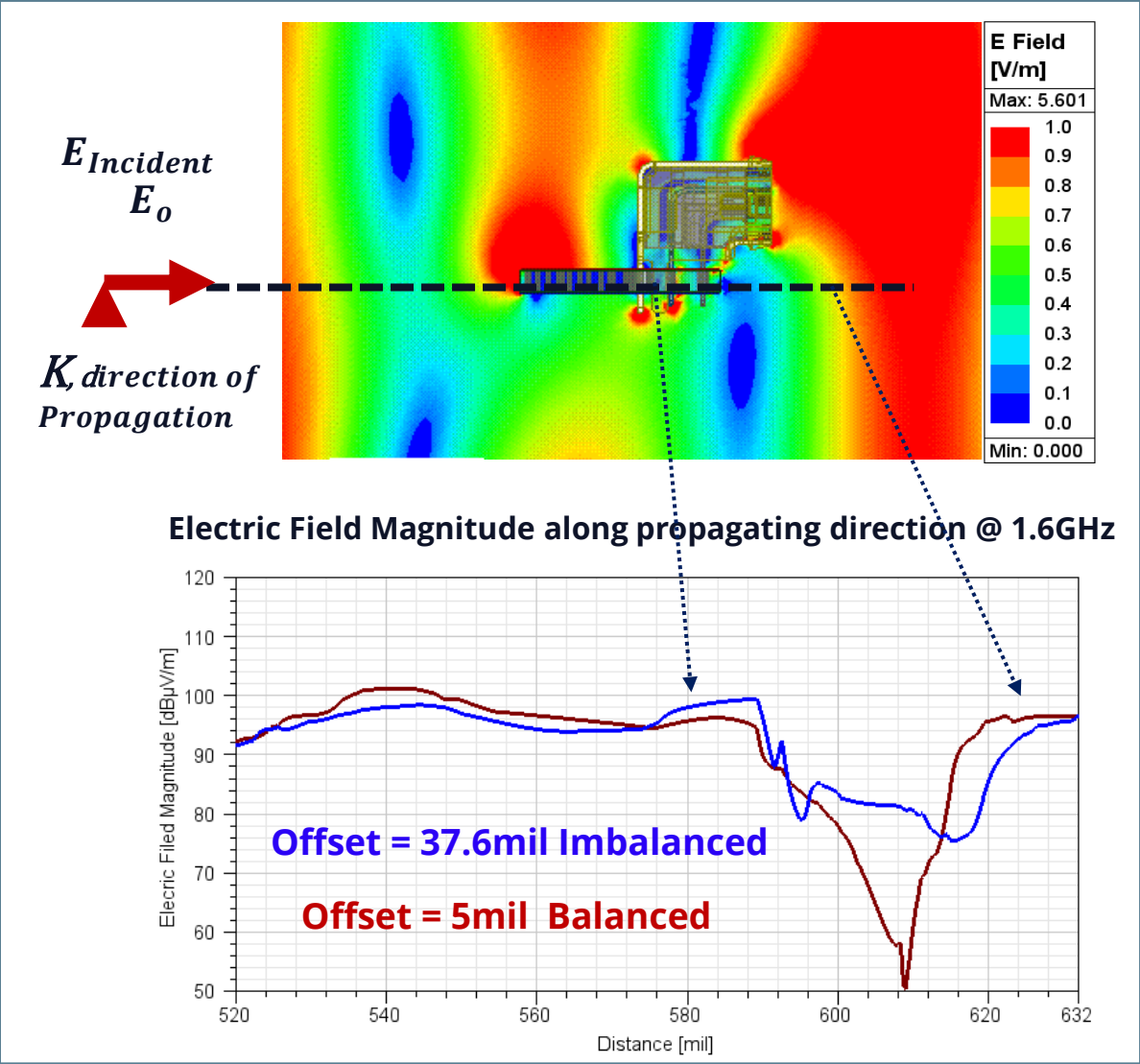
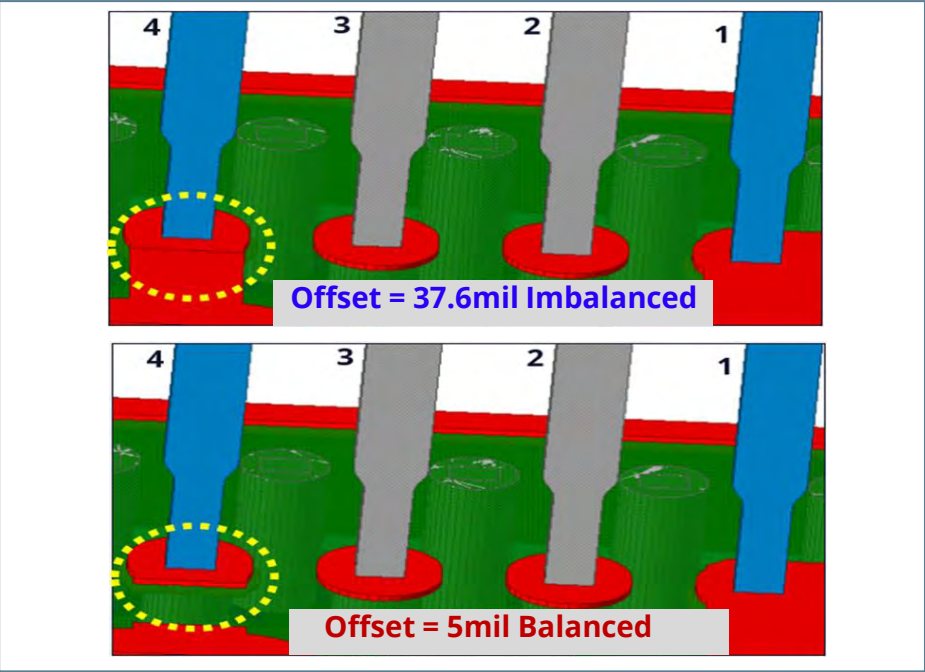
TESTING



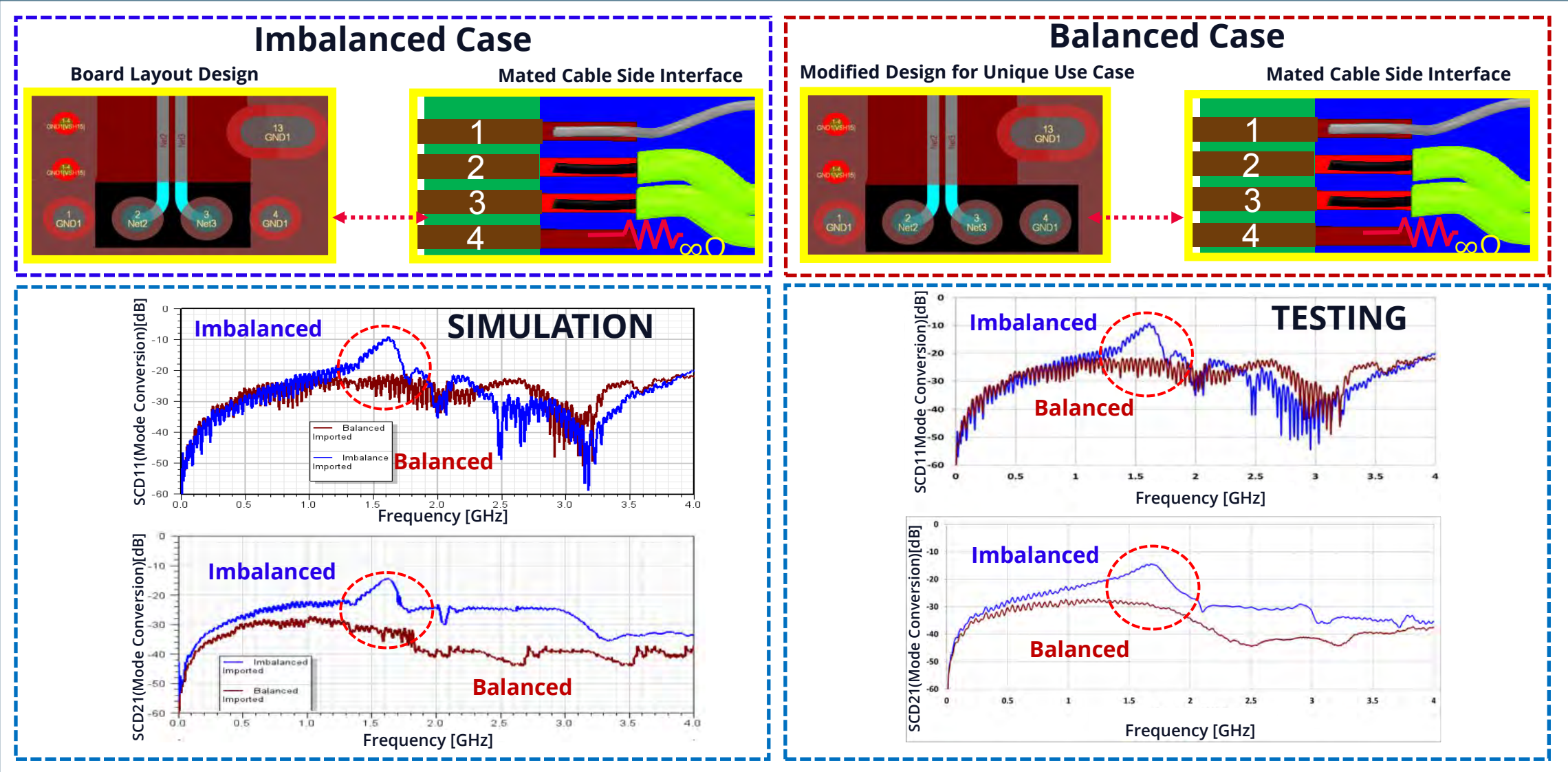
Maintaining symmetry across signals helps minimize mode conversion

Connector Mitigation Scenario: Shielding Effectiveness

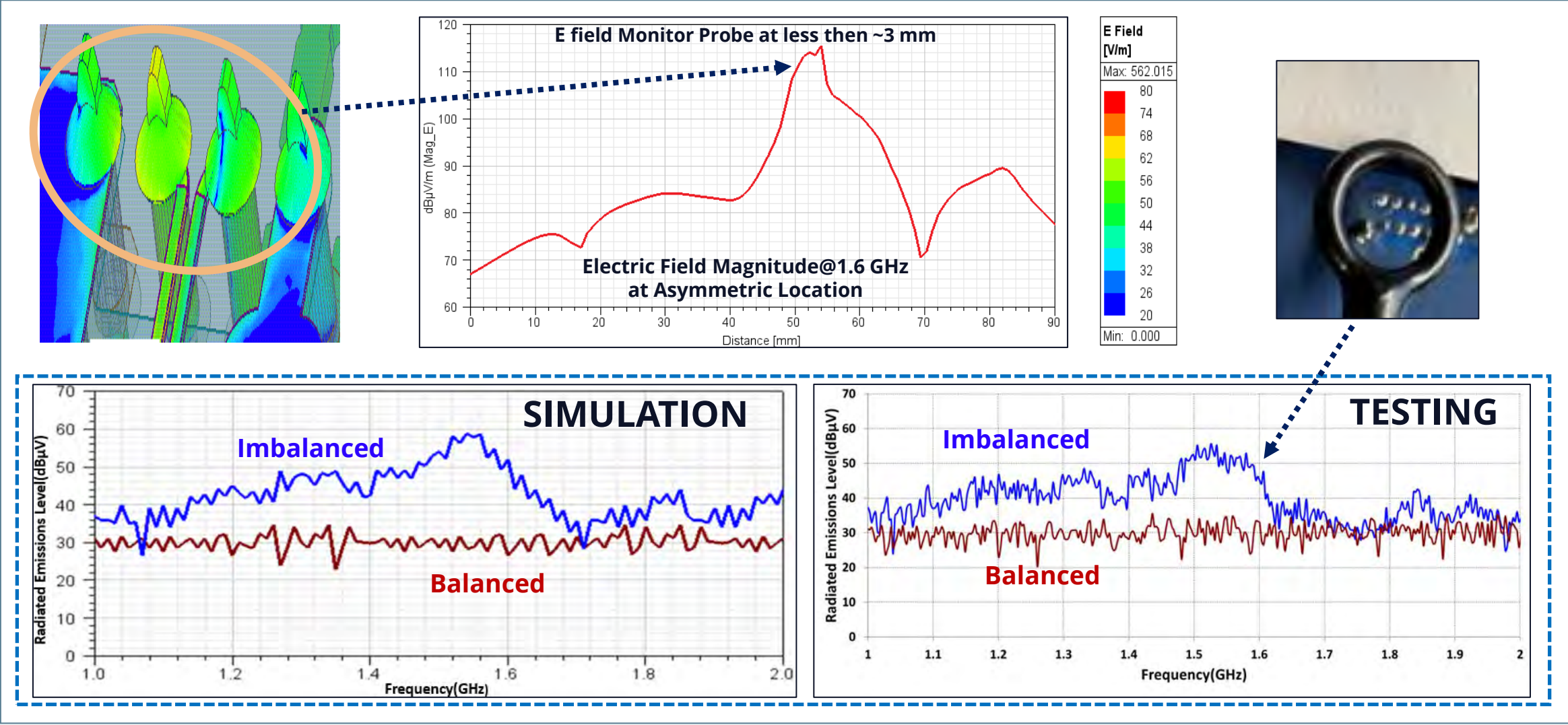
- Transverse electric and magnetic fields, which are mutually perpendicular, generate an electric field aligned with the direction of propagation
- This phenomenon affects the effectiveness of shielding, and any imbalance within the shielded circuitry significantly impacts EMC



Connector Mitigation Scenarios: Results



Connector Mitigation Scenarios: Results



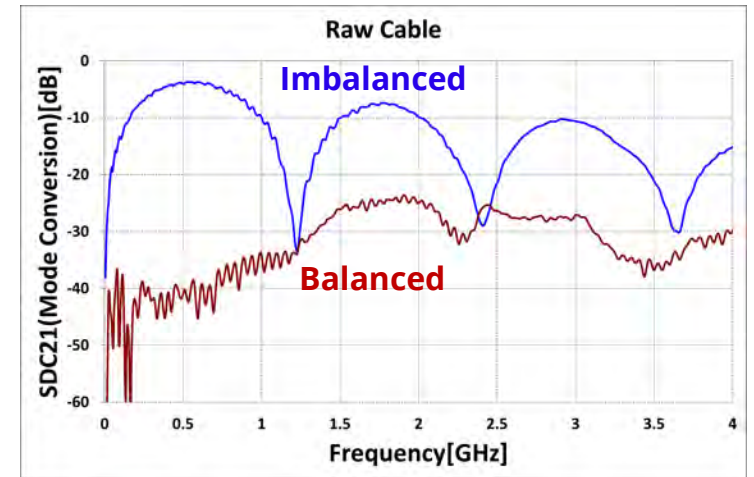
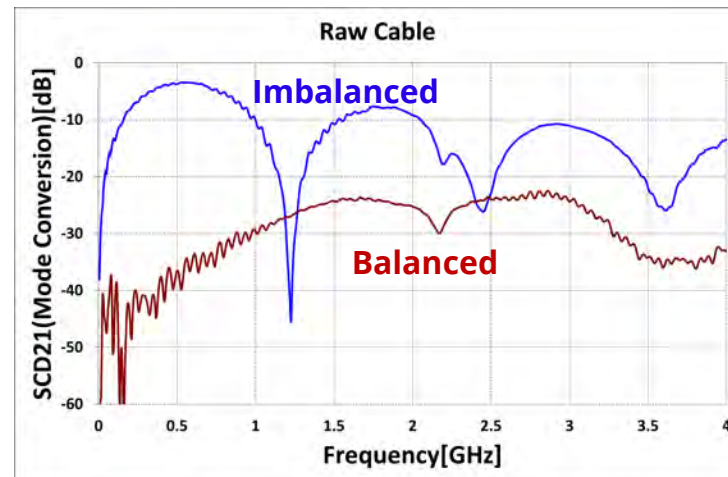
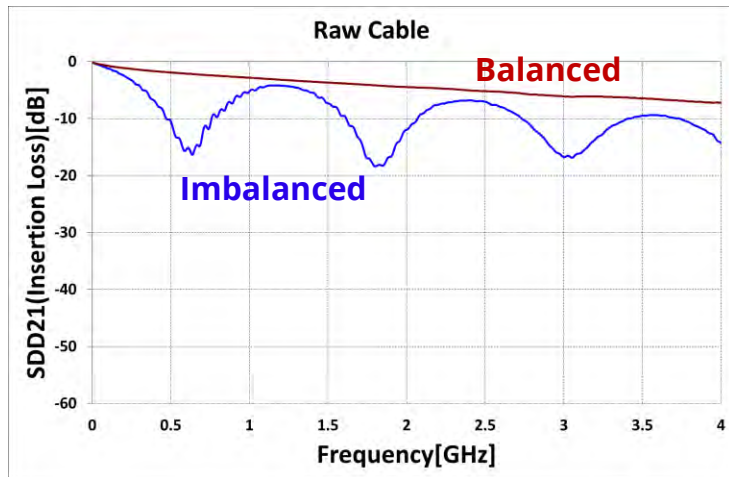
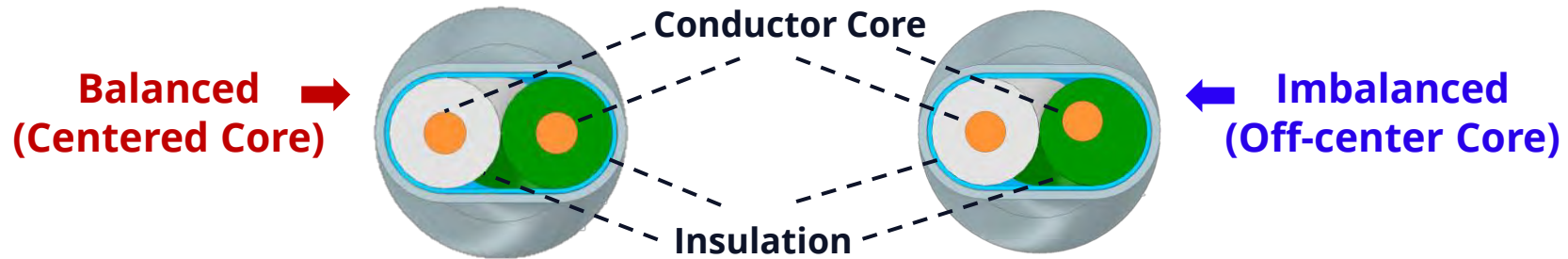
Improper Pin termination can Become Unintended Antennas, Causing EMI

Raw Cable Scenario

- S-Parameter data shows the impact on cable performance caused by an improper cable construction (e.g., conductor concentricity, twist rate, conductor balance, etc.)



Conductor Concentricity Example



Key Takeaways

Ensuring Balanced System Performance

- It is necessary to ensure that the channel components—PCB, connector, and cable—operate together as a balanced system
- Design imbalances may result in increased mode conversion, which can cause unintended noises leading to EMC challenges
- It is essential to carefully examine each key component that could cause imbalances affecting EMC
- Although achieving an interference-free channel is not feasible, it can be made robust by taking all key factors into consideration





Questions?



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

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