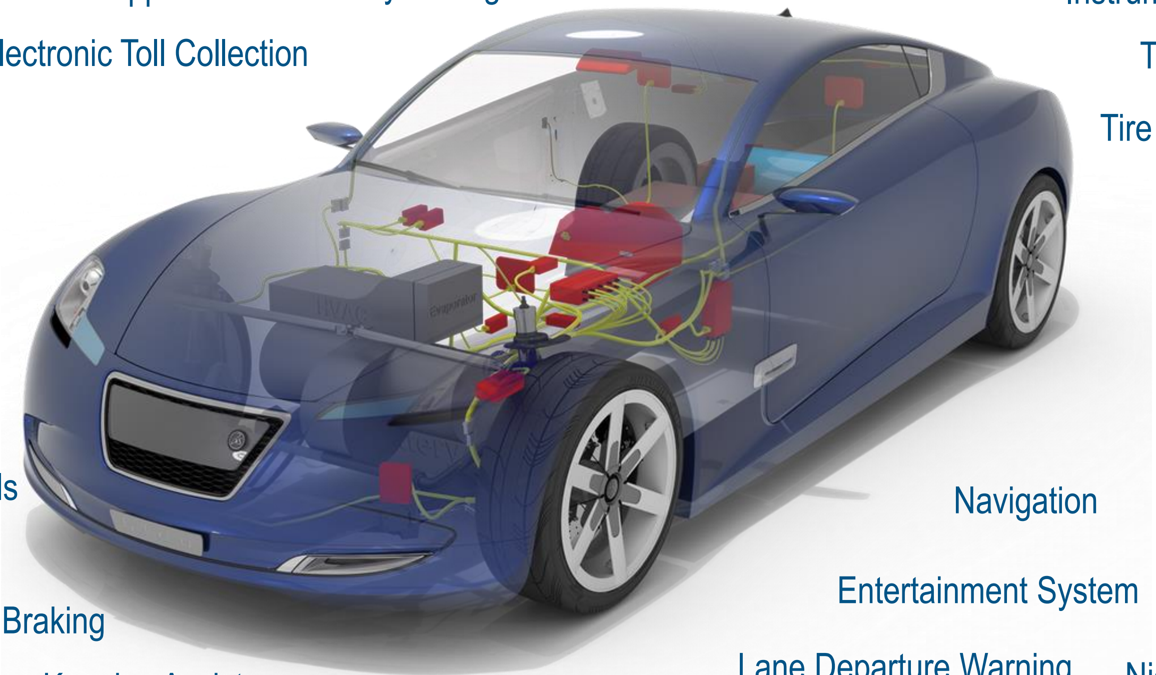
# EMC Simulation for Automotive Ethernet

CST joins SIMULIA

3DEXPERIENCE®

DASSAULT SYSTEMES | The 3DEXPERIENCE® Company

- Electronic Valve Timing
- Hill Hold Control
- Driver Alertness Monitoring
- Remote Keyless Entry
- Windshield Wiper Control
- Active Exhaust Noise Suppression
- Battery Management
- Convertible Top Control
- Instrument Cluster
- Adaptive Cruise Control
- Electronic Toll Collection
- Transmission Control
- Idle Stop-Start
- Tire Pressure Monitoring
- Electronic Stability Control
- Security Systems
- Traction Control
- Rear-view Camera
- Cylinder Deactivation
- Engine Control
- Head-Up Displays
- Parking Systems
- Blind Spot Detection
- Cabin Environment Controls
- Navigation
- Precrash Safety
- Traffic Sign Recognition
- Entertainment System
- Interior Lighting
- Autonomous Emergency Braking
- Lane Departure Warning
- Night Vision Systems
- Communication Systems
- Lane Keeping Assist
- Airbag Deployment
- Regenerative Braking
- Intelligent Turn Signals
- Active Vibration Control
- Adaptive Front Lighting
- Antilock Braking
- Active Suspension
- Electronic Seat Control
- Electronic Throttle Control
- On-Board Diagnostics



# In Vehicle Communication Standards

## Powertrain

- Latency: < 10 µs
- Bandwith: Low

- CAN
- FlexRay

## Chassis

- Latency: < 10 µs
- Bandwith: Low

- CAN
- FlexRay

## Body & Comfort

- Latency: < 10 ms
- Bandwith: Low

- CAN
- LIN


## ADAS

- Latency: < 250 µs
- Bandwith: 50 Mbps per camera

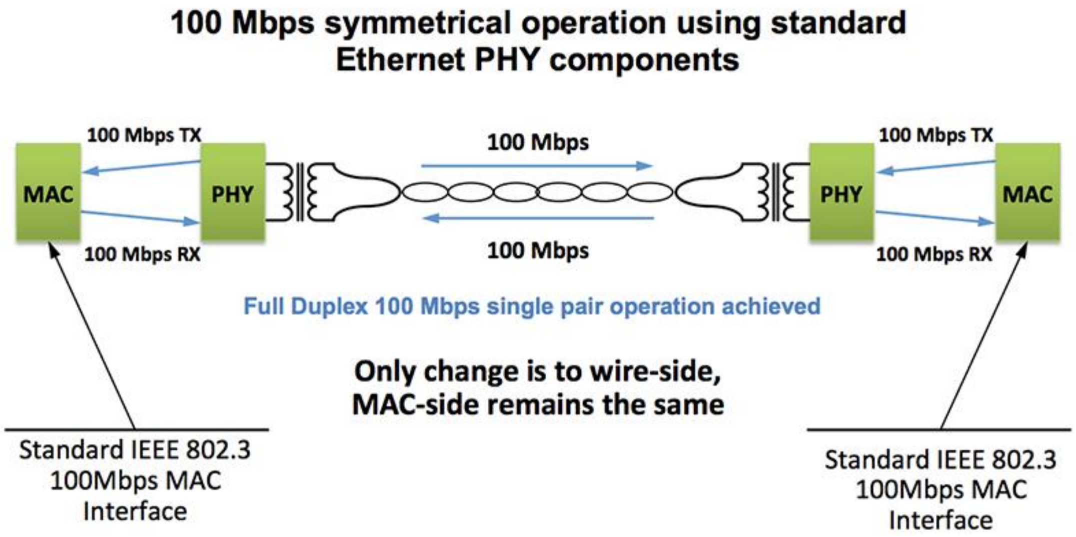
- FlexRay
- MOST
- LVDS
- Ethernet

## Infotainment

- Latency: < 10 ms
- Bandwith: High and growing

- Ethernet

# Replace the PHY, Nothing Else Changes




## Reducing connectivity cost and weight

Source: http://www.opensig.org/

# One Pair Ether Net

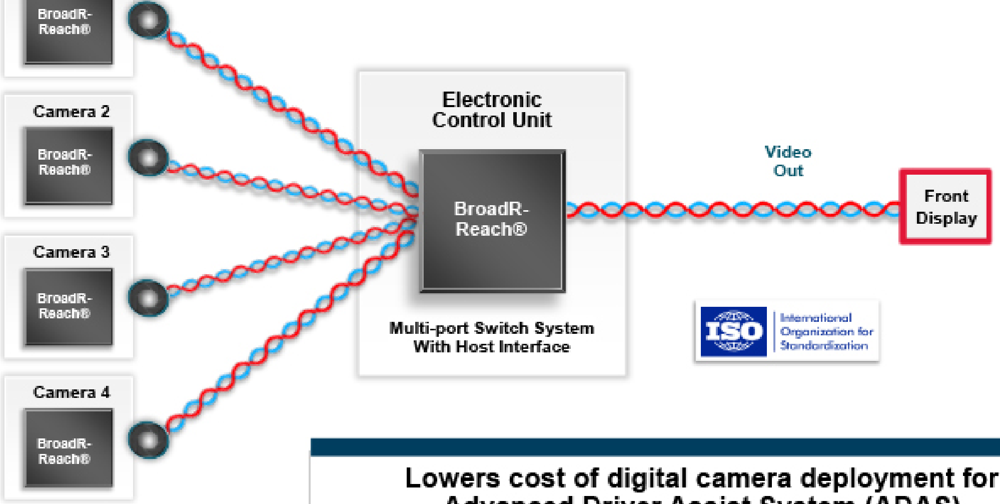
OPEN ALLIANCE

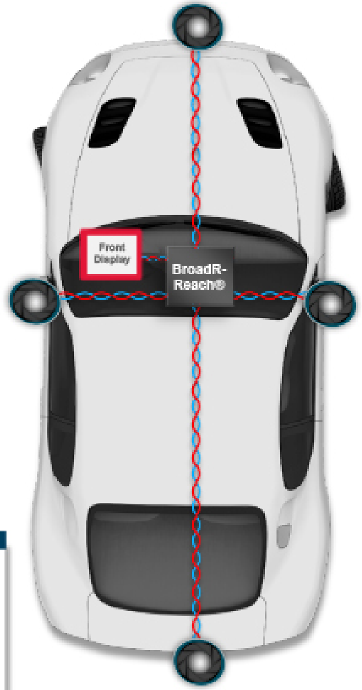
Partner with the Industry's Leading Automotive & Tech Companies



Source: http://www.opensig.org/

# Use Case: ADAS




**Lowers cost of digital camera deployment for Advanced Driver Assist System (ADAS)**

- Object detection, surround view parking
- Lane departure warning and high beam control

Source: http://www.opensig.org/

# Scope of EMC/EMI

## The ability of an electrical system to work

- in its electromagnetic environment
- without influencing the surrounding devices (emissions)
- or being influenced by surrounding equipment (susceptibility)

## EMC compliance is crucial to all products!

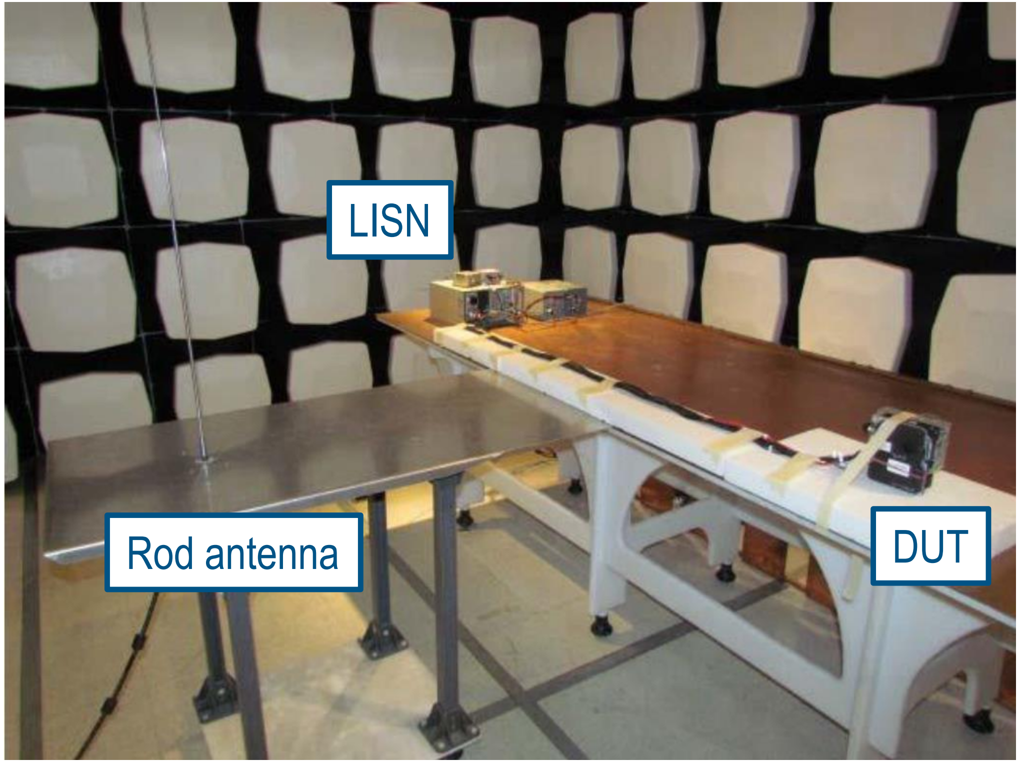
- Susceptibility and emssions are a well regulated area
- Automotive OEM impose strict standards on components

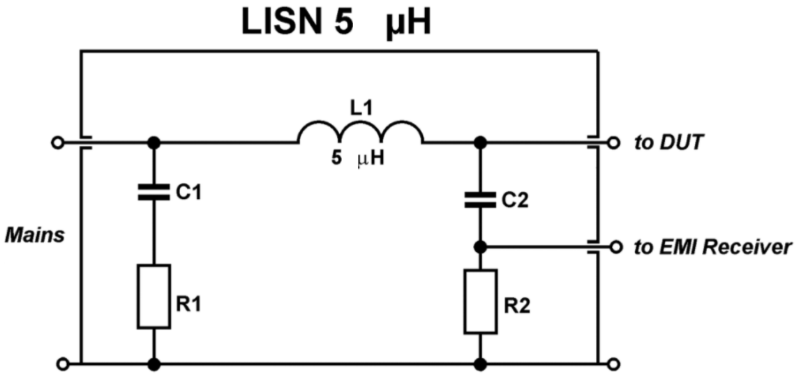
kHz – Inverter, Voltage Regulators

MHz – Radio, Communication Systems

GHz – Digital electronics, Radar

# Emission Testing



# Conducted Emission Limits

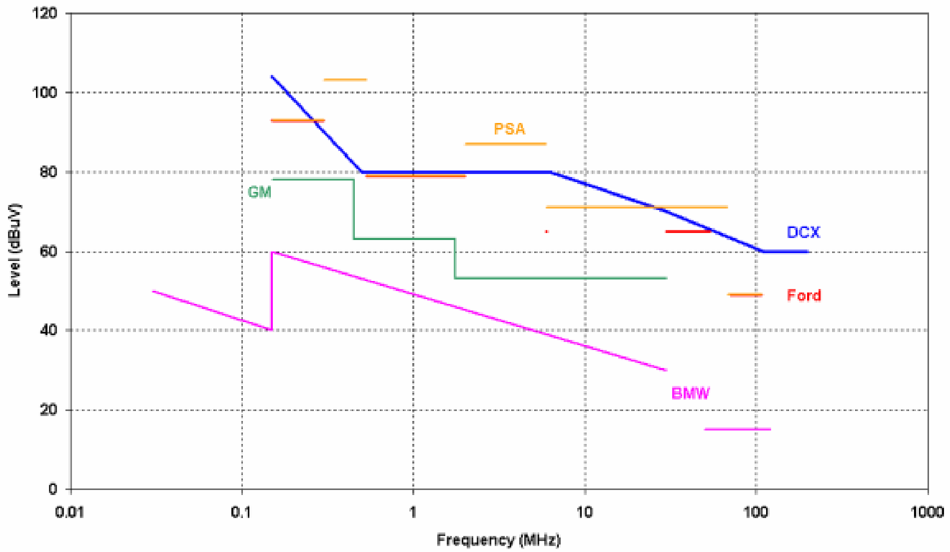


Figure 5: VM Conducted Emissions Limits

From:

A GENERIC AUTOMOTIVE (TIER1) EMC TEST STANDARD

**Martin O'Hara**

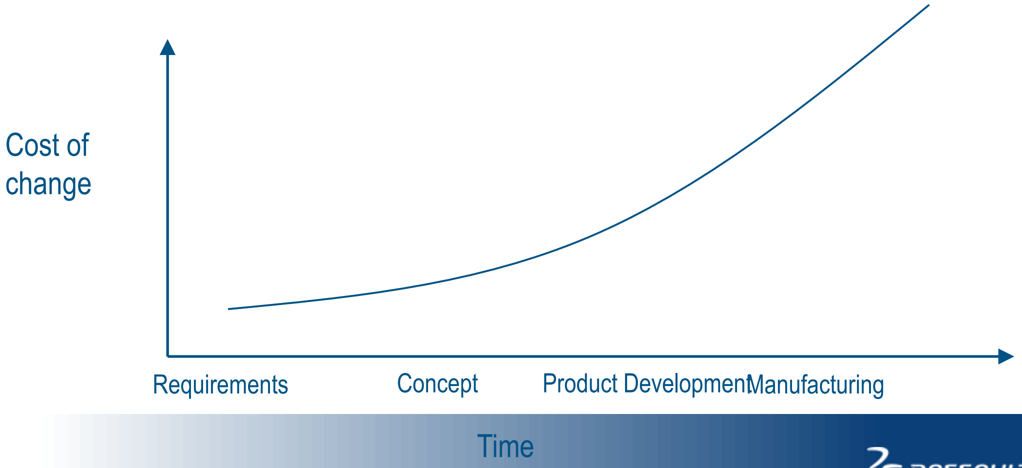
The Automotive EMC Network, P.O. Box 3622, Newport Pagnell, MK16 0XT

http://www.autoemc.net/

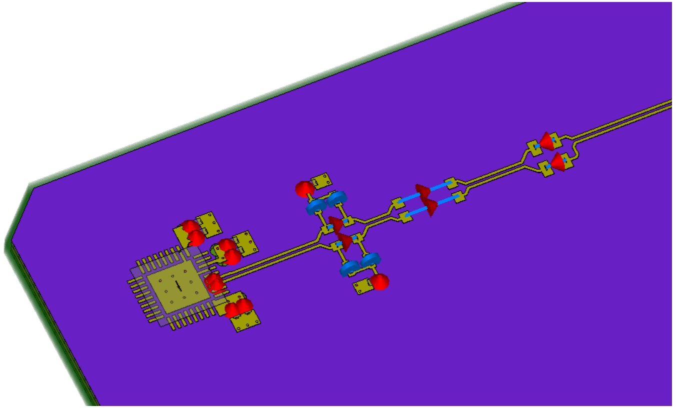
# EMC Simulation in the Design Process

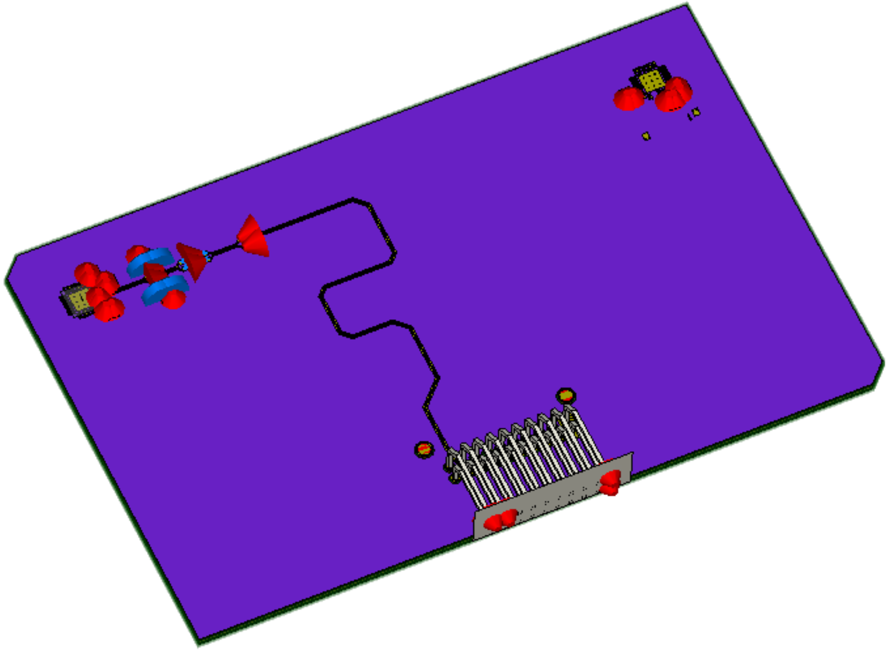
## EMC at all Stages of the Design Process

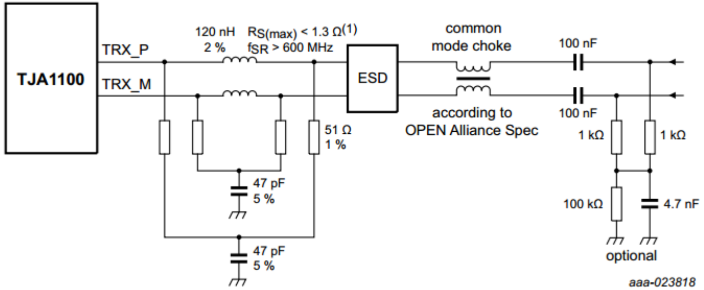
- multiple troubleshooting iterations
- high effort and costs to correct
- delayed time to market



# Simulation Model

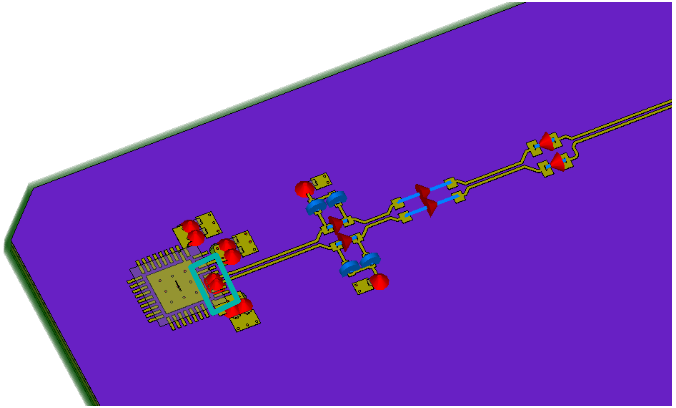


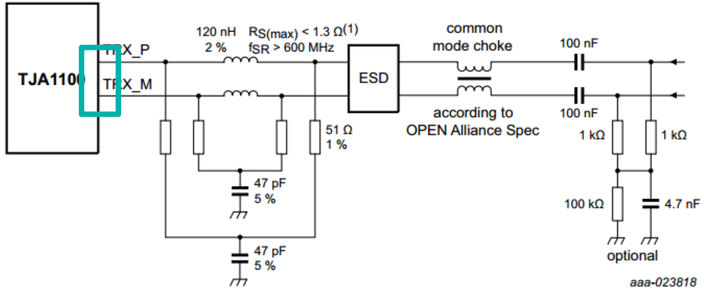





(1) $R_{S(max)}$ = maximum series resistance; $f_{SR}$ = self resonant frequency

**Fig 18. MDI application diagram**







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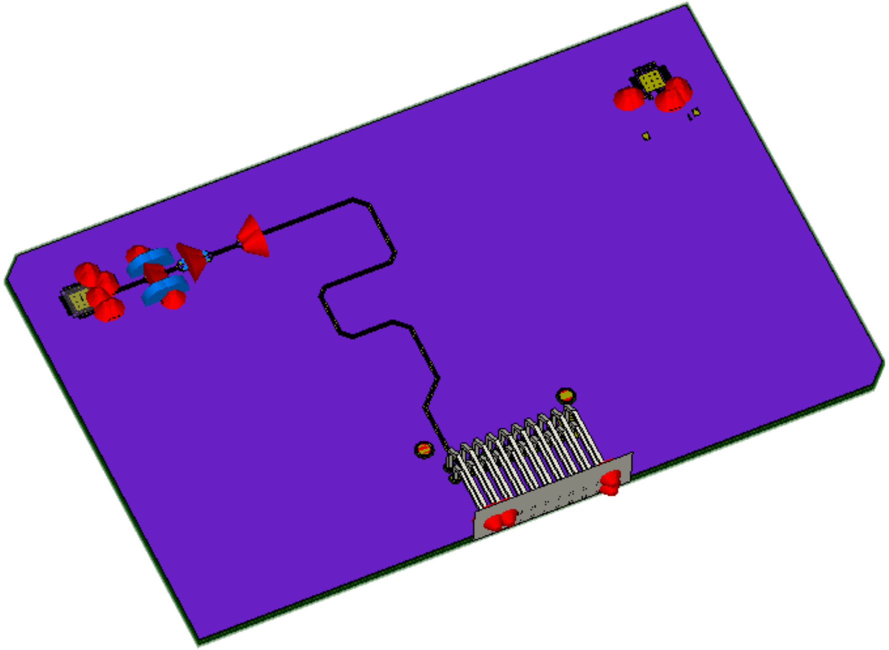

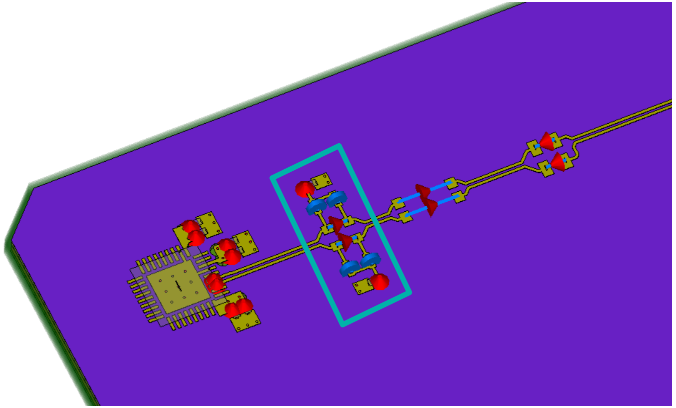

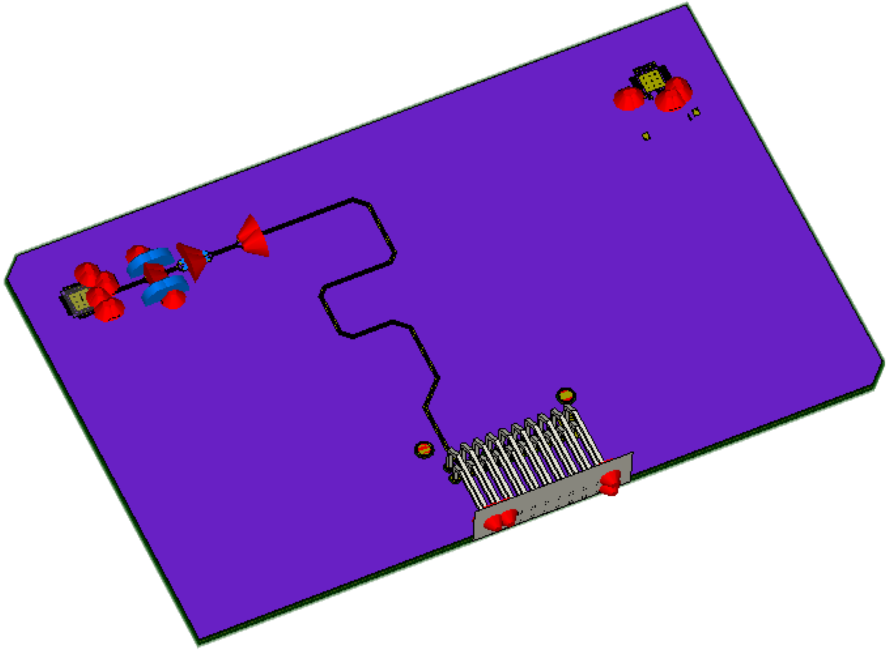

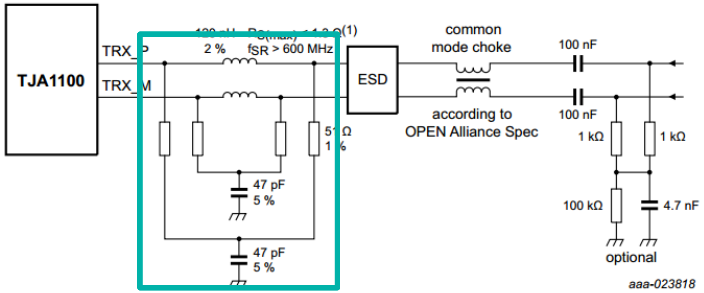


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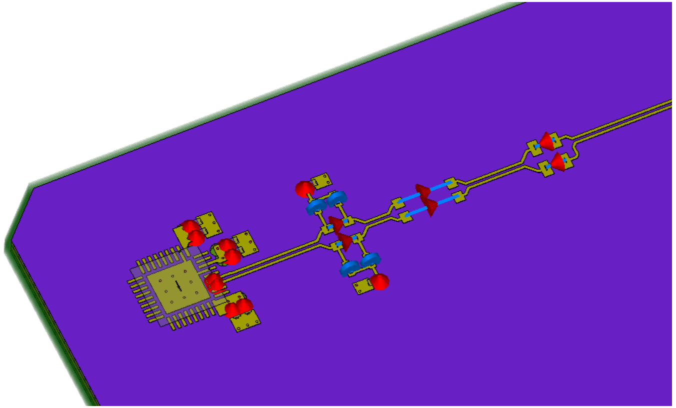

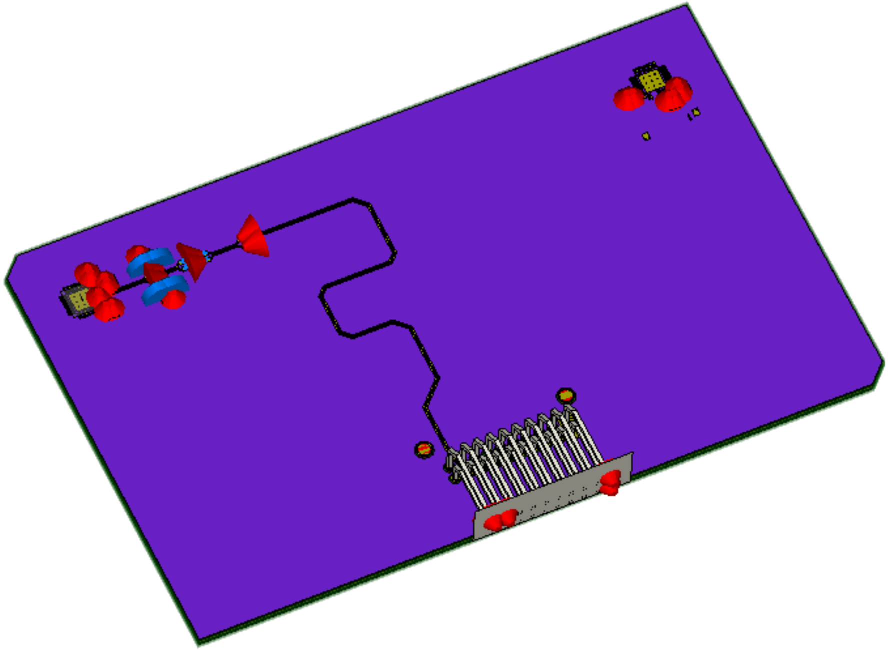

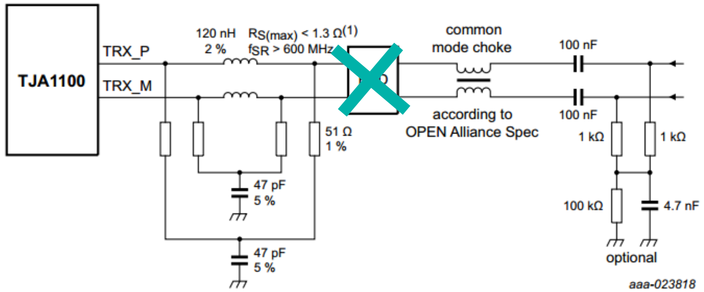


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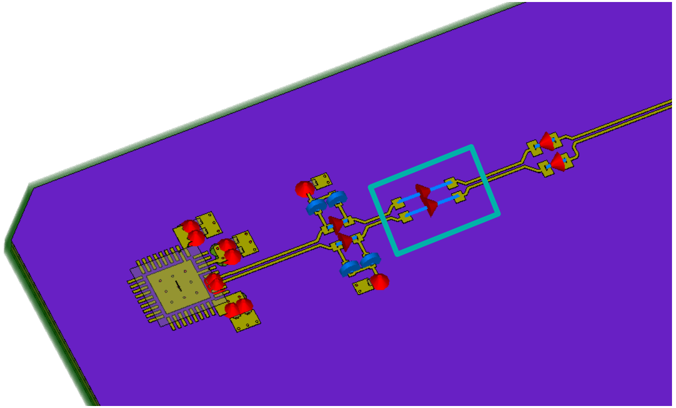

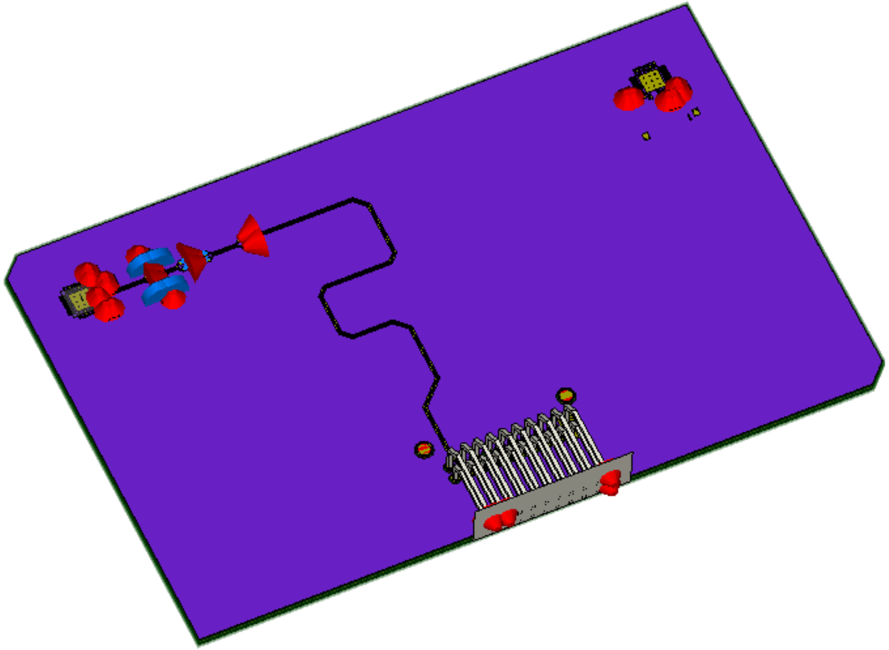

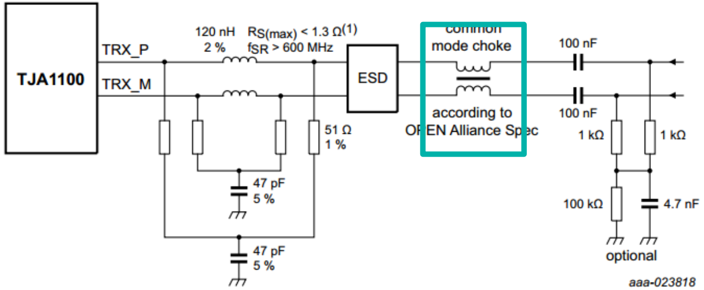


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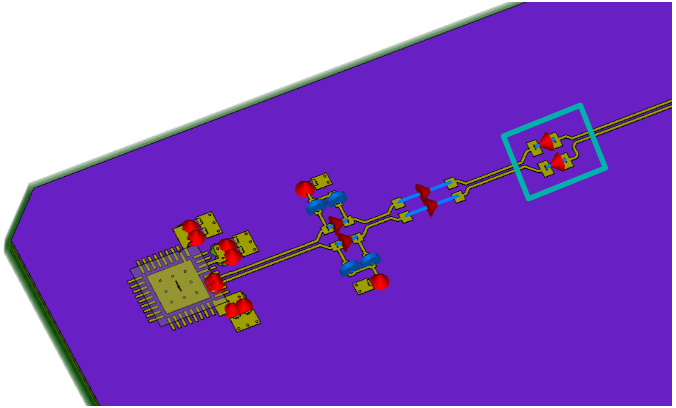
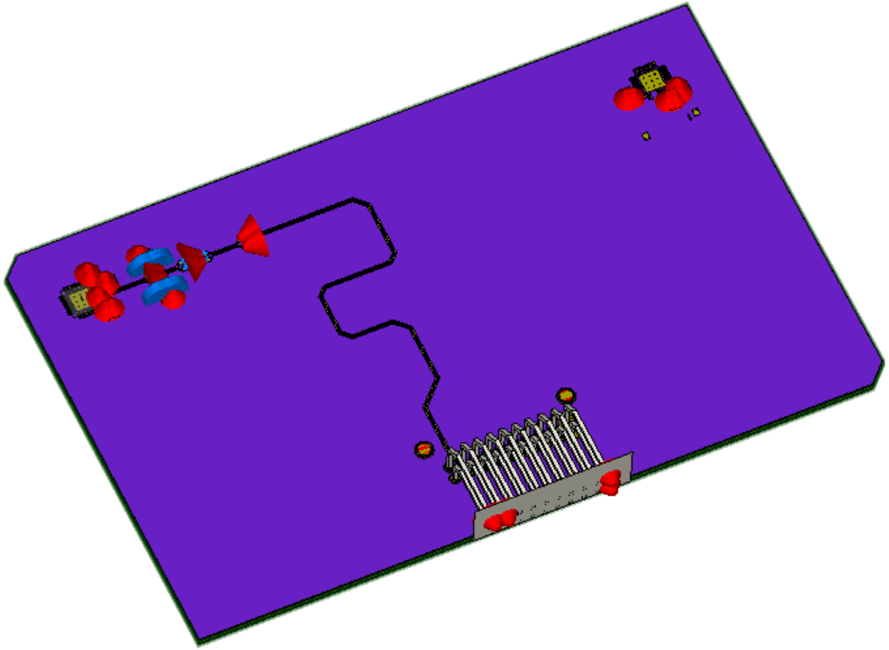
**Fig 18. MDI application diagram**





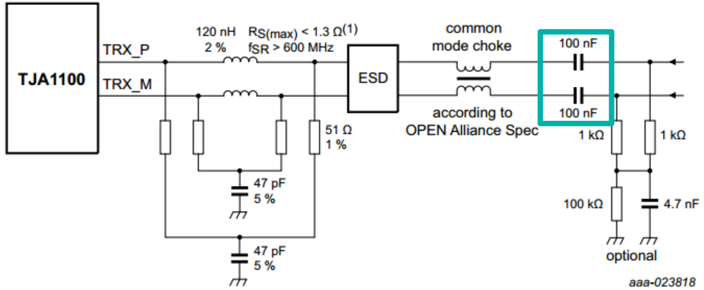



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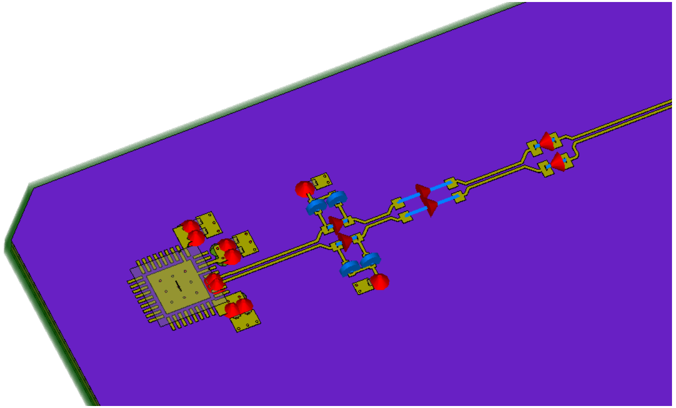
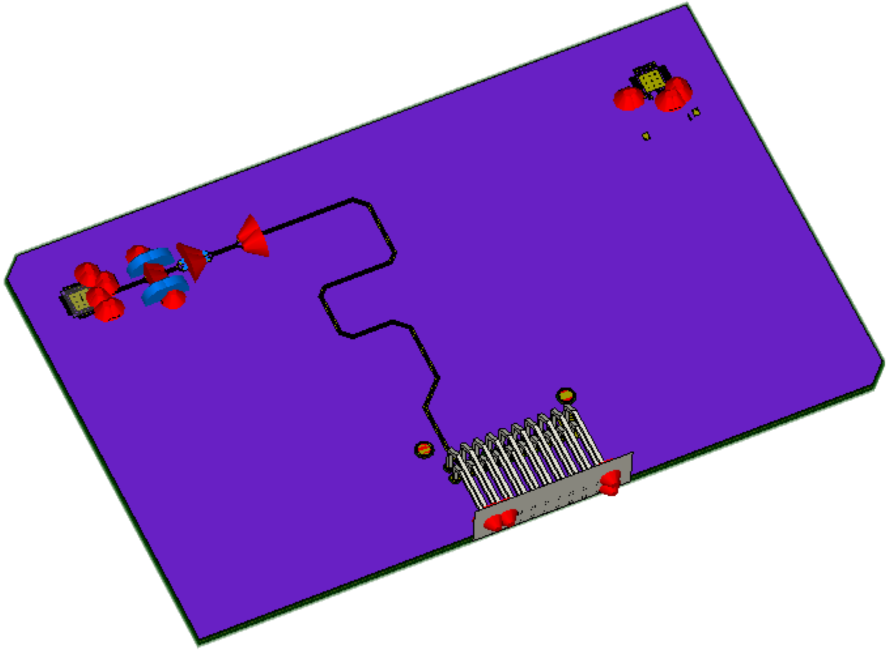
**Fig 18. MDI application diagram**





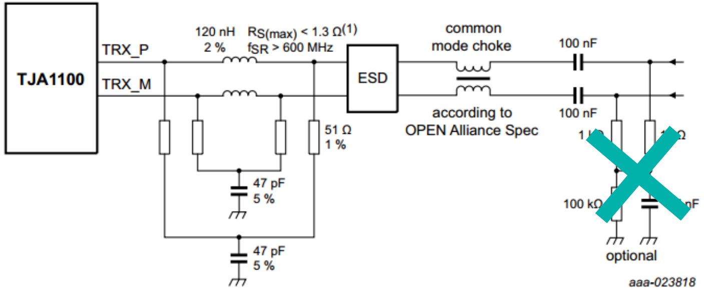



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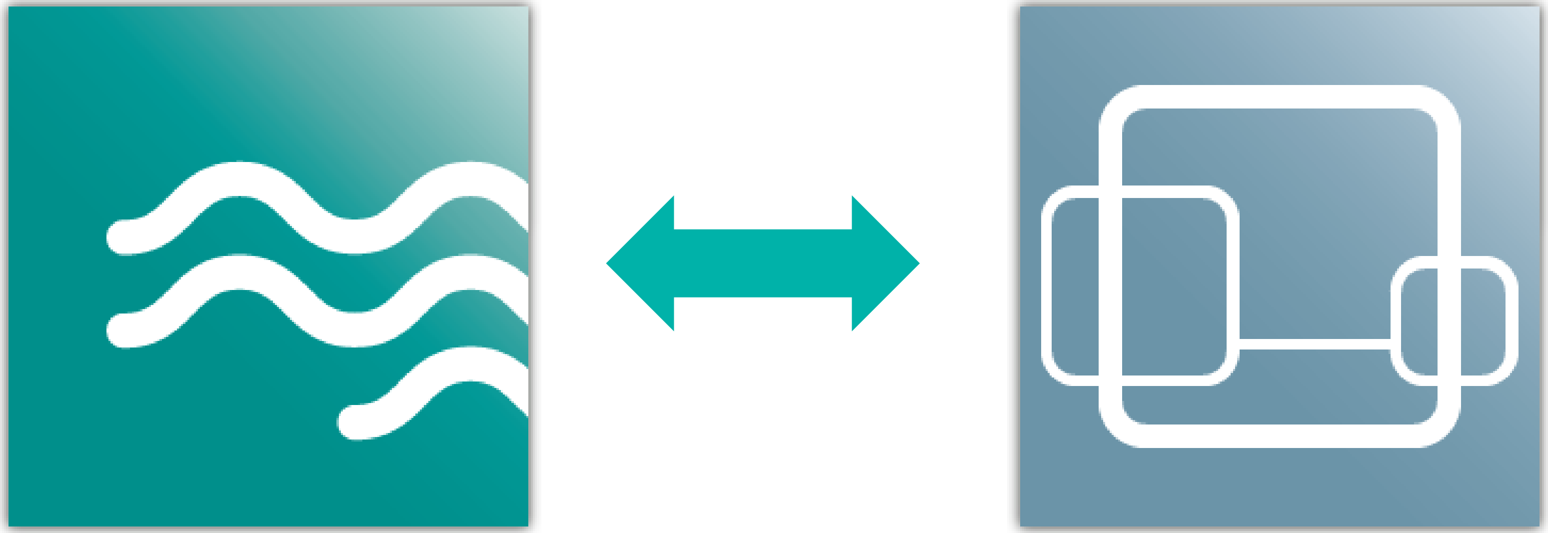
**Fig 18. MDI application diagram**

# Field Circuit Coupling



Events

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## Getting Ahead with Coupled 3D Field and Circuit Simulation

Webinar Recording

Recording date: *February 18th, 2016*

Duration: 60min

Register with MyCST

In the fast paced electronics world, simulation has become an indispensable tool for every designer over the past years. In this webinar, we will show you how to set up a coupled simulation from a SPICE-like circuit simulation and a full wave 3D simulation. This coupling offers the possibility to calculate the field distribution in a 3D model, considering the effects of an attached circuit. Because the coupled schematic is somehow different from the standard way of connecting circuits in SPICE simulation, the main focus will be on explaining the differences and providing you with the understanding of such coupled models.

For more information contact CST or call +49-6151-7303-0.

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### Related Events

**EMC Simulation of Automotive Ethernet**

November 2nd, 2017

**CST Automotive Conference 2017**

November 14th, 2017

Neckarsulm, Germany

**RF Co-Site Interference Simulation in Complex Electromagnetic Environments**

October 24th, 2017

**IEEE COMCAS 2017**

November 13th-15th, 2017

Tel Aviv, Israel

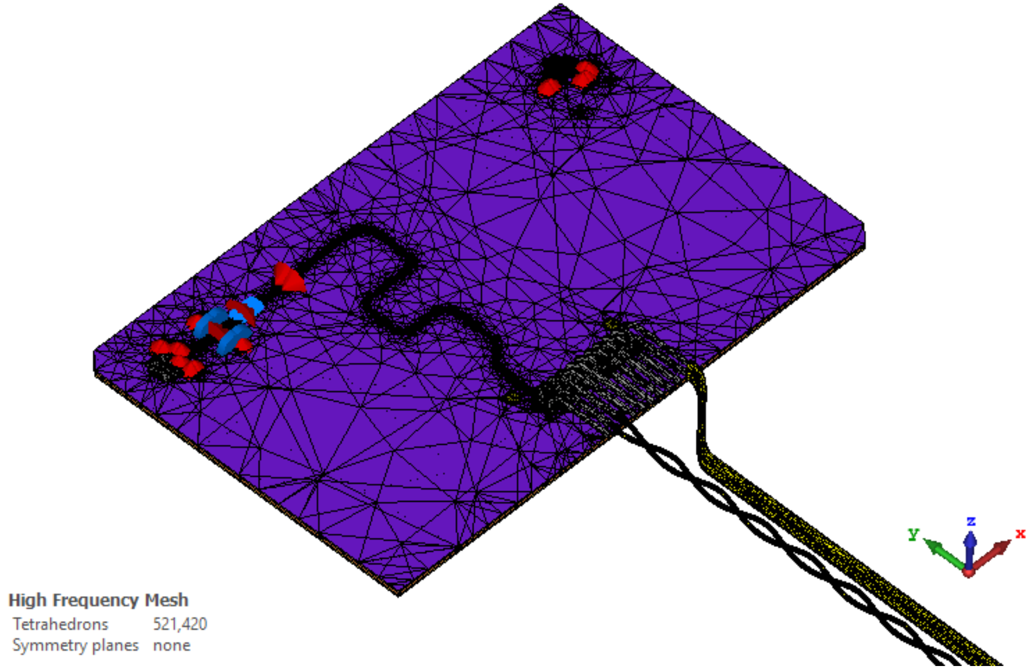
**Asia Pacific Microwave Conference 2017**

November 13th-16th, 2017

Contact

Support

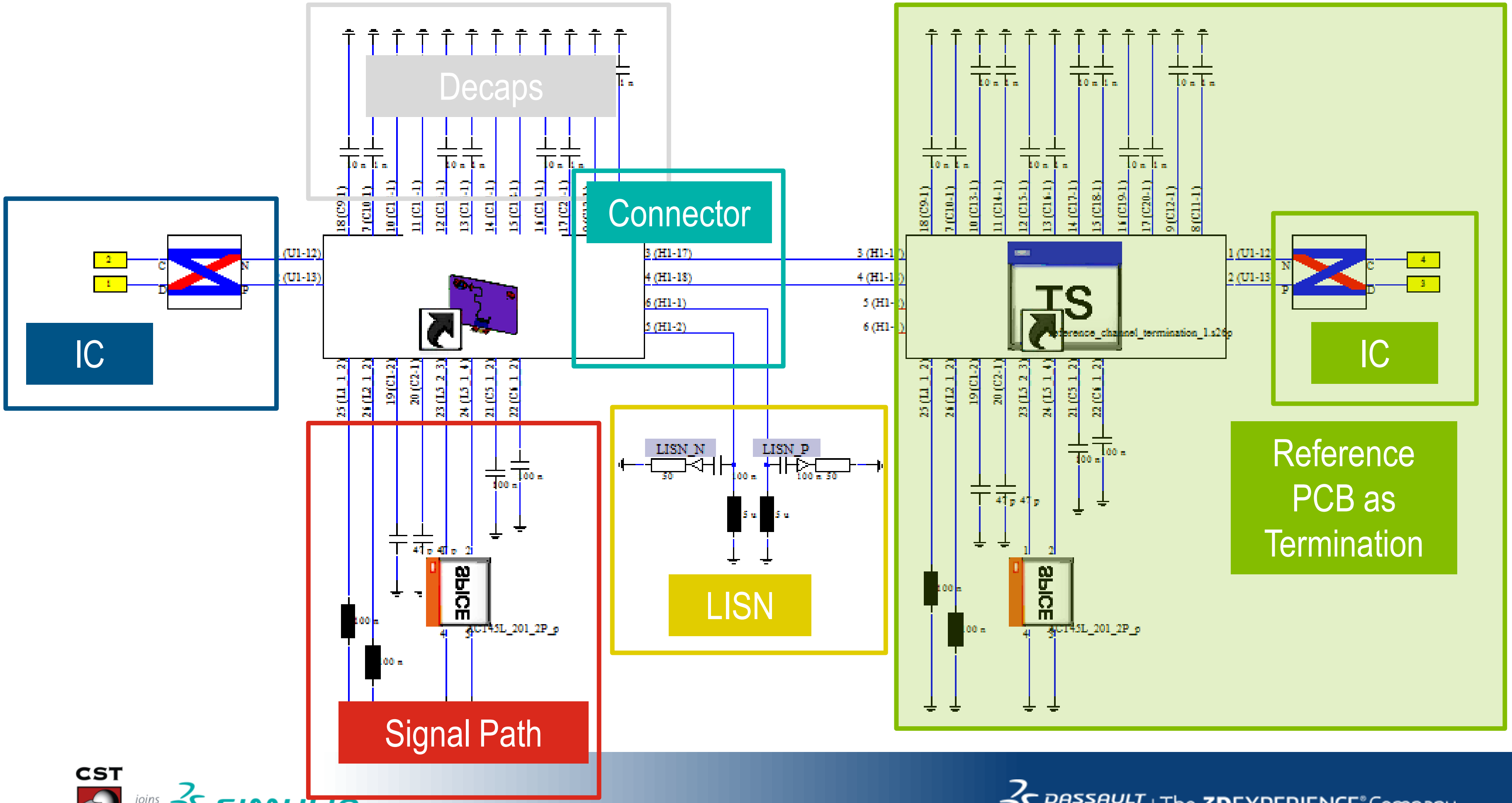
# 3D Full-Wave Solution




Finite Element Method
Frequency Domain
Adaptive Meshing

0-200 MHz in 60 samples
26 Ports

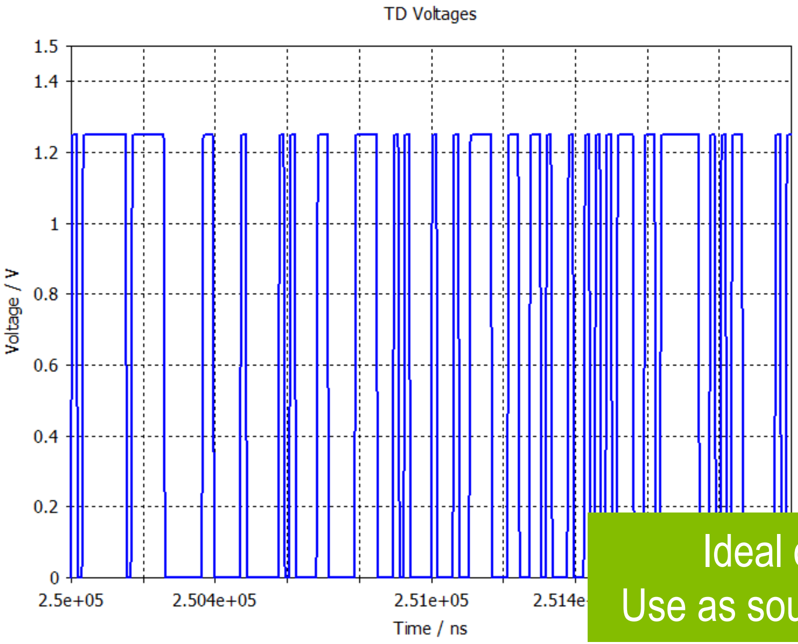
3h15m on dual Xeon E5-2643
28 GB RAM



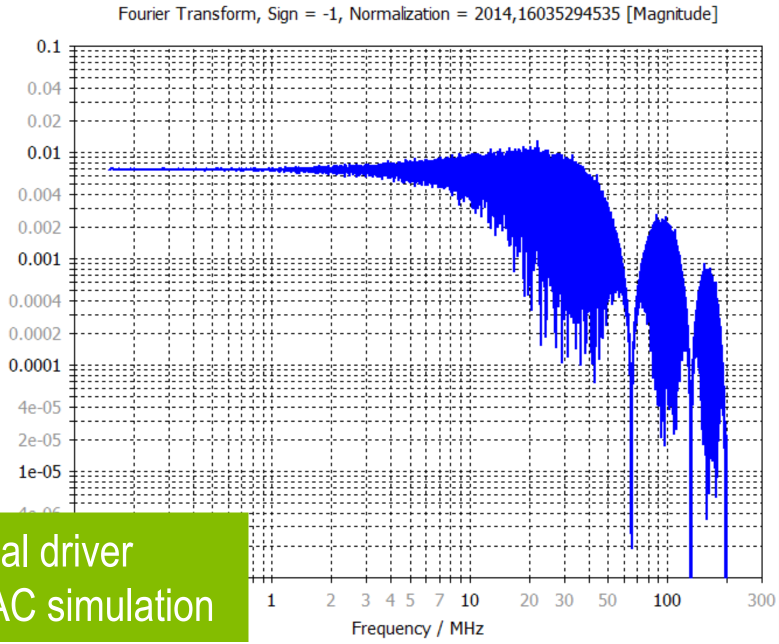
Decaps
Connector
IC
Signal Path
LISN
LISN_N
LISN_P
Reference PCB as Termination
IC

# PRBS Signal & Spectrum

## PRBS Signal

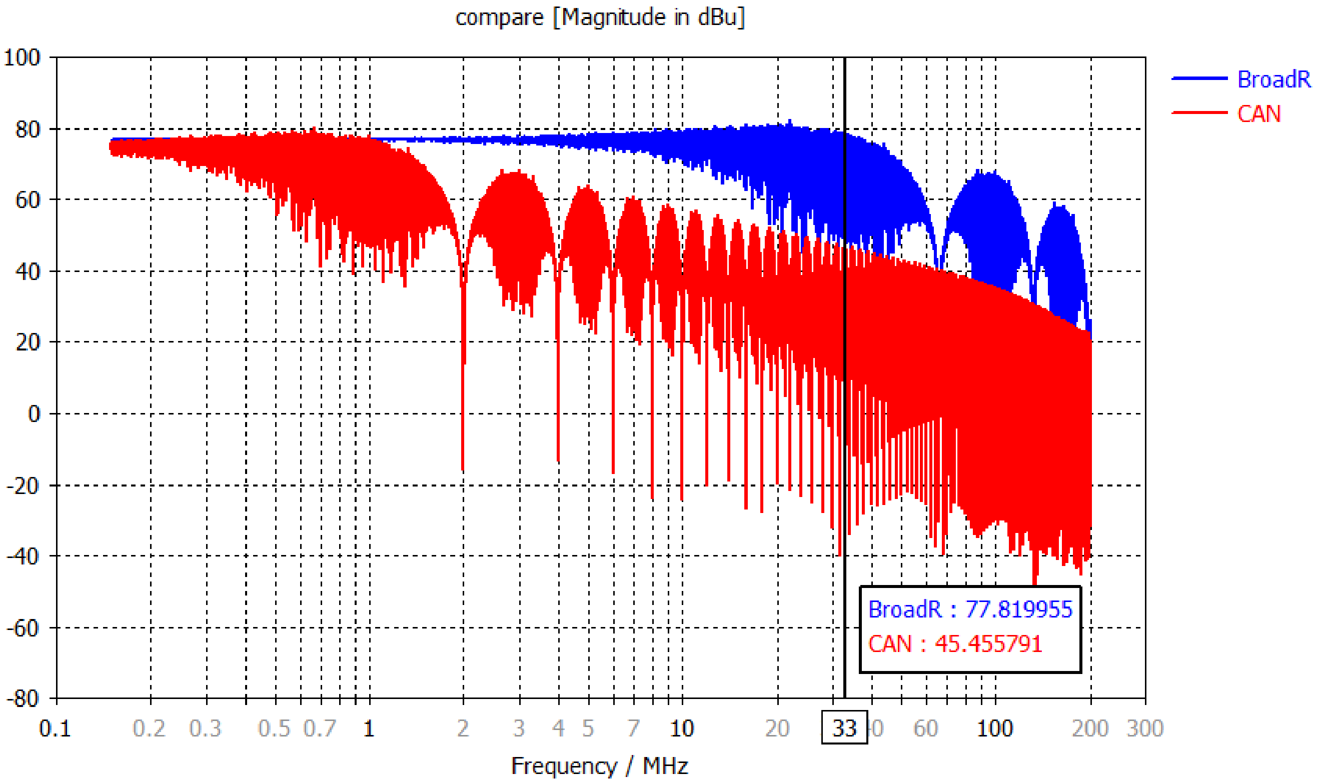



## PRBS Spectrum




Ideal differential driver
Use as source for AC simulation

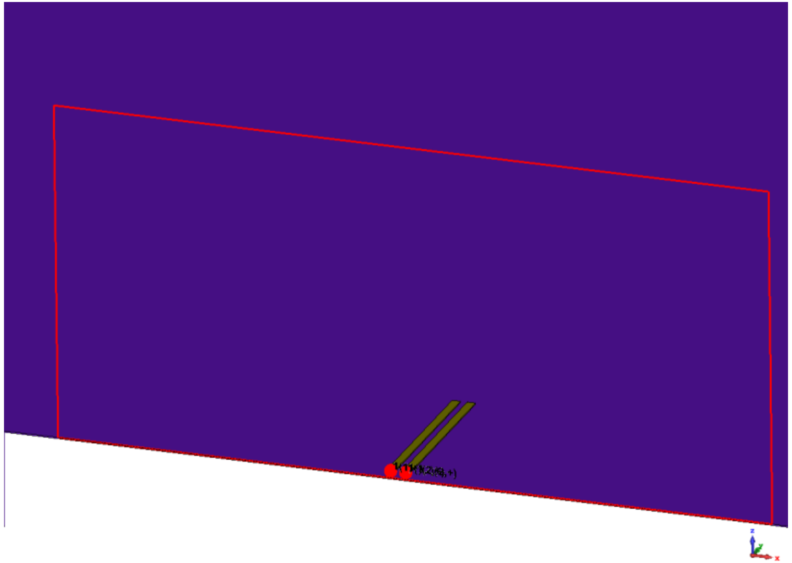
# BroadR vs. CAN

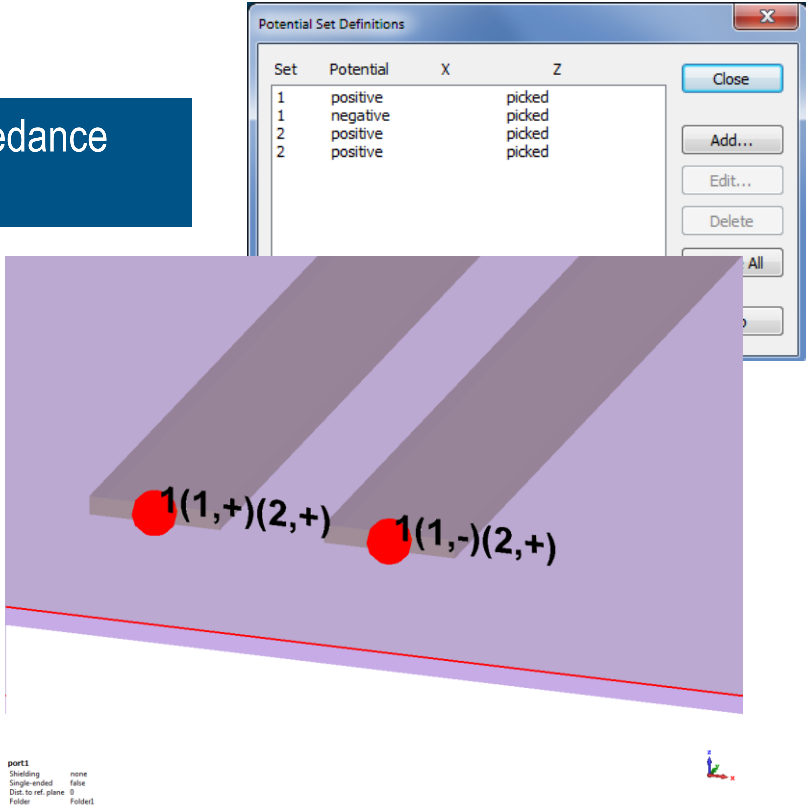


# Common and Differential Mode

# Modes on Differential Pair

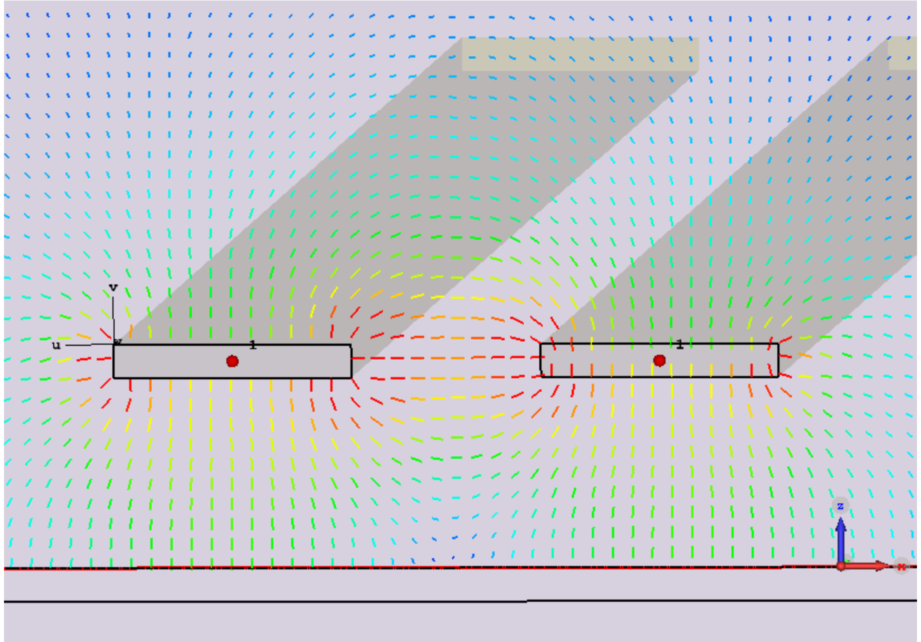
Calculate the differential and common mode impedance using a waveguide port



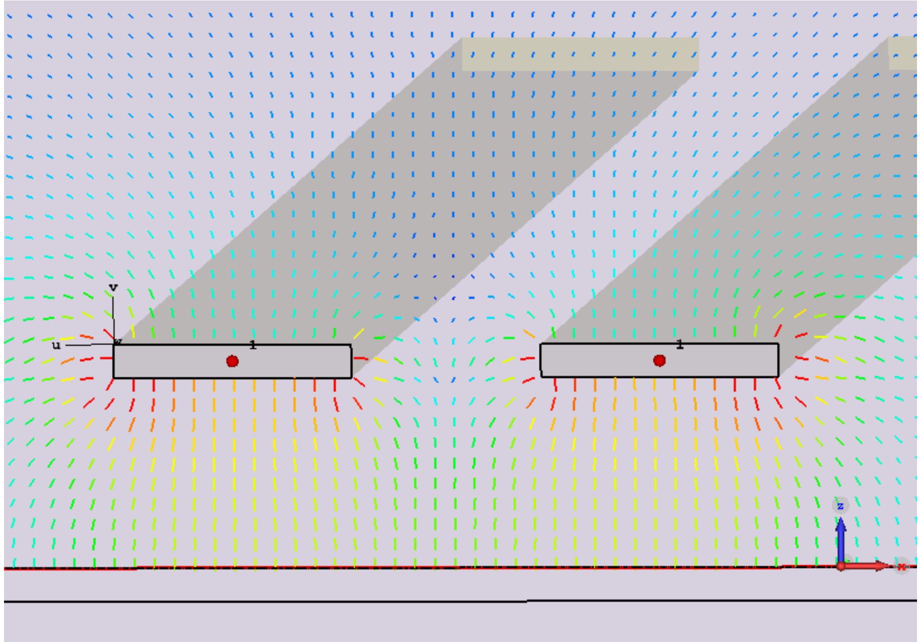


# Modes on Differential Pair

Differential 101 Ohm



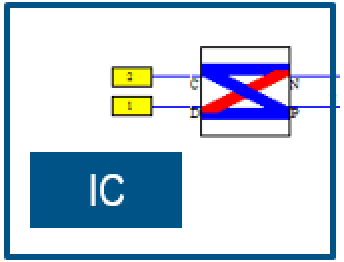
Common 35 Ohm



# Common and Differential Mode

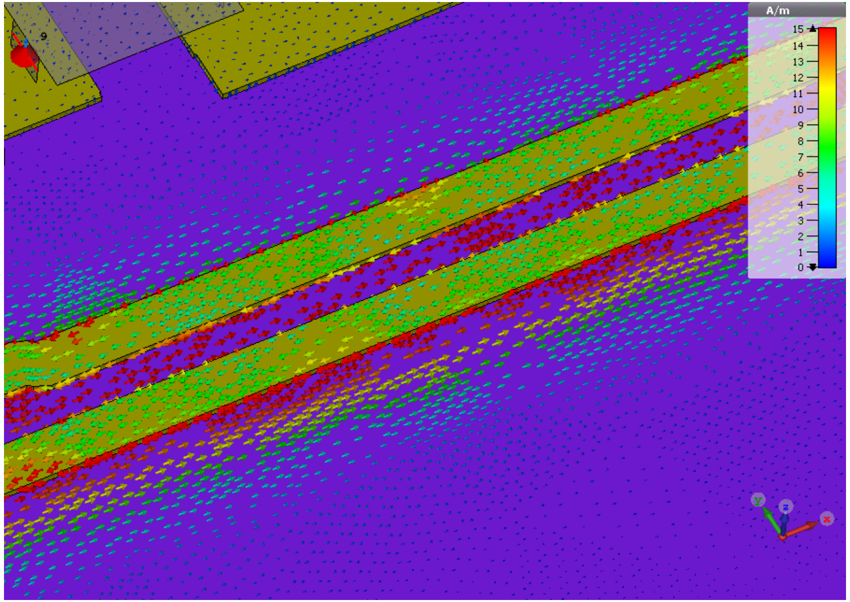
Ideal Excitation

1V differential
1V common mode

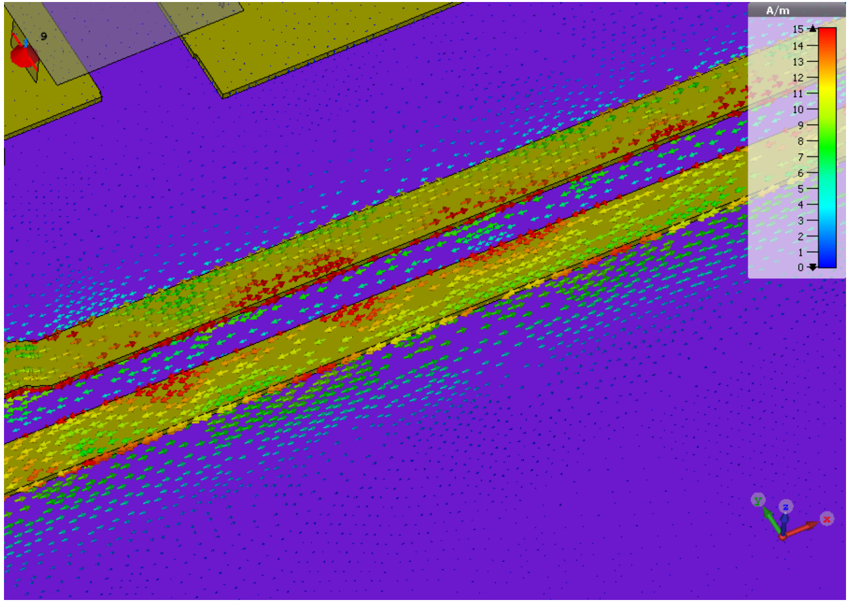


# Current at Driver – 33 MHz

## Common Mode

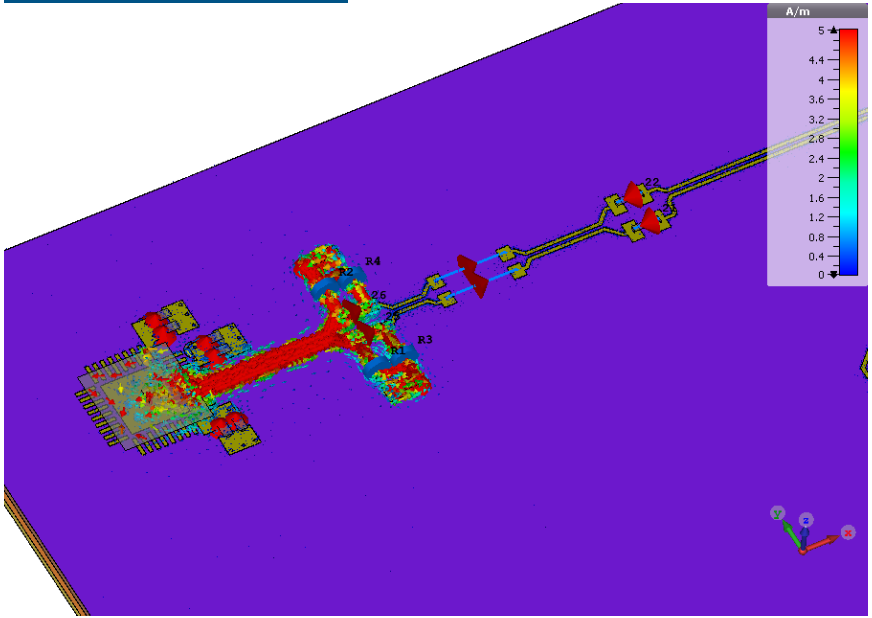



## Differential Mode

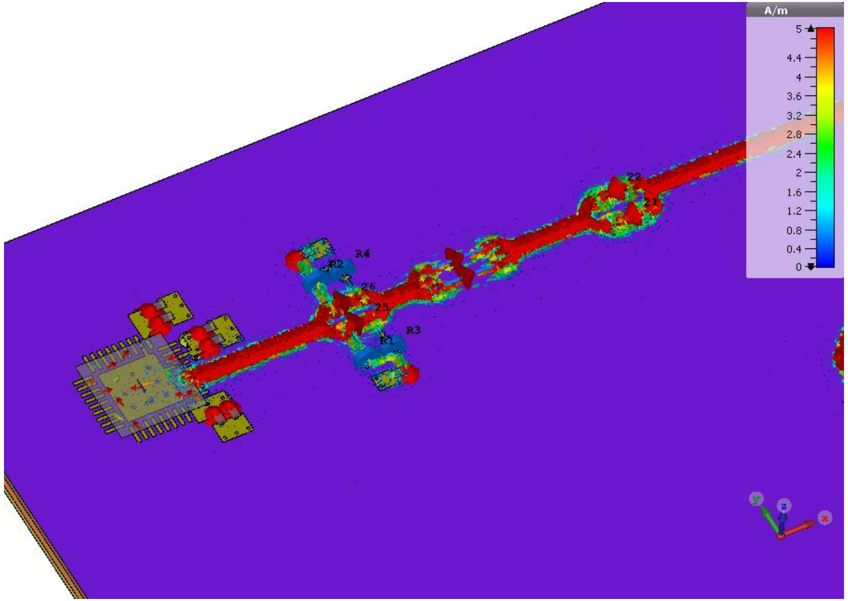


# Current Through CMC – 33 MHz

## Common Mode

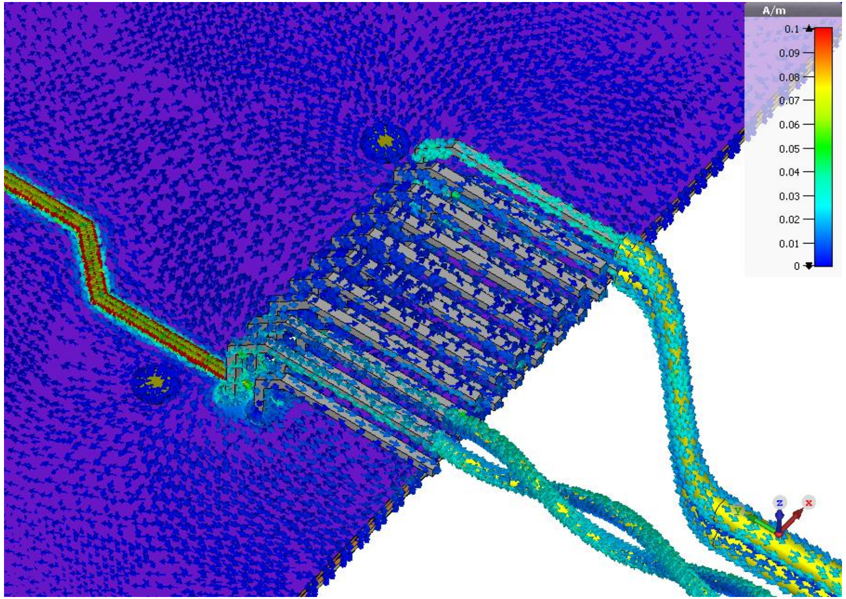



## Differential Mode

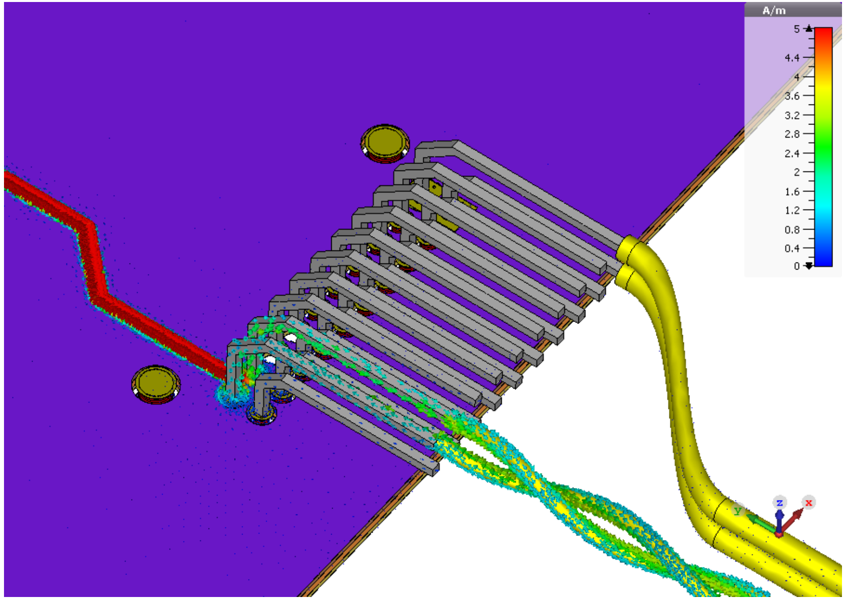


# Current at Connector – 33 MHz

## Common Mode

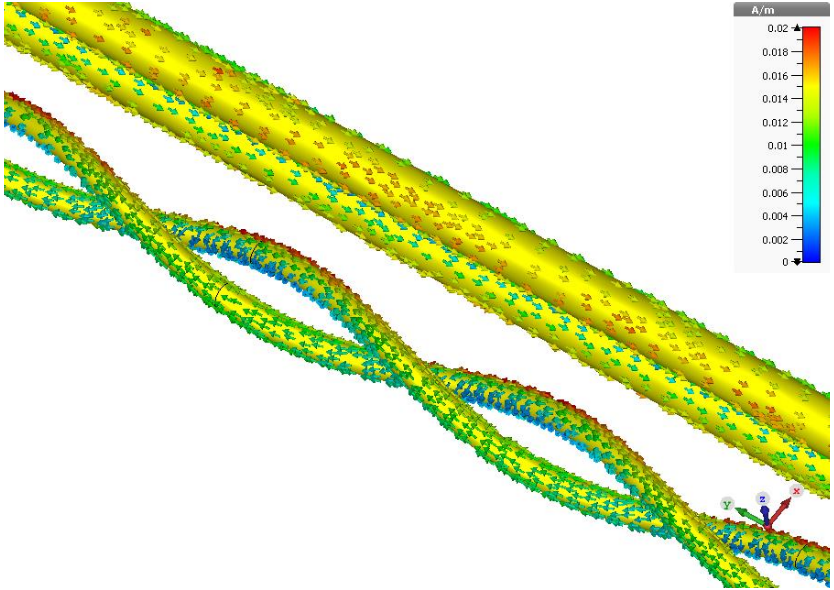



## Differential Mode

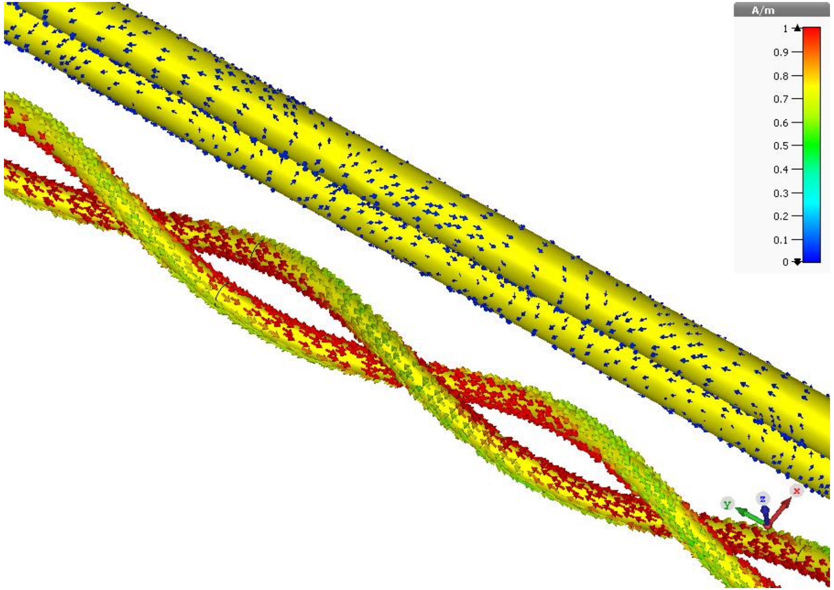


# Current on TWP – 33 MHz

## Common Mode




## Differential Mode



# Common Mode

## Differential to Common Mode Conversion

- Created due to non-ideal symmetry
- Only the common mode contributes to conducted emission

## Timing

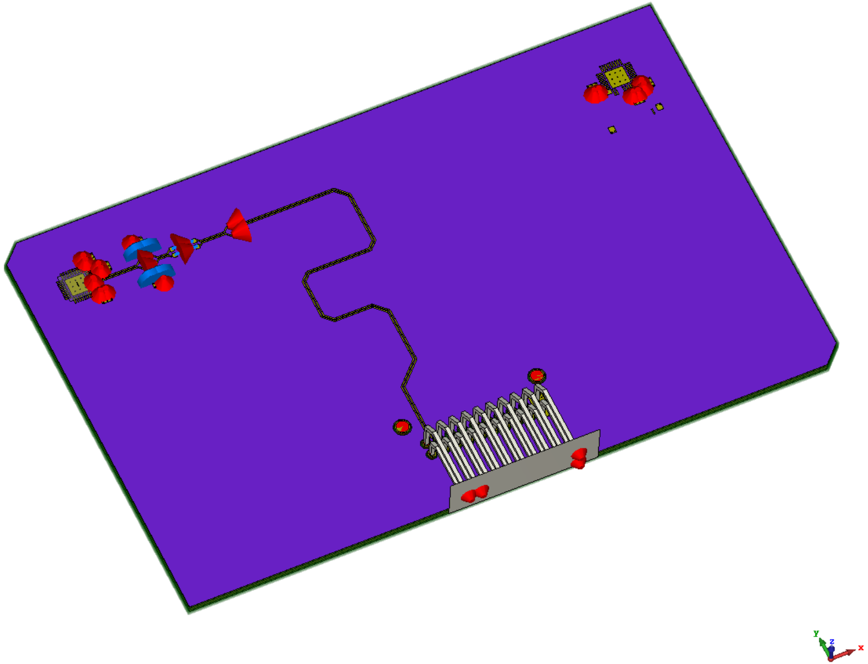
- Jitter and skew in signal generation
- Depends on the silicone
- No access for the electronic designer

## Geometry

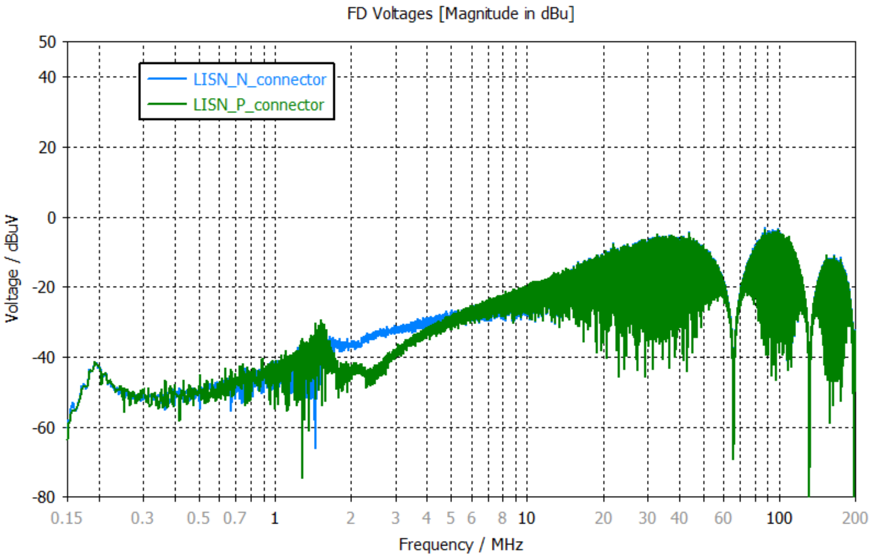
- Routing Constraints
- Connectors and cable bonding

# Conducted Emission

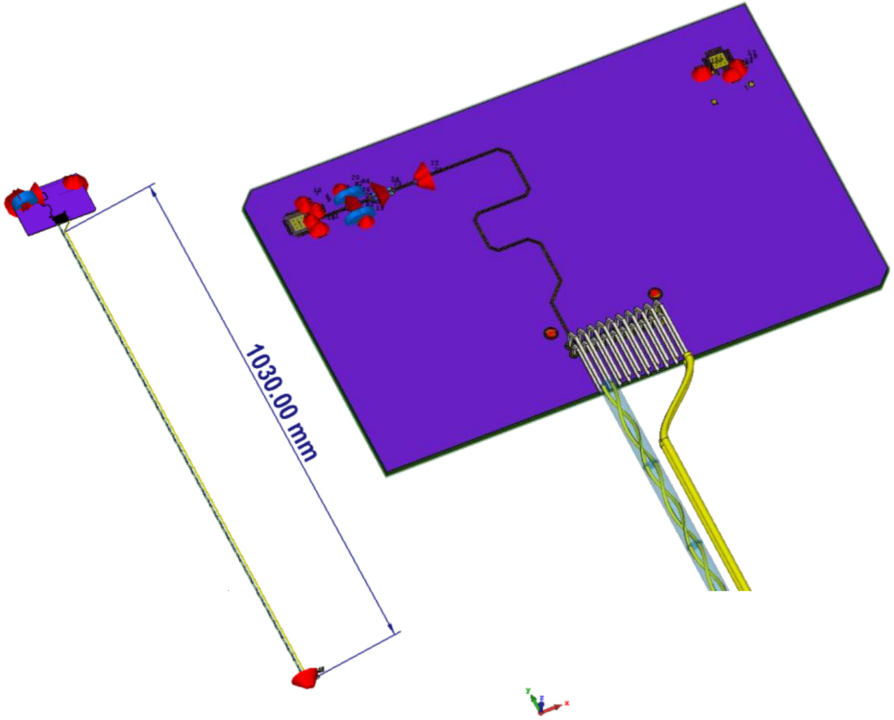
# Only Connector



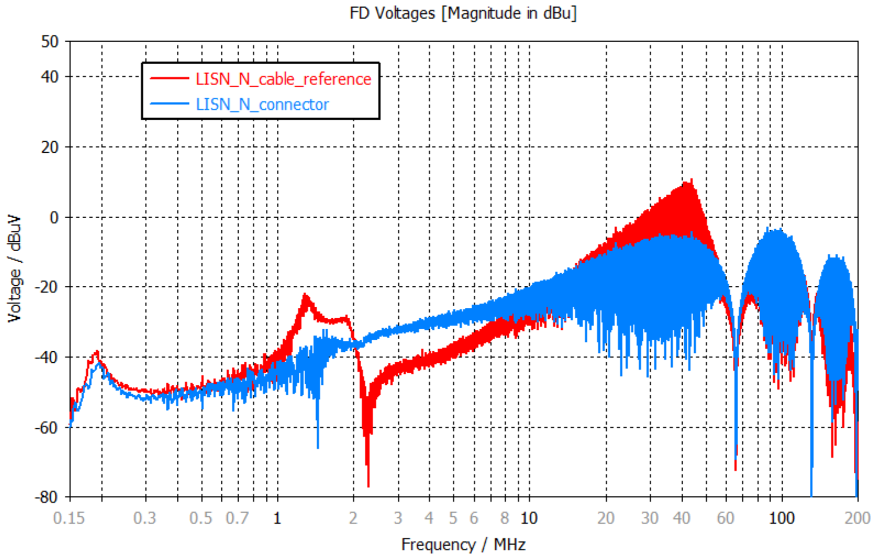
## Emission at LISN N



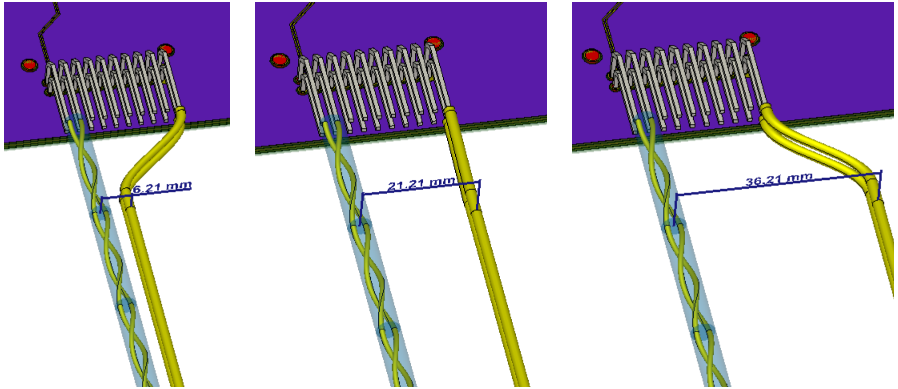
# Cable Reference



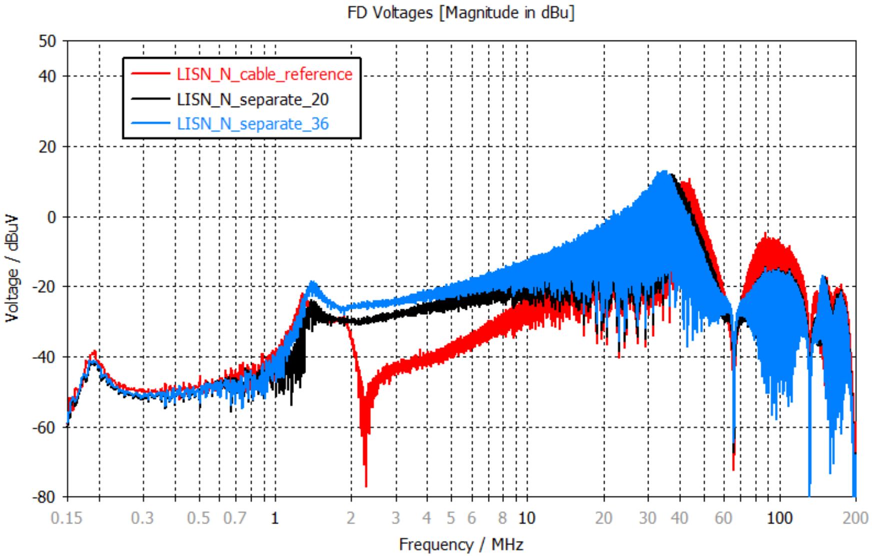

## Emission at LISN N



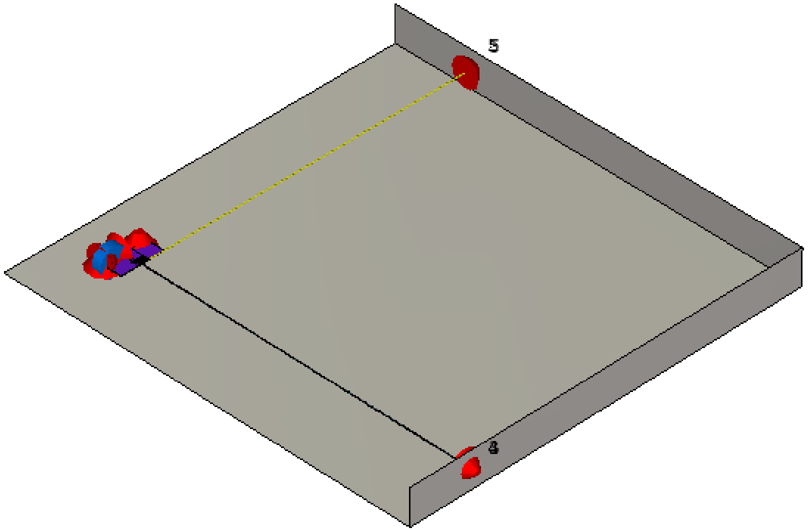
# Cable Separation



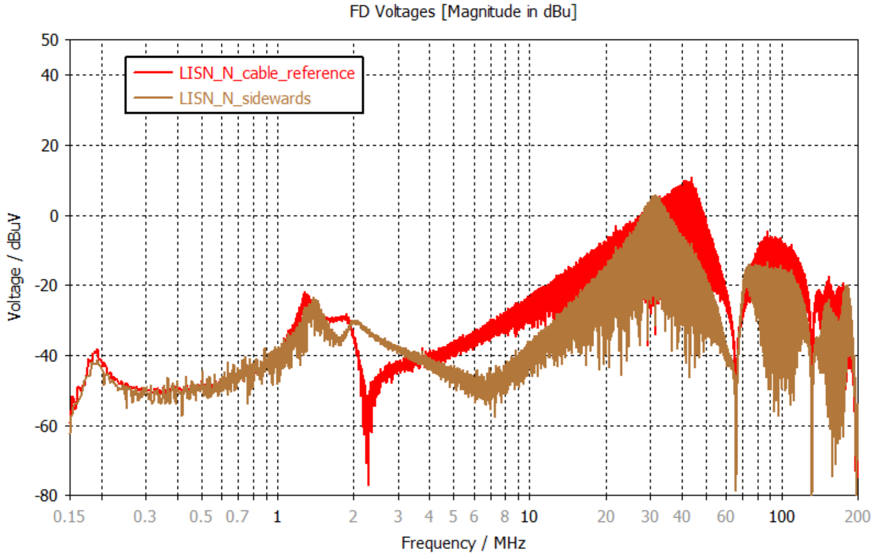

## Emission at LISN N



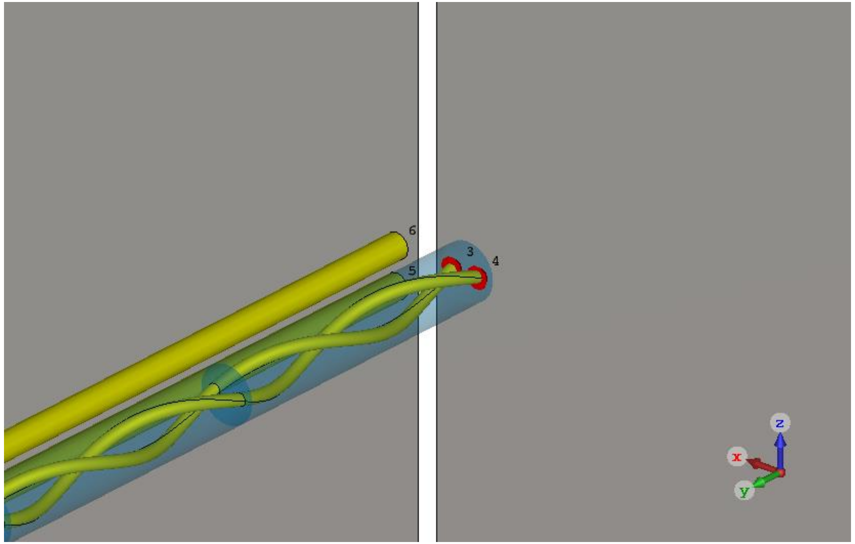
# Power Cables Sidewards



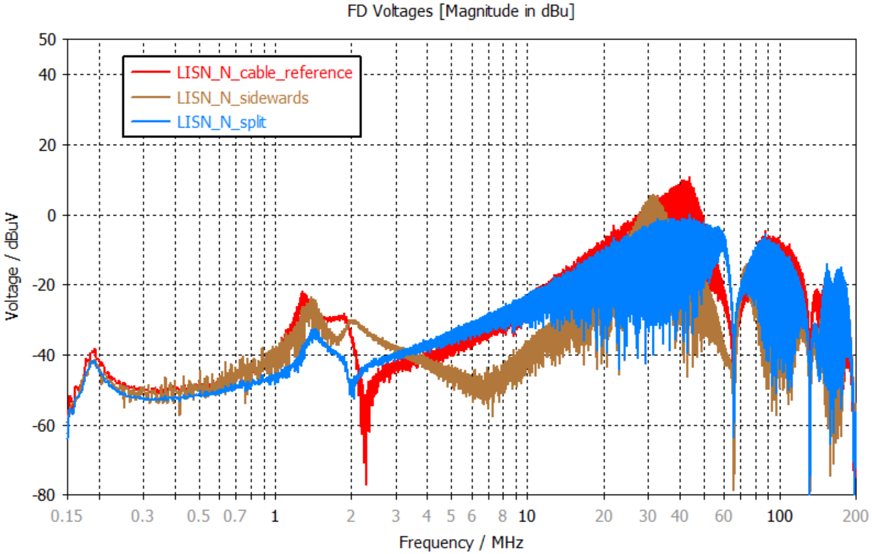

## Emission at LISN N



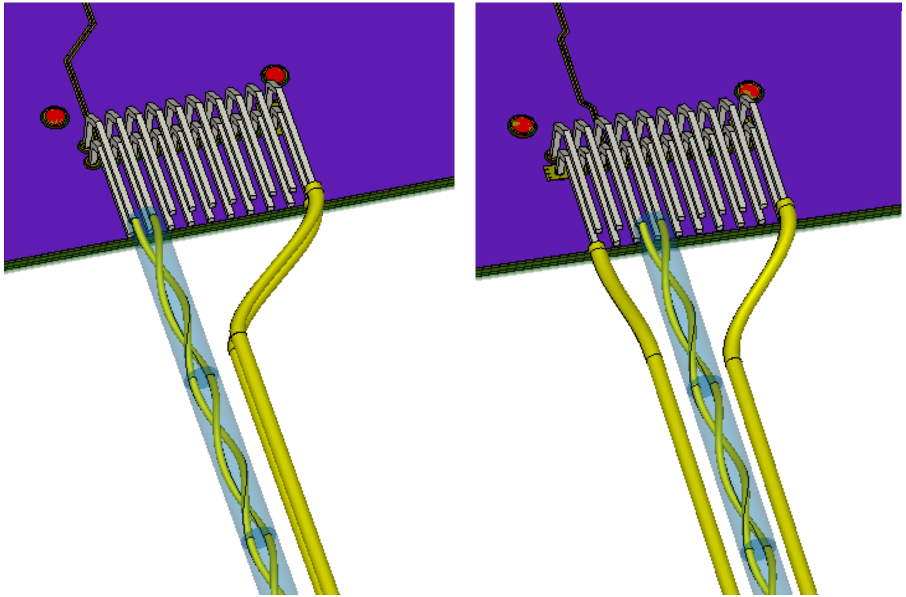
# Split Reference for LISN



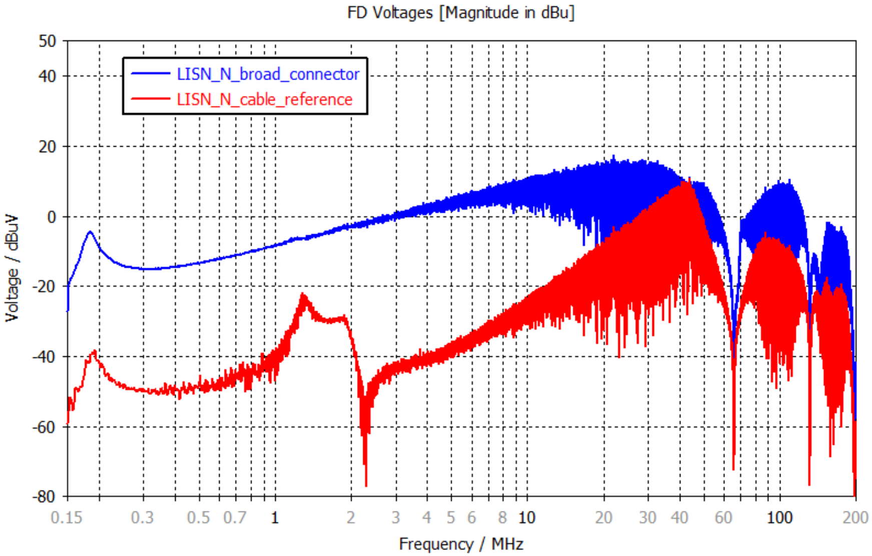

## Emission at LISN N



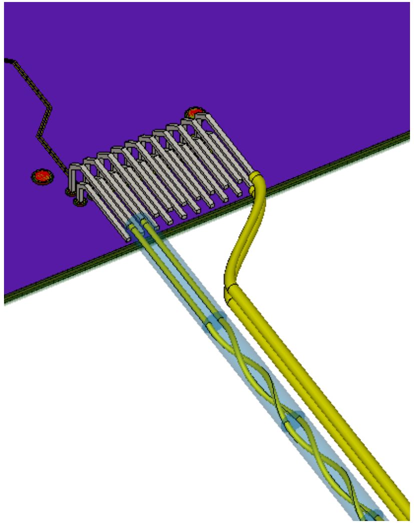
# Connector Pinout

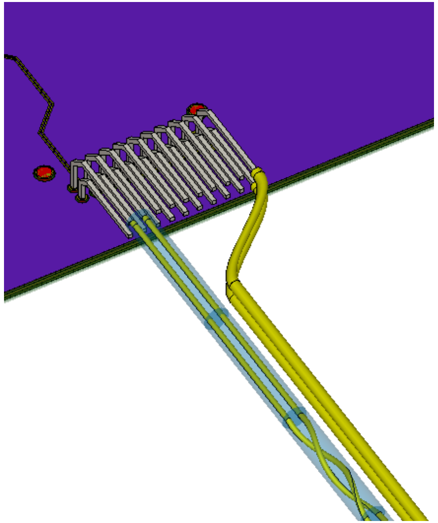


## Emission at LISN N

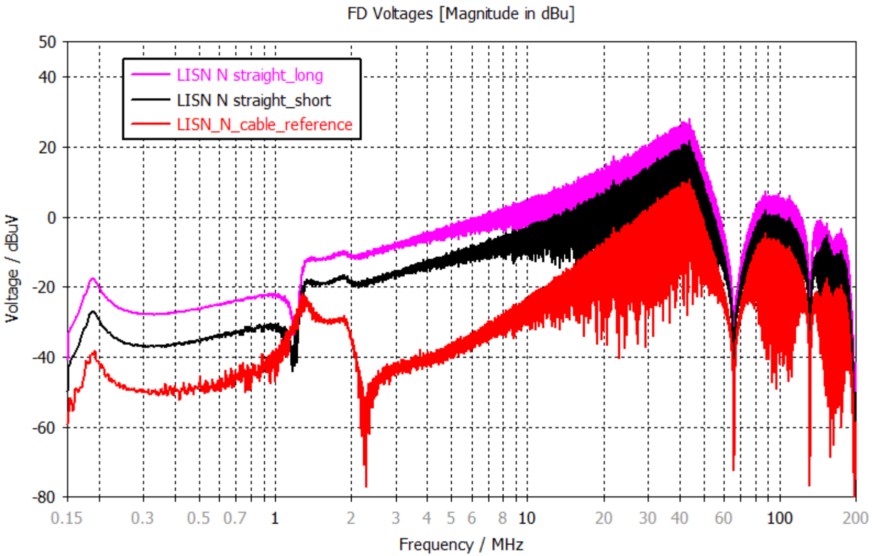


# Untwisting at Connector

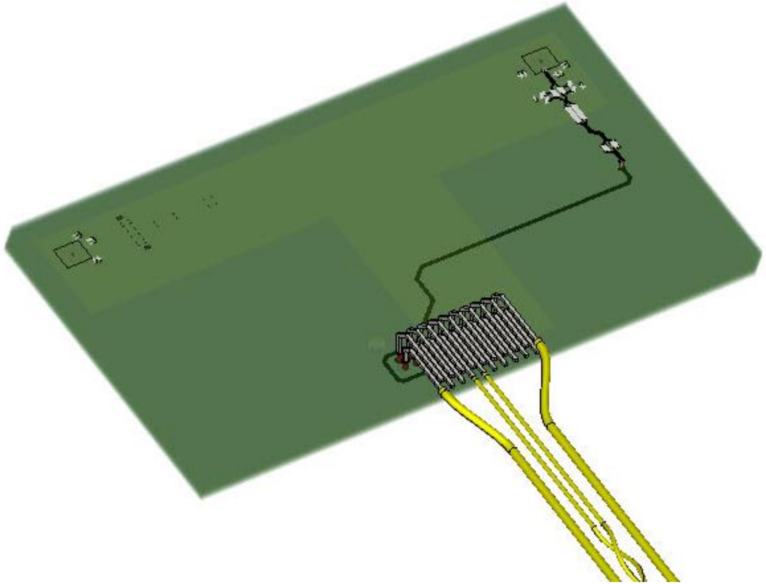




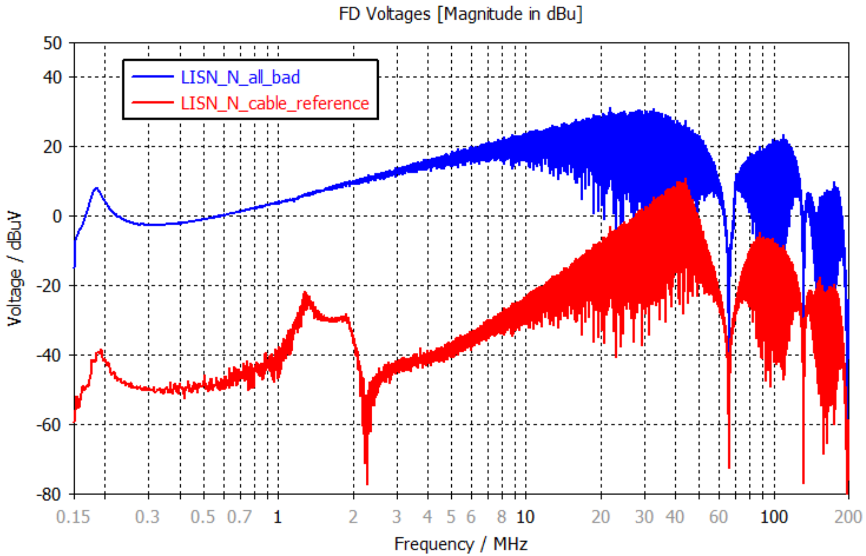
## Emission at LISN N



# Bad PCB Layout + Connector + Untwisting



## Emission at LISN N



# Summary

## Common Mode

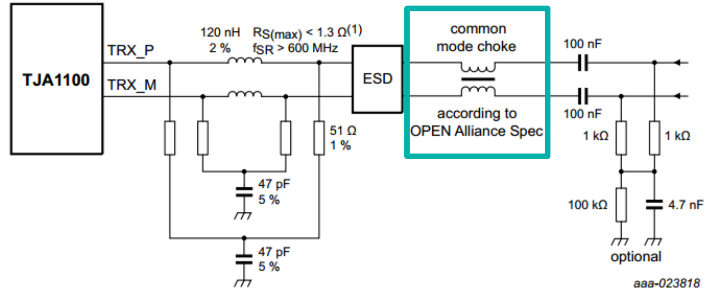
- Created by unsymmetries
- understand the return current

## Emission Levels

- PCB layout
- Connector layout + pinout
- Untwisting at the connector

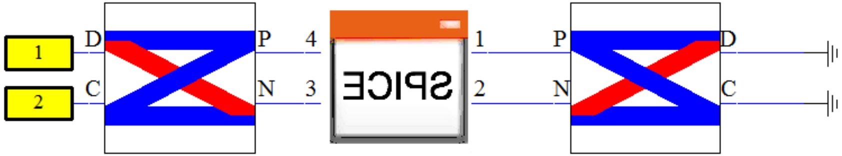
# Countermeasures

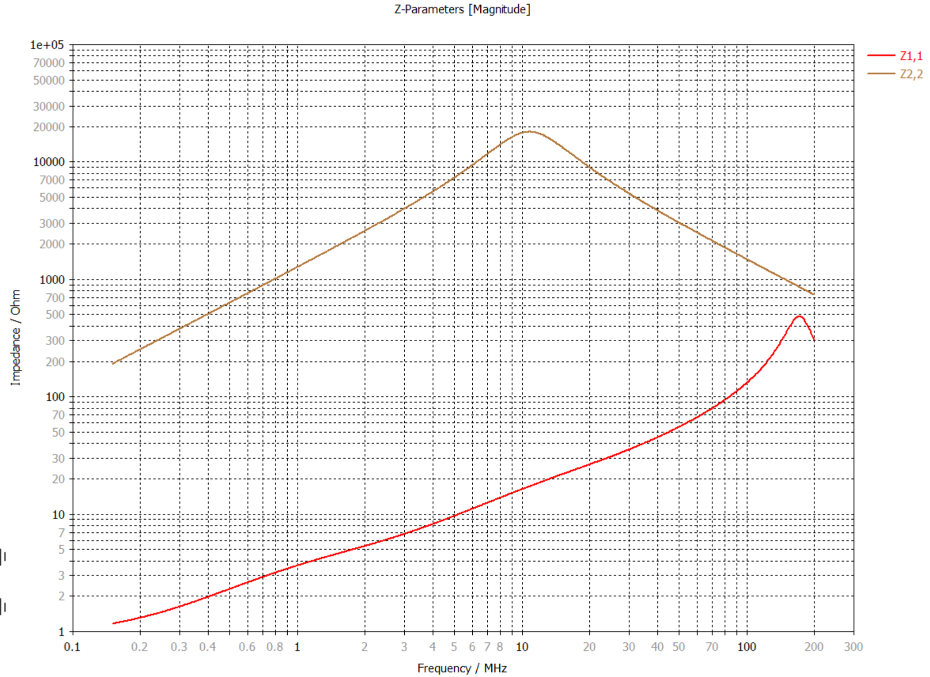
# Common Mode Choke



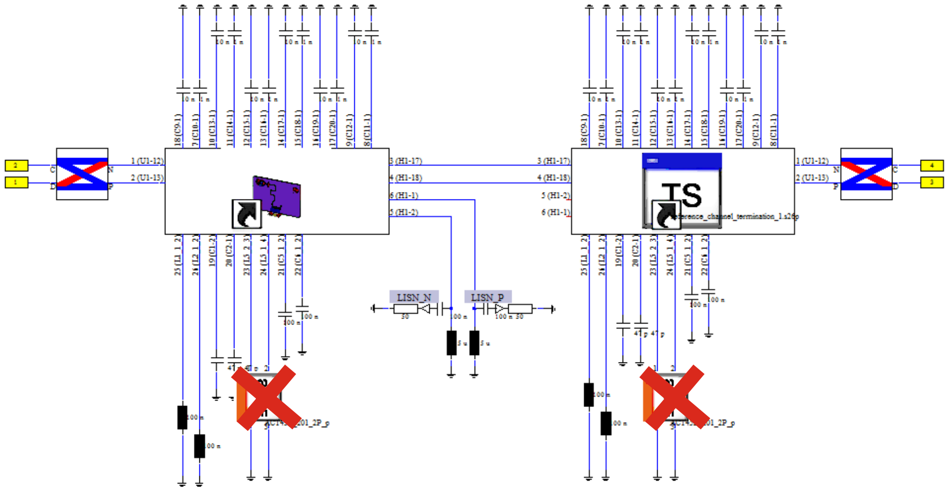

(1) $R_{S(max)}$ = maximum series resistance; $f_{SR}$ = self resonant frequency

**Fig 18. MDI application diagram**

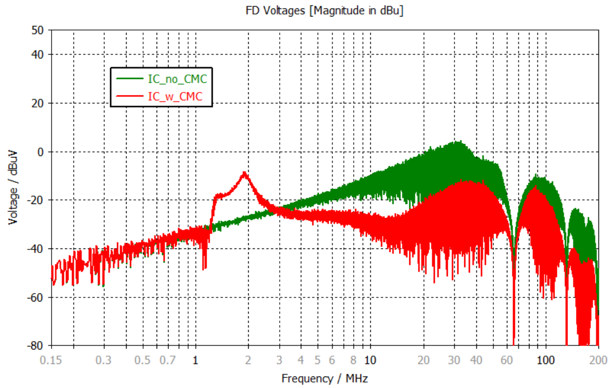


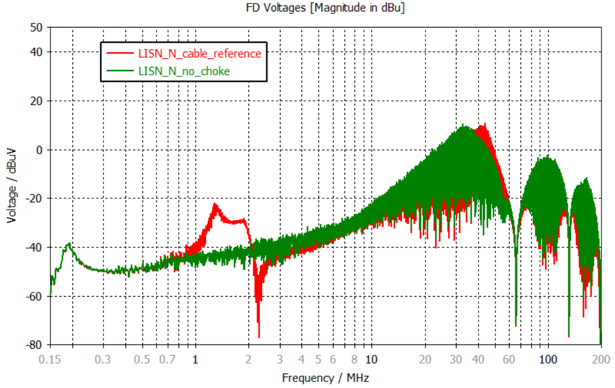
# Common Mode Choke



## Common Mode at Rx IC




## Emission at LISN N



# Common Mode

## Differential to Common Mode Conversion

- Created due to non-ideal symmetry
- Only the common mode contributes to conducted emission

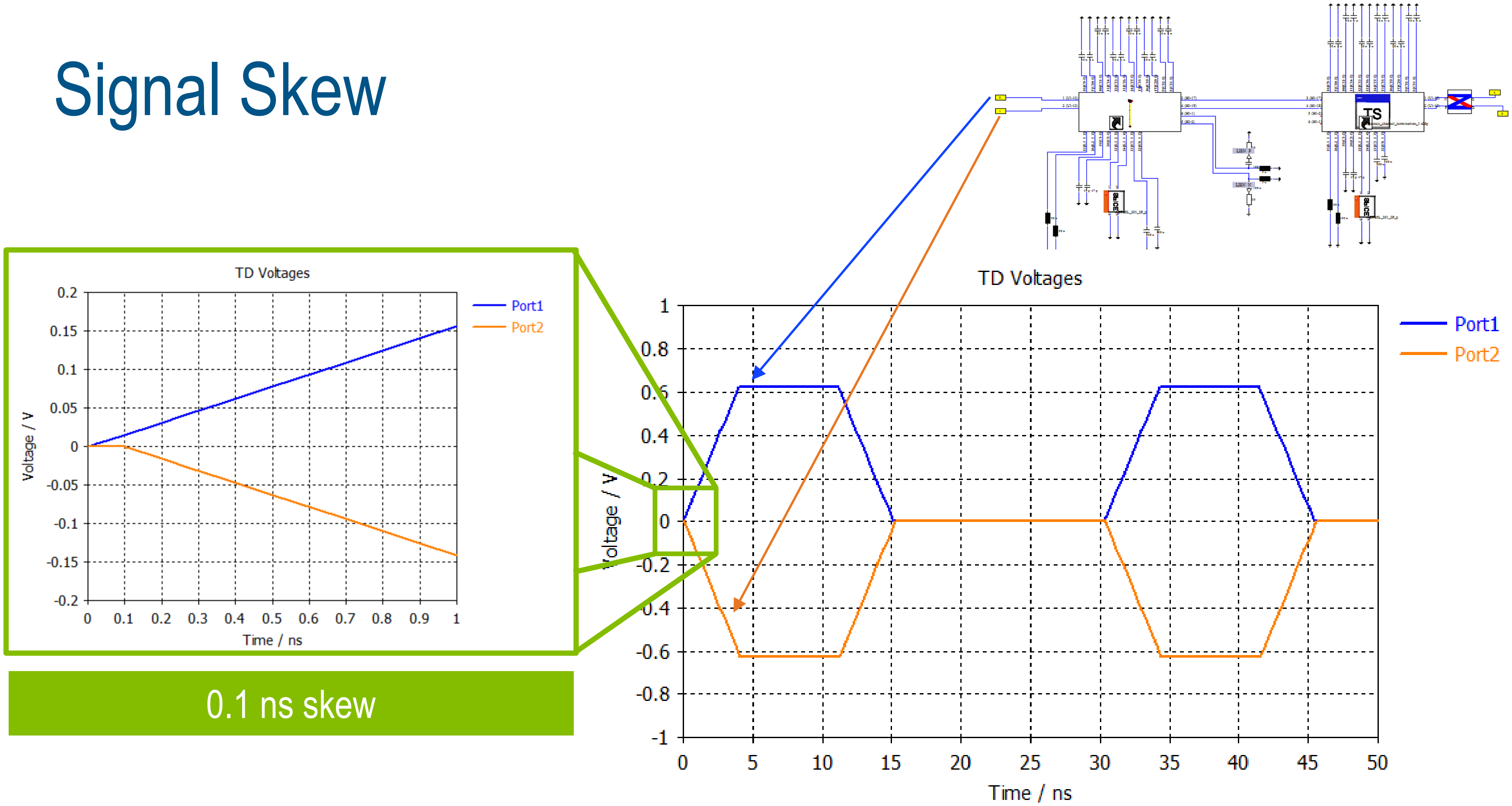
## Timing

- Jitter and skew in signal generation
- Depends on the silicone
- No access for the electronic designer

## Geometry

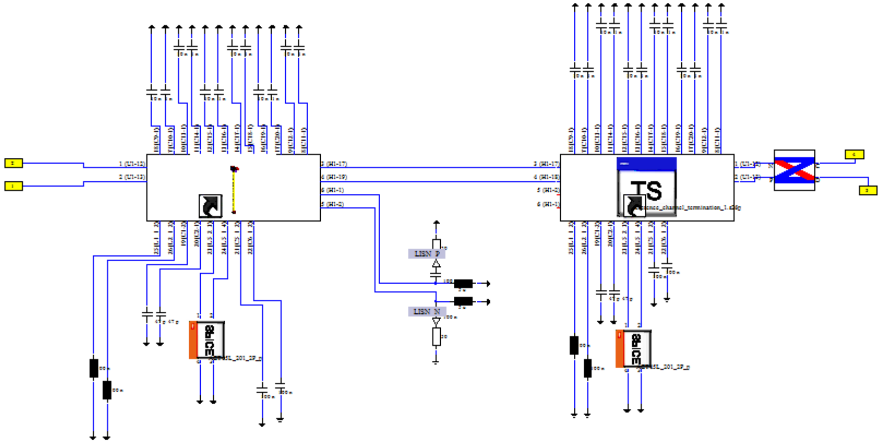
- Routing Constraints
- Connectors and cable bonding

# Signal Skew

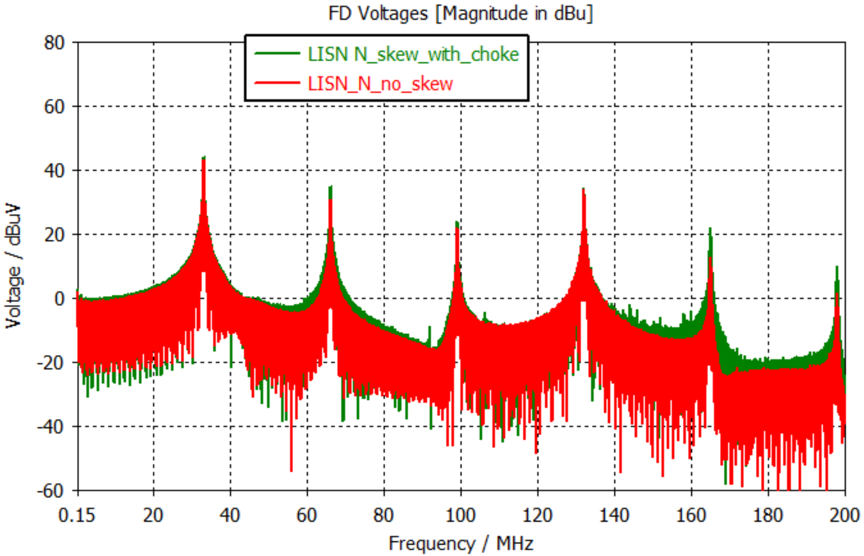



0.1 ns skew

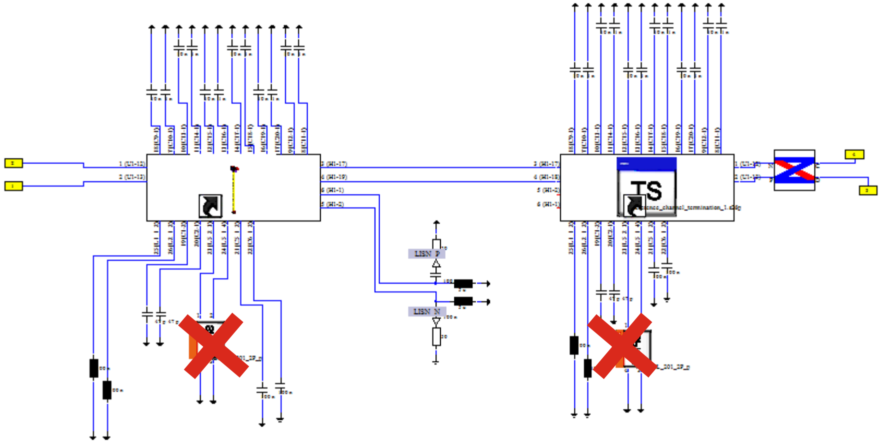
# Signal Skew



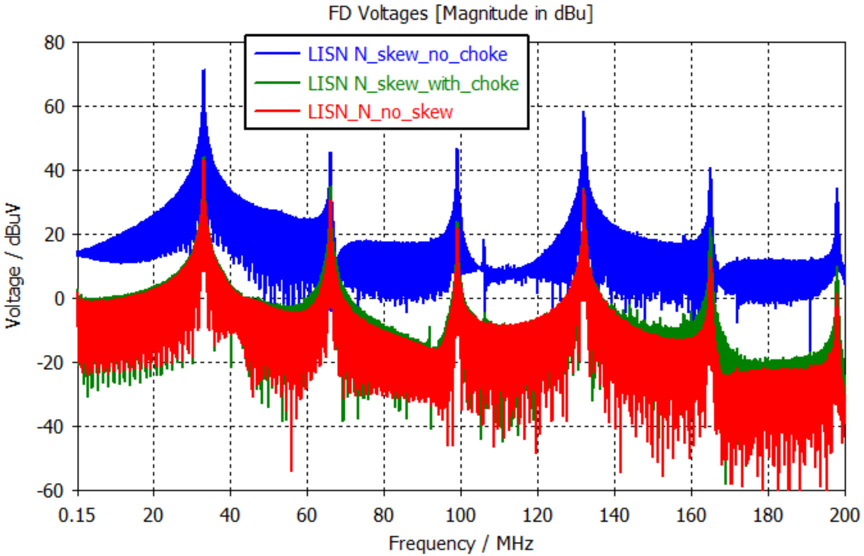
## Emission at LISN N



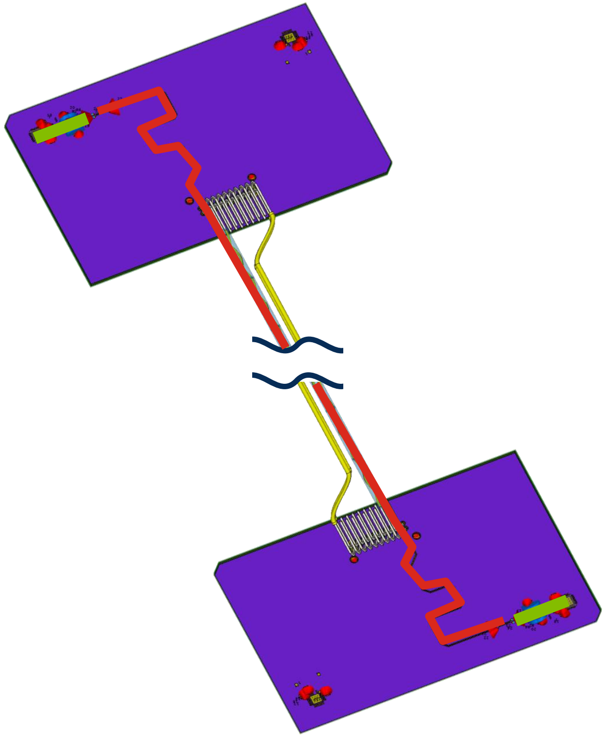
# Signal Skew



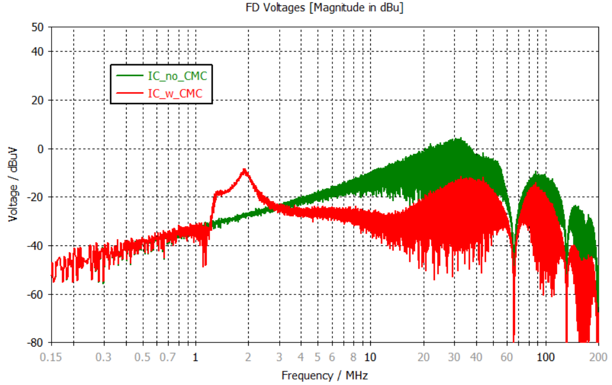
## Emission at LISN N



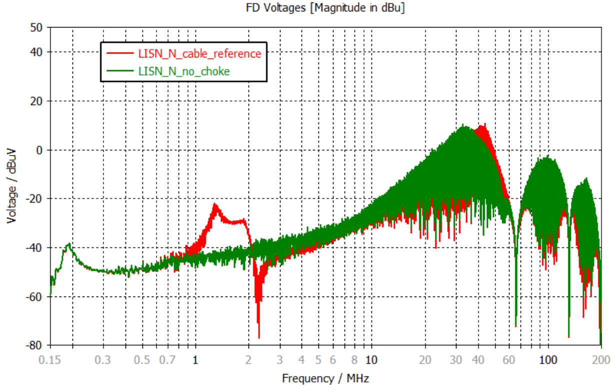
# Choke Positioning



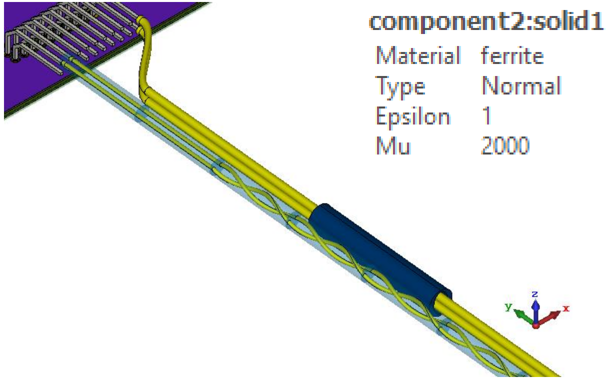
## Common Mode at Rx IC



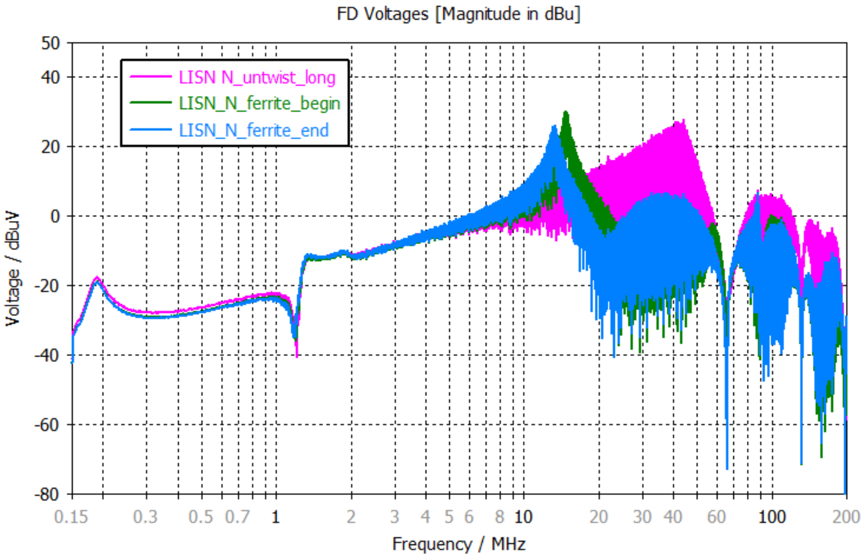

## Emission at LISN N

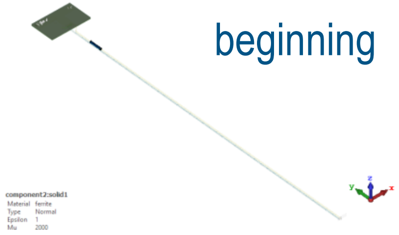


# Ferrite Clamp – Untwist long

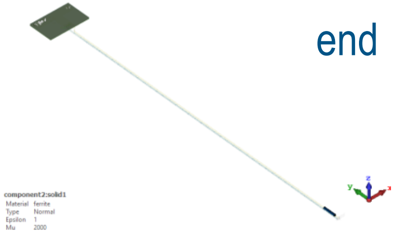



## Emission at LISN N



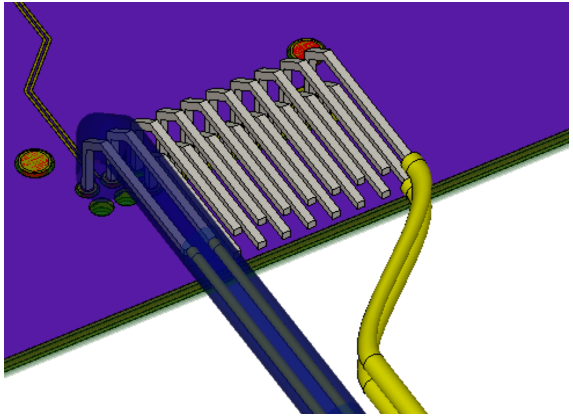



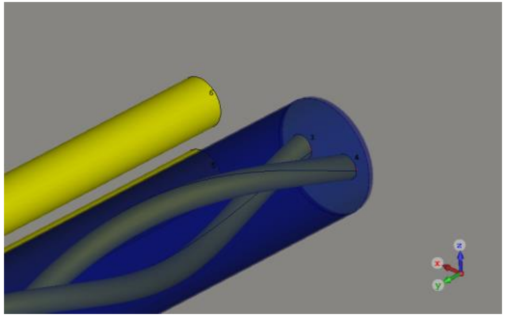

beginning

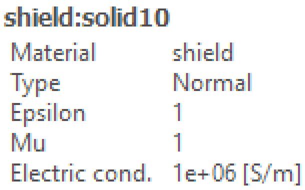



end

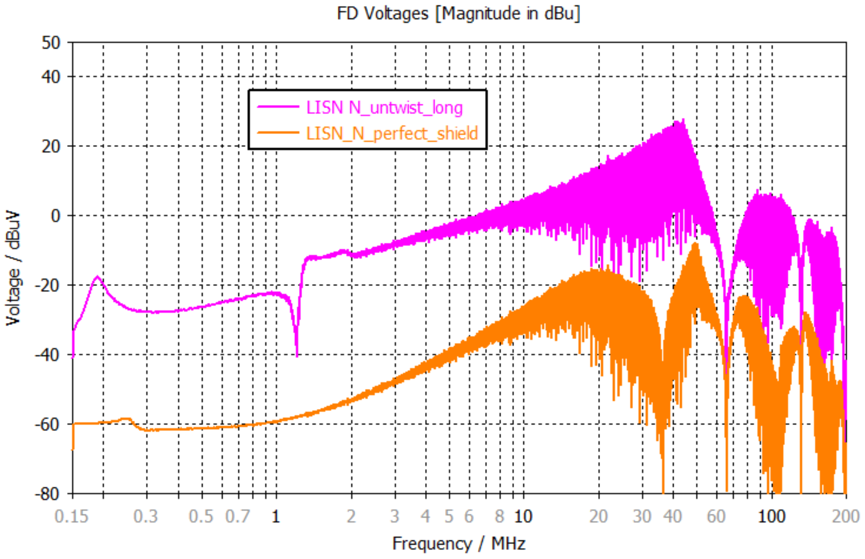
# Shielding



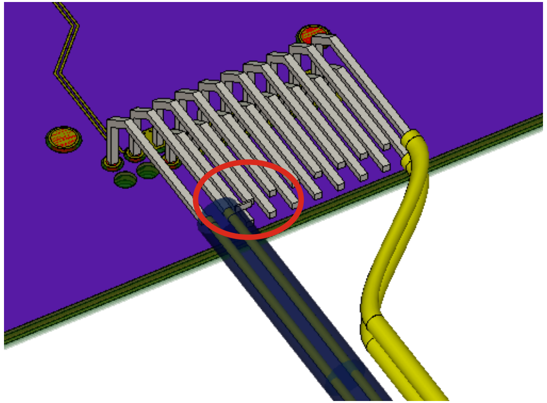


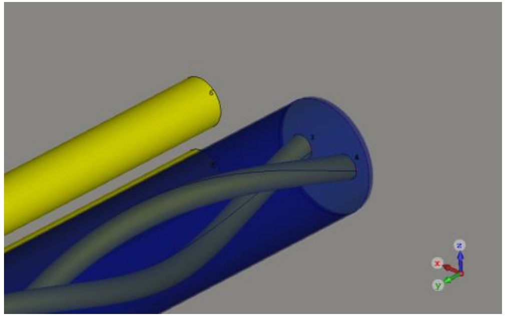



## Emission at LISN N



# Shielding

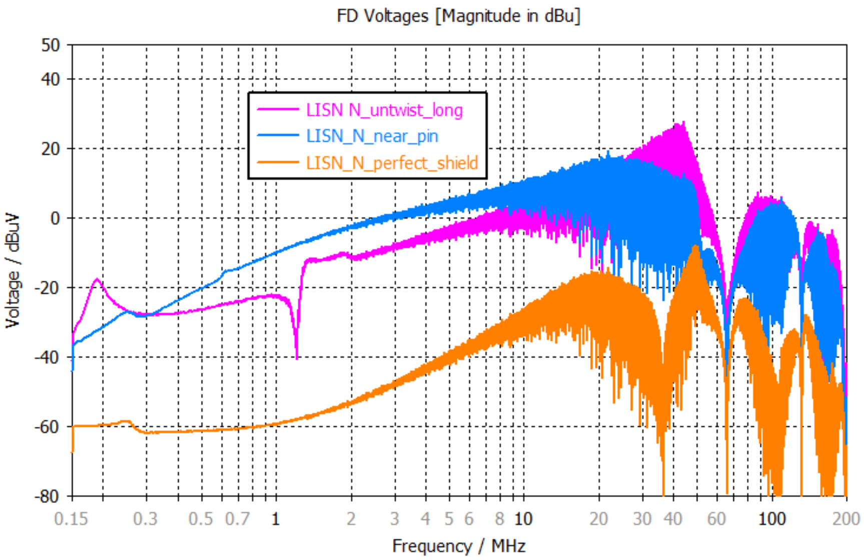




**shield:solid10**

| | |
|---|---|
| Material | shield |
| Type | Normal |
| Epsilon | 1 |
| Mu | 1 |
| Electric cond. | 1e+06 [S/m] |

## Emission at LISN N



# Summary

## Common Mode Choke

## Ferrites

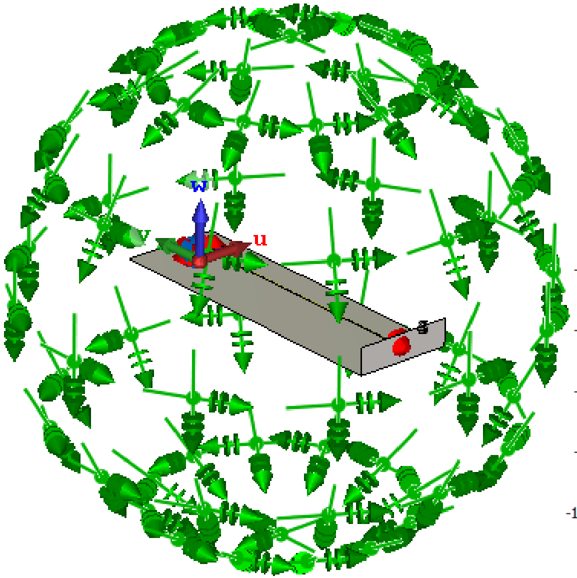
- Simple to apply but increase costs
- Careful check the performance

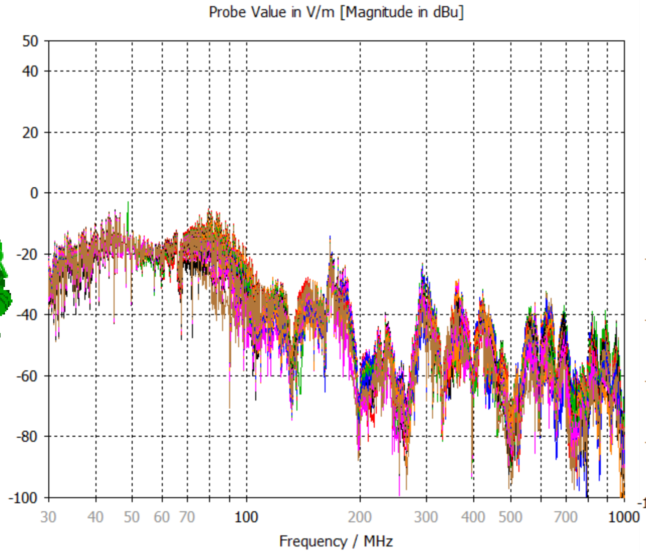
## Shields

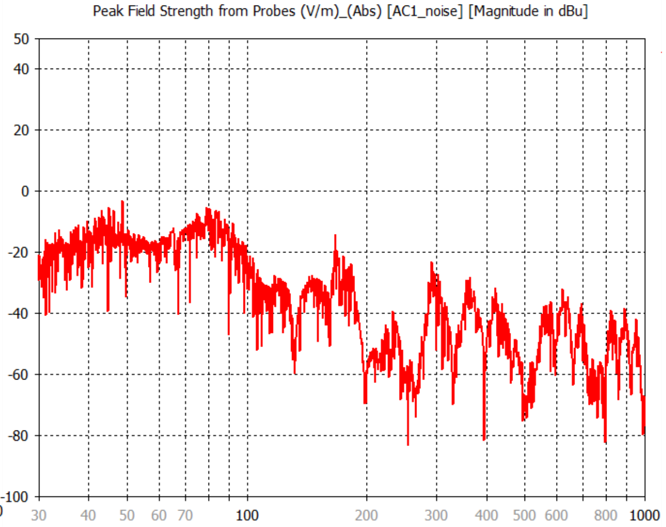
- Can be difficult to bond in standard connector
- If done right can provide excellent performance

# Radiated Emission

# Radiated Emission Workflow




Far field probes → All probe results → Worst case envelope



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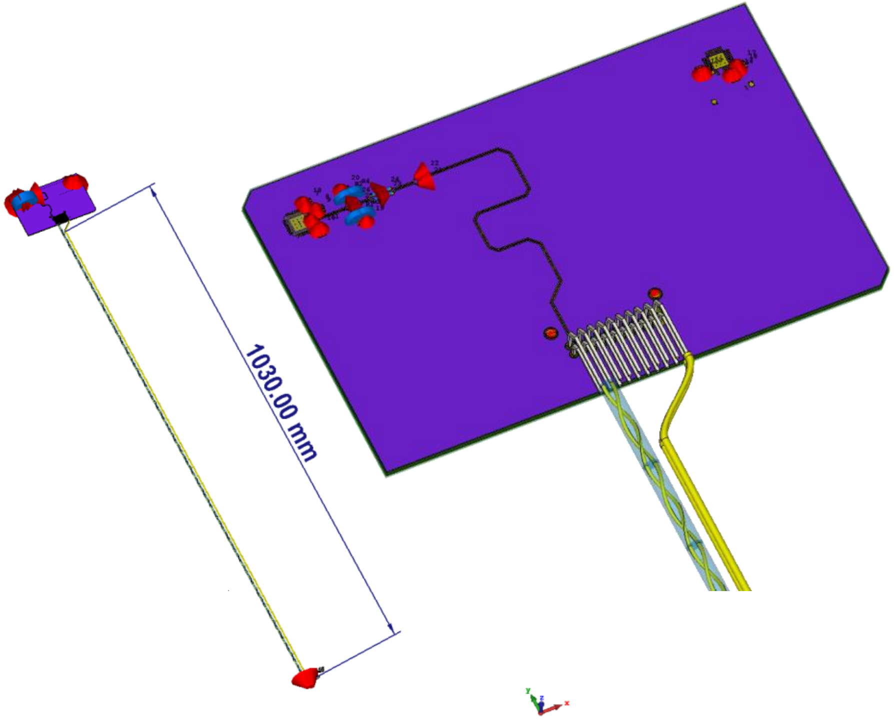
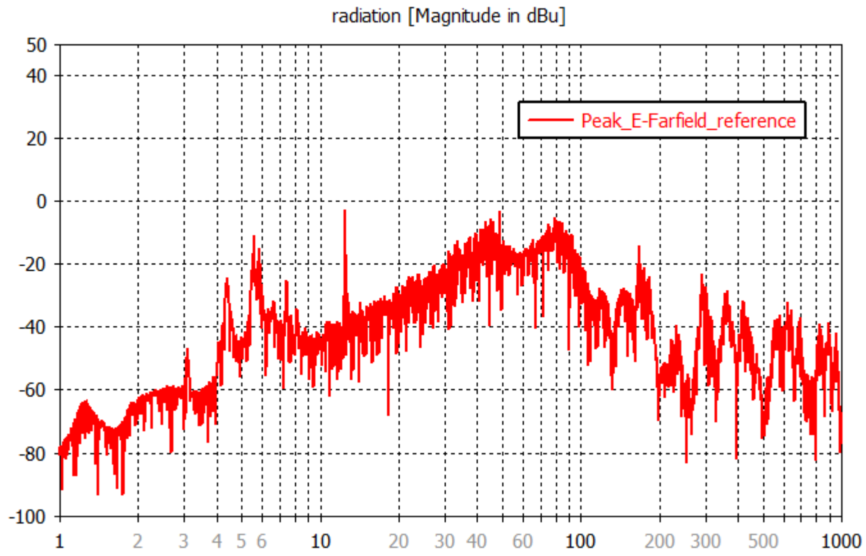
# Cable Reference

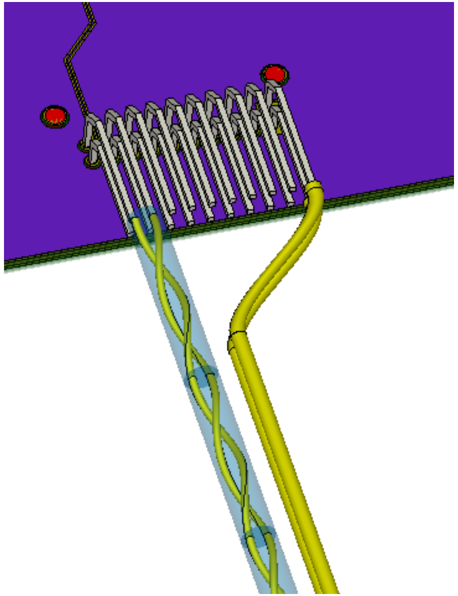


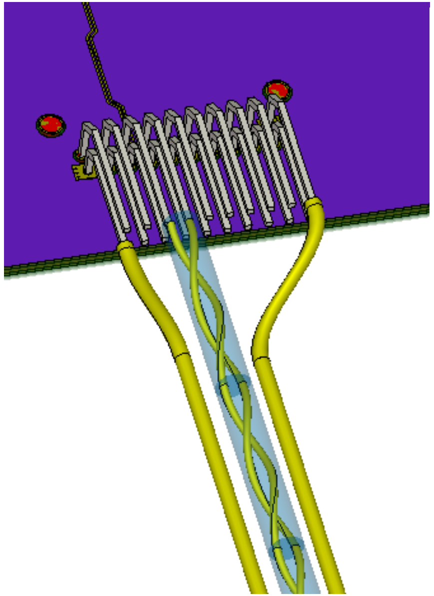



## Electric Field @ 1m

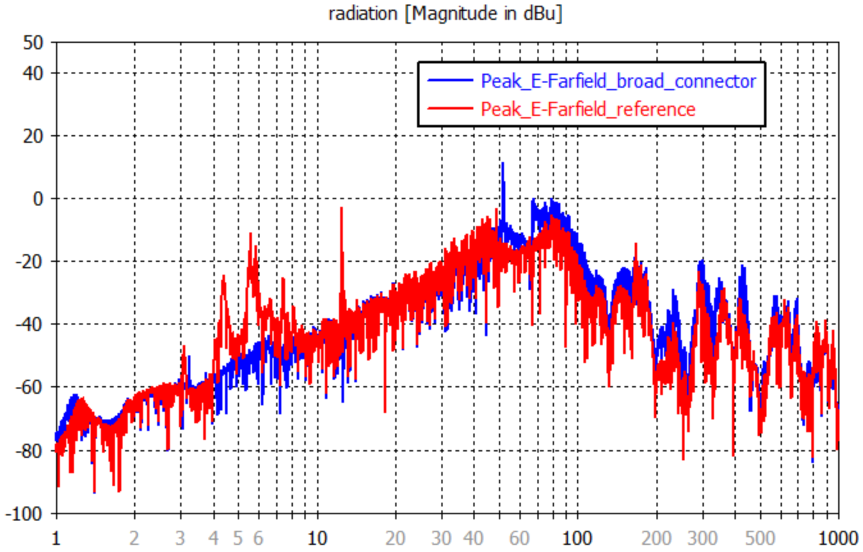


# Connector Pinout

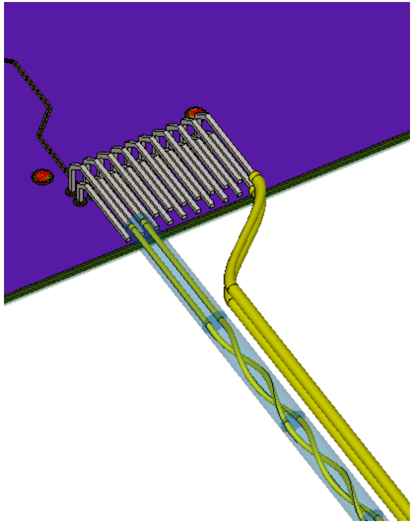


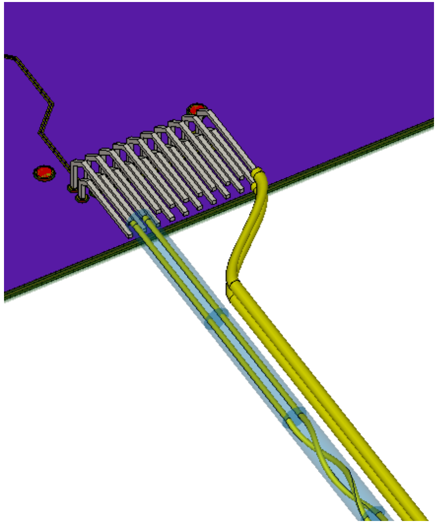


## Emission at LISN N

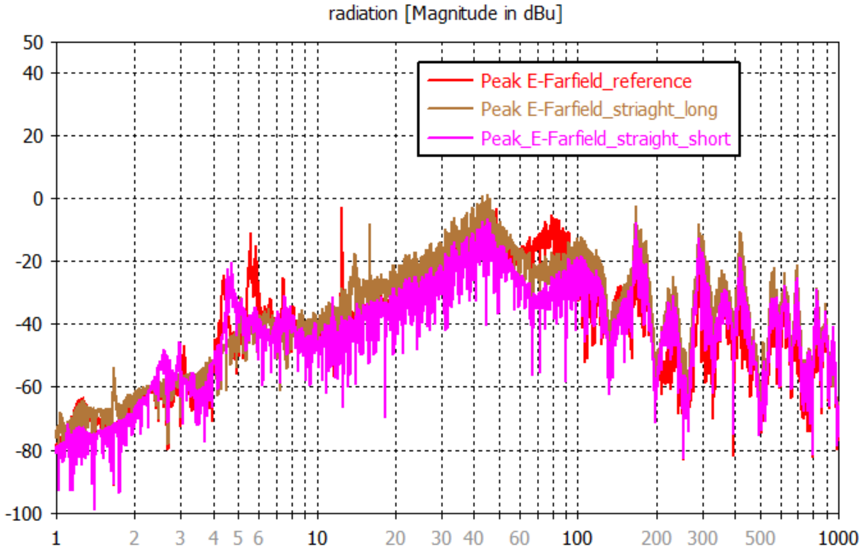


# Untwisting at Connector

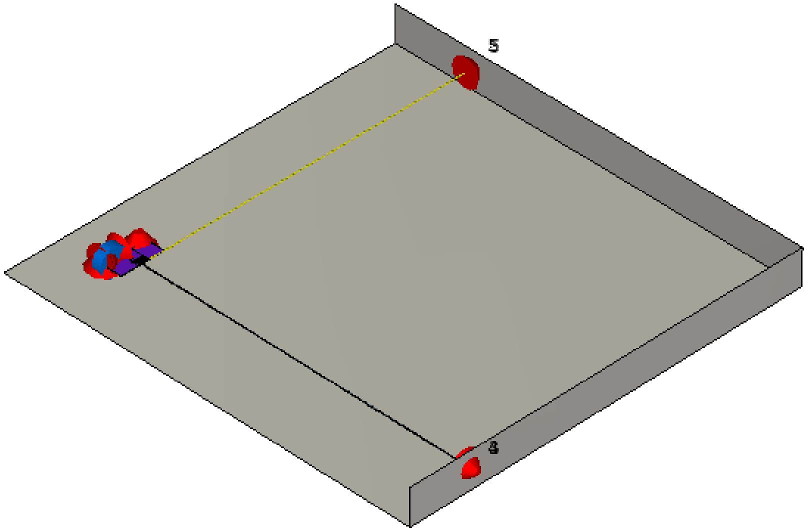




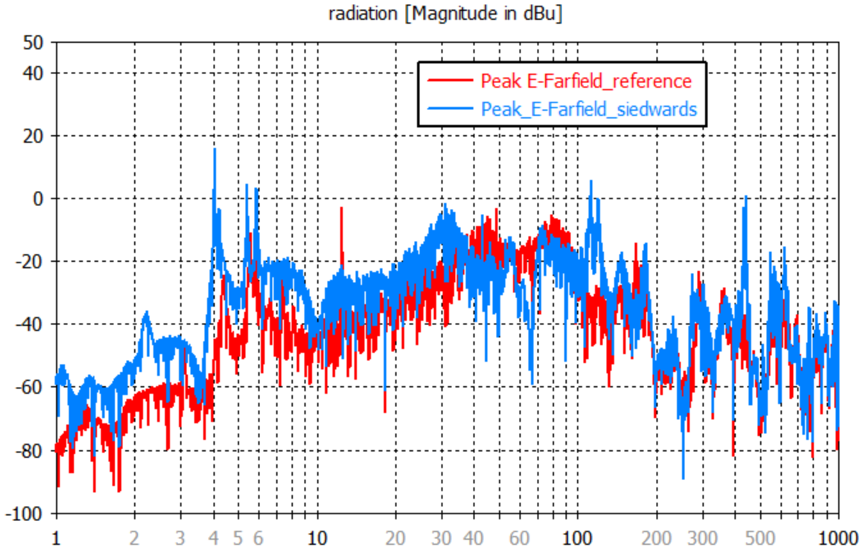
## Emission at LISN N



# Power Cables Sidewards




## Emission at LISN N



# Summary

## Estimating Radiated Emission

- Using a probe sphere

## Emission Levels

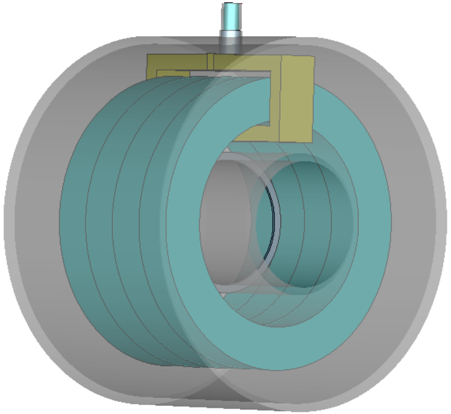
- Loop created by TWP and PWR is important
- Untwisting has the highest effect

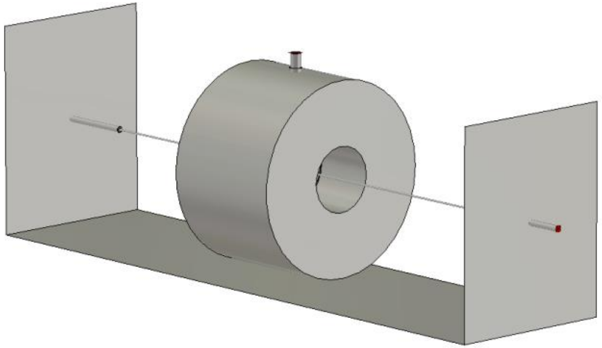
# Bulk Current Injection

# BCI Clamp

TEST PROBE: Fischer Custom Communications F-130a
Freq. range: 10kHz – 400MHz

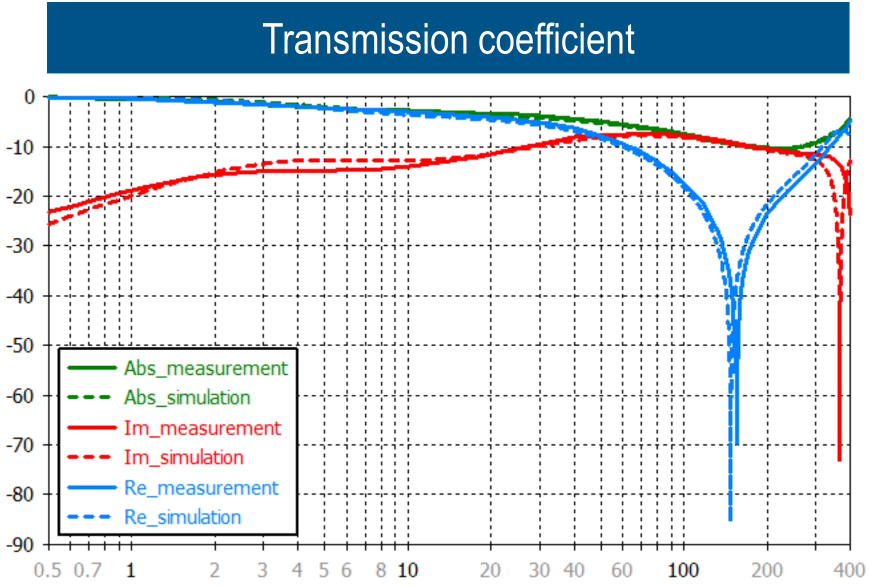
http://www.fischercc.com

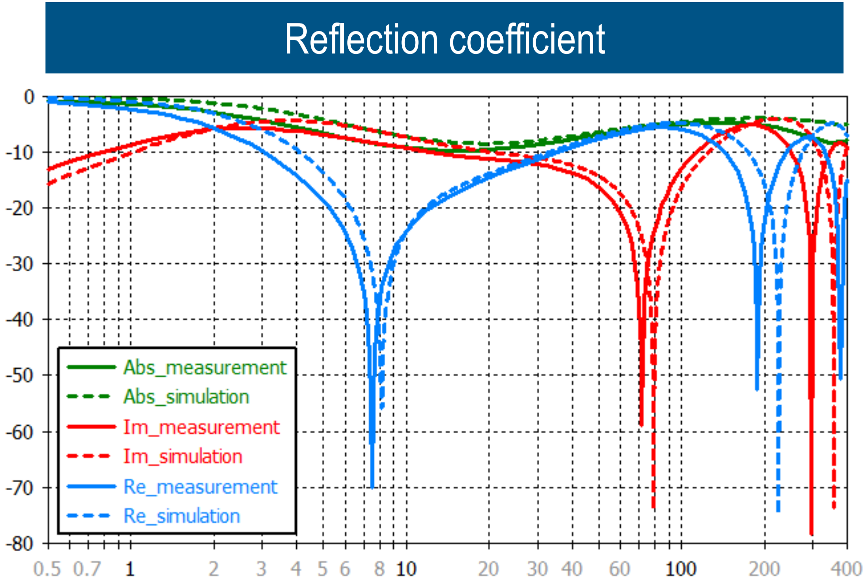




„Circuit Modeling of injection Probes for Bulk Current Injection“ by F. Grassi et al, IEEE Transactions on Electromagnetic Compatibility Vol. 49, Issue 3, 2007.

# BCI Calibration

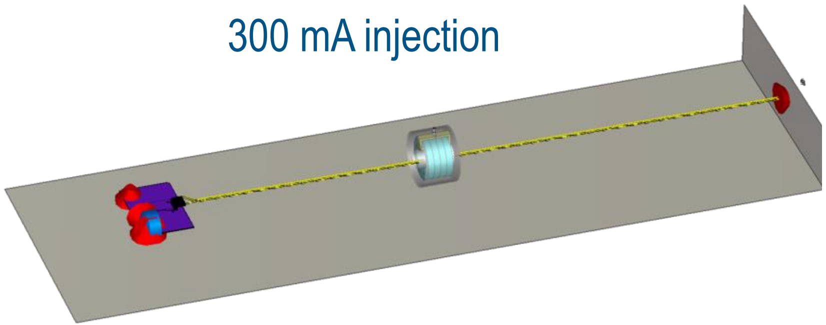


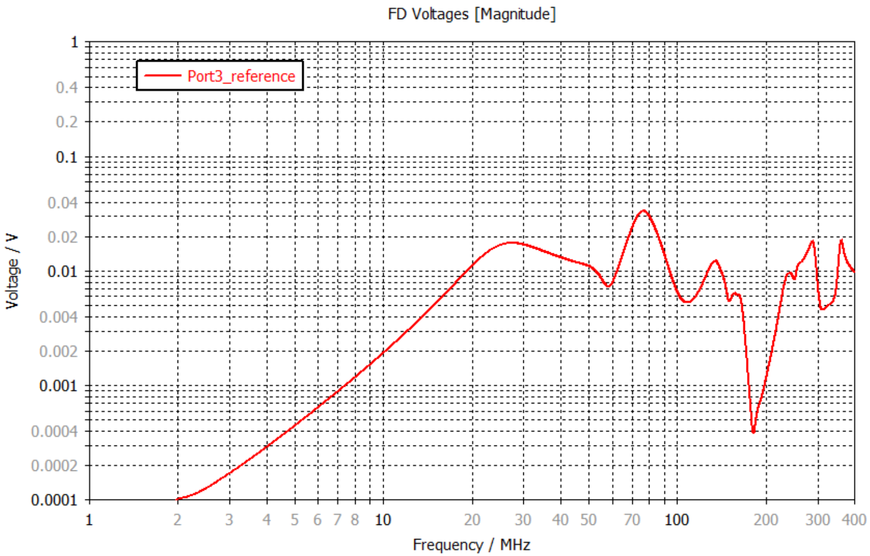

„Circuit Modeling of injection Probes for Bulk Current Injection“ by F. Grassi et al, IEEE Transactions on Electromagnetic Compatibility Vol. 49, Issue 3, 2007.

# BCI Reference

300 mA injection

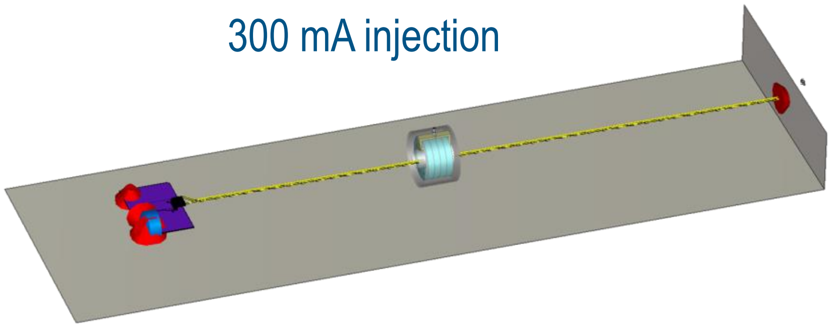


## Differential Signal at IC

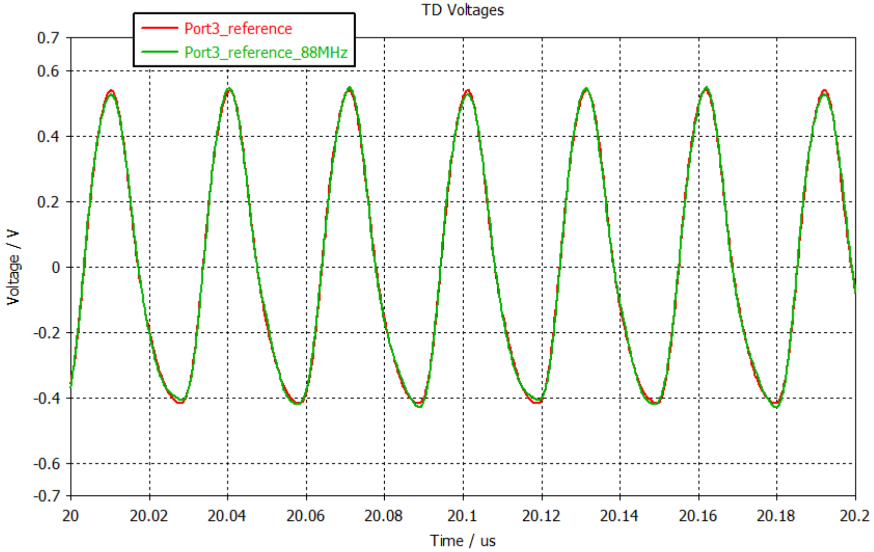


# BCI Reference

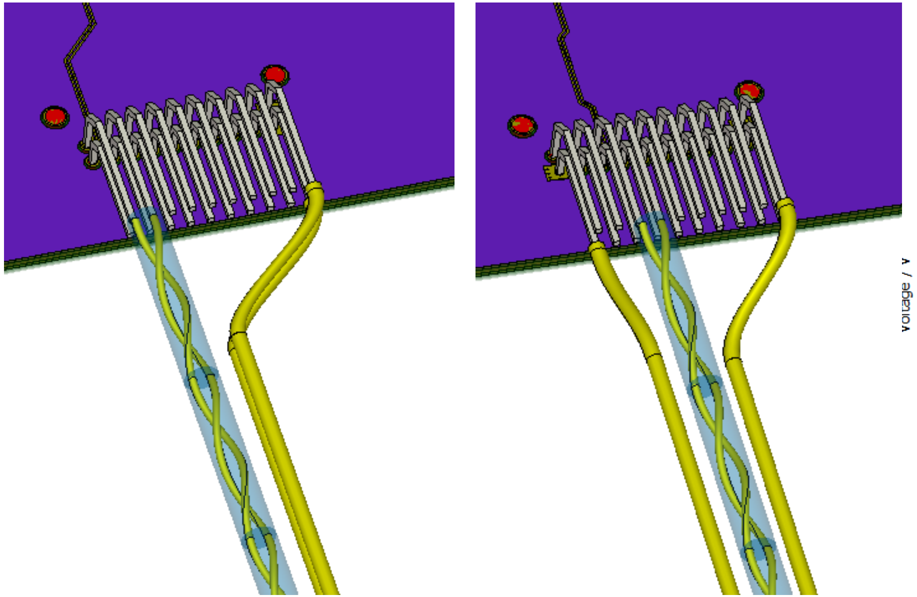
300 mA injection



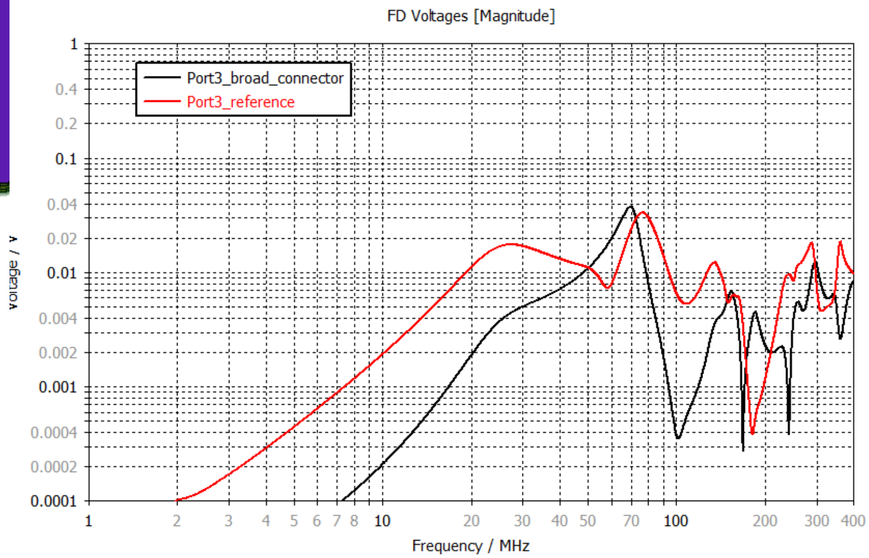
## Differential Signal at IC



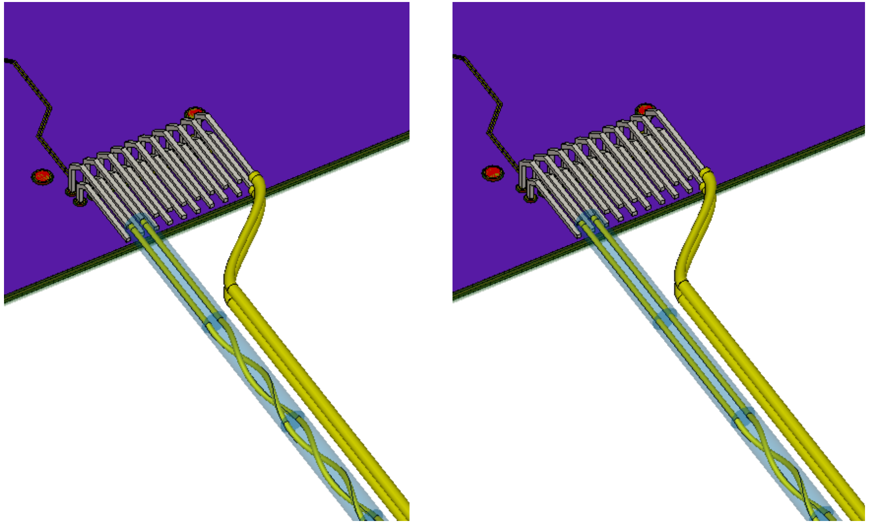
# BCI Connector Pinout



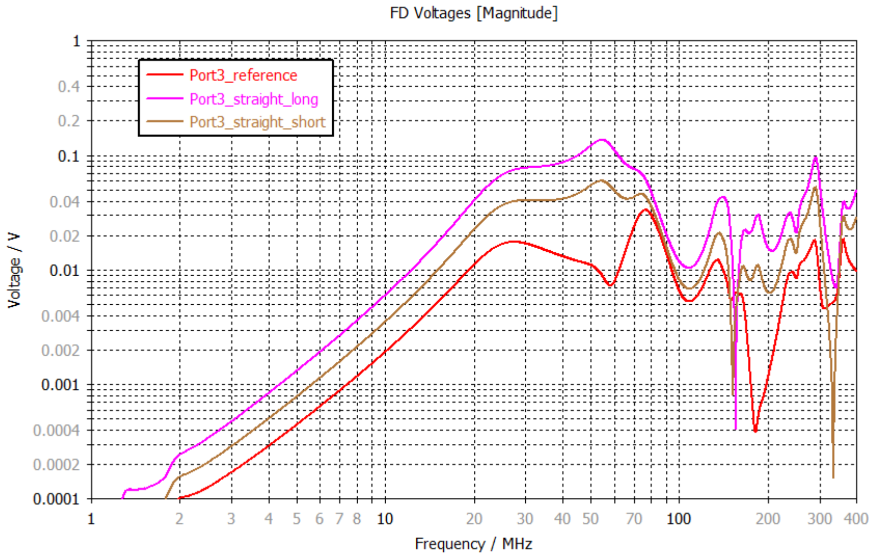
## Differential Signal at IC



# BCI Untwisting



## Differential Signal at IC



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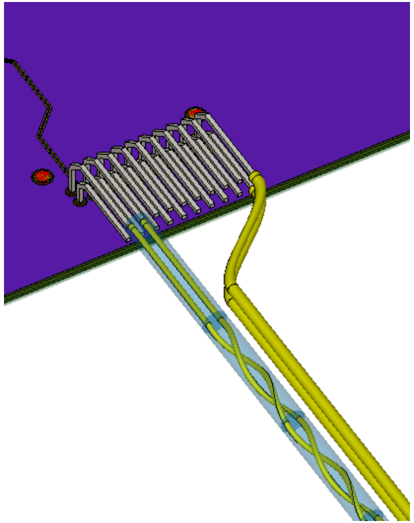
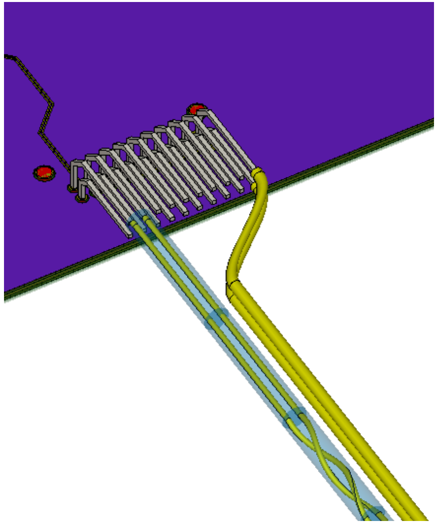
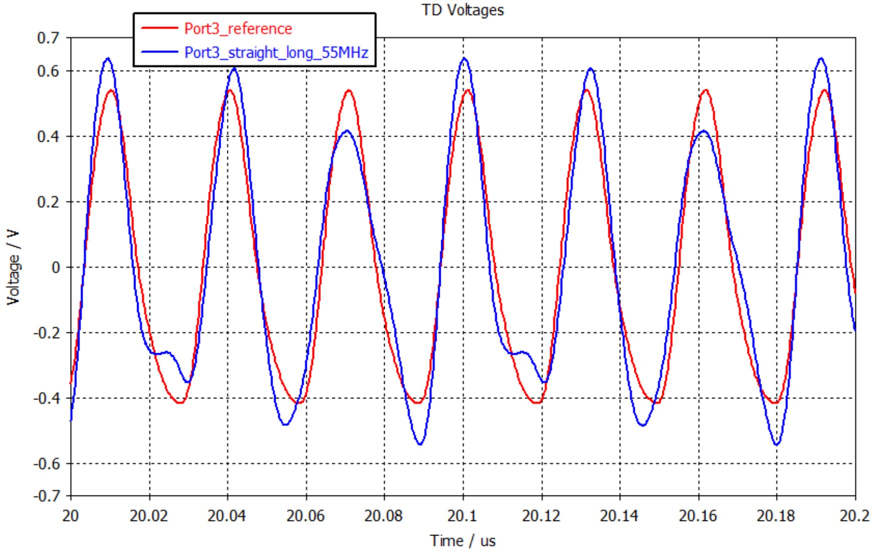
# BCI Untwisting





## Differential Signal at IC



# Summary

## BCI Modeling

- Clamp model provided

## Susceptibility Levels

- Results in frequency and time domain
- Untwisting has the highest effect

# Summary

## Automotive Ethernet

- Next generation signal bus
- Higher frequency content

## Emission Simulation

- Early design stage
- Full-wave 3D coupled to circuit simulation

## Results

- Understanding common mode is the key
- Layout can have significant effect on emission
- Untwisting of the TWP at the connector has a substantial effect on emission and susceptibility
- Not all countermeasures are efficient

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