OPTIMIZATION OF A MINIATURIZED ETHERNET 10 GBITS/S 8 CONDUCTORS INTERCONNECT FOR HARSH ENVIRONMENTS

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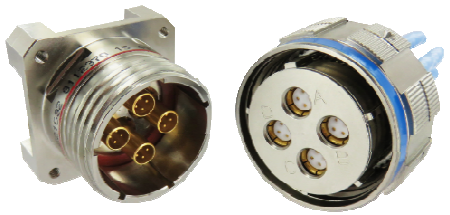
Overview

- **Design of a high speed Ethernet contact for military and aerospace industries**

Category 6A
Ethernet standard

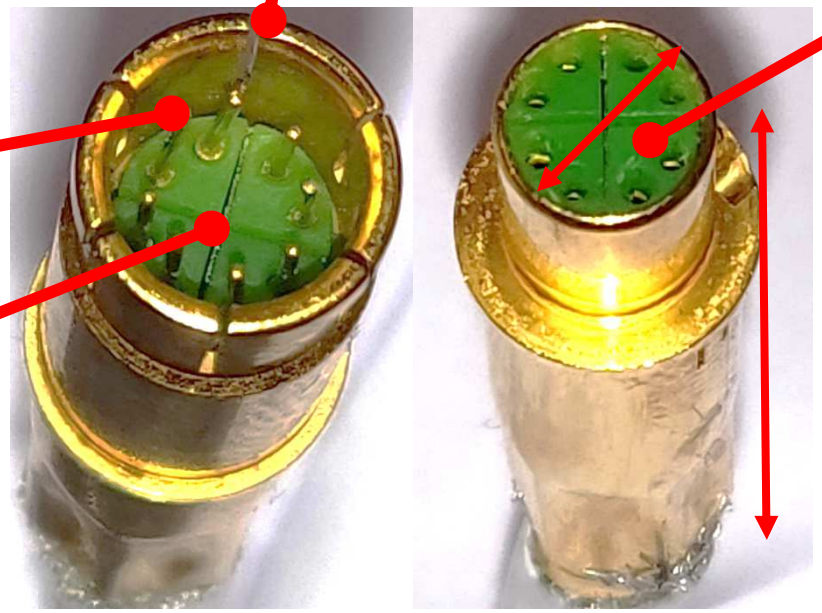
MIL-DTL-38999 and EN3645



Miniaturization

- Bitrate: 10 Gbits/s
- Thermal constraints: [-65°C, 200°C]
- Vibratory constraints: 10 to 20 G per axis
- Contacts into a confined space

Ethernet contact prototype #1



Category 6A Ethernet standard

Cat 6A criterions	Design optimization
Insertion Loss (IL) ↘↘	Low dielectric losses
Return Loss (RL) ↘↘	Zc≈ 100Ω
NEXT loss (NL) ↘↘	Internal shielding

F=[1MHz-500MHz]

Goal: 10 Gbits/s

Outline

I. 2D-3D electromagnetic simulation approaches

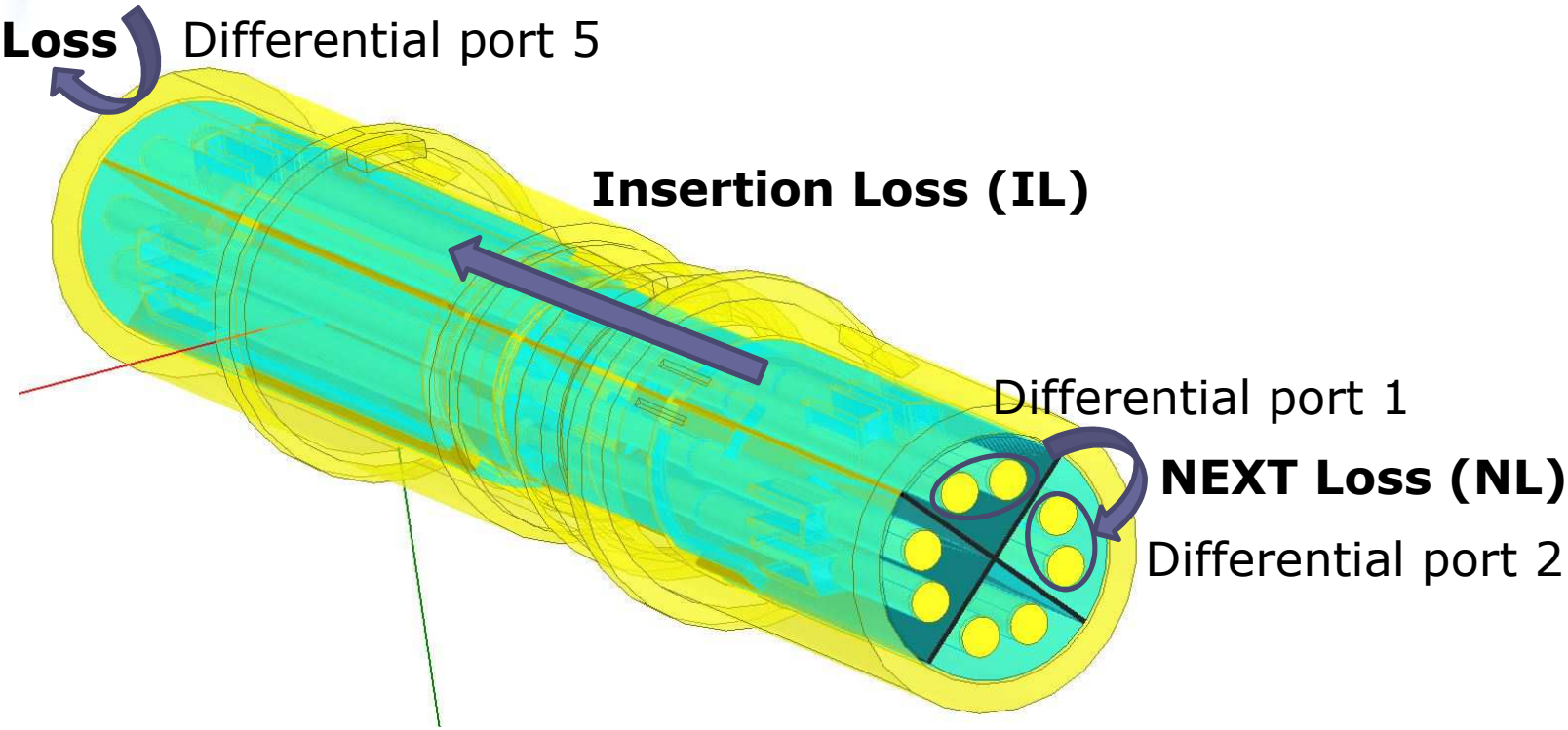
II. Prototype #1: validation of measurements & simulation tools

III. Prototype #2: optimized Ethernet contact

IV. Perspectives

2D-3D electromagnetic simulation approaches

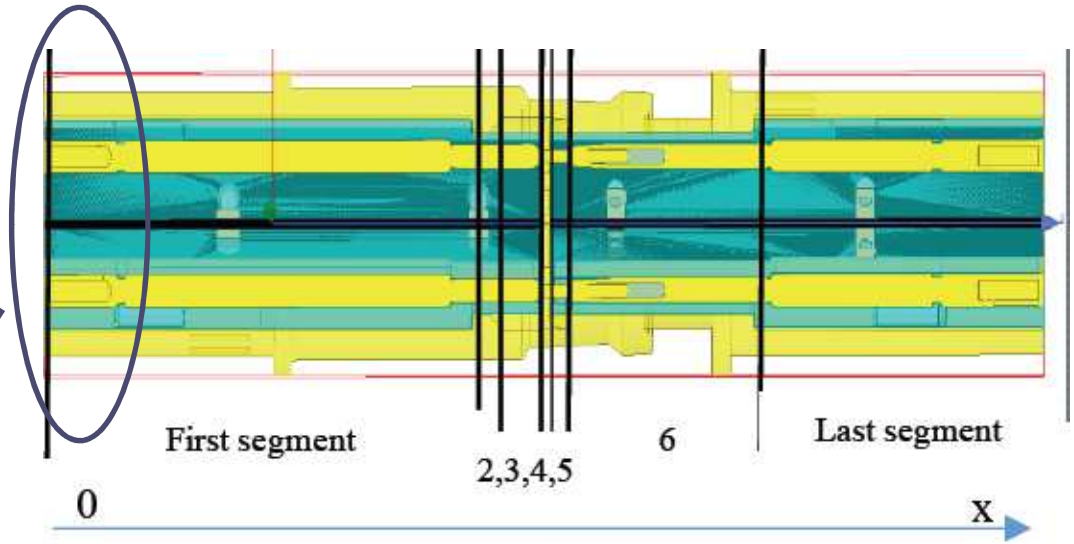
3D simulation tool

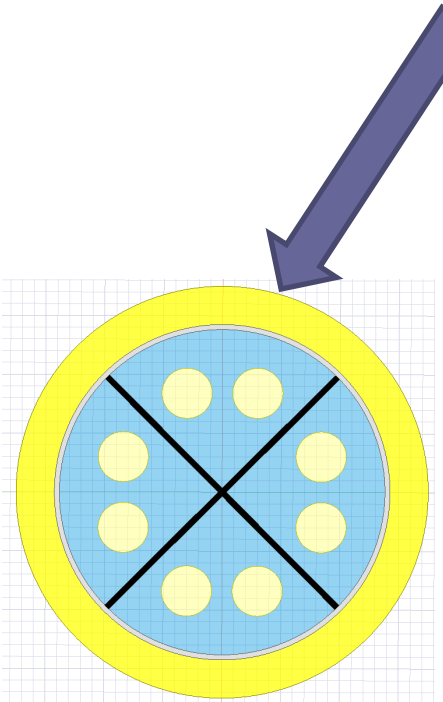


- Simulation using ANSYS HFSS 3D full wave solver
- BW = [10MHz, 1GHz]

2D-3D electromagnetic simulation approaches

2D segmentation approach





- The contact Ethernet #8 1.0 is represented as 7 cascaded segments
- Segments are modeled under ANSYS 2D Extractor solver

RLGC matrix of every segment [8x8]

2D-3D electromagnetic simulation approaches

[RLGC] matrix of every segment [8x8]

$$[ABCD]_i = \begin{bmatrix} {Y_E^{-1}}_i * coshm(\Gamma_i) * Y_{E_i} & Z_{c_i} sinhm(\Gamma_i) \\ sinhm(\Gamma_i) * {Z_c^{-1}}_i & coshm(\Gamma_i) \end{bmatrix}$$

$$\Gamma_i = sqrtm(Y_{E_i} * Z_{M_i}) * l_i \qquad Y_{E_i} = G_i + j\omega C_i$$

$$Z_{c_i} = sqrtm({Y_E^{-1}}_i * Z_{M_i}) \qquad Z_{M_i} = R_i + j\omega L_i$$

l_i: segment length, $i \in [1,7]$

[ABCD]$_i$ matrix of every segment [16x16]

$$[ABCD] = \prod_{i=1}^{7} [ABCD]_i$$

[ABCD] matrix of the contact [16x16]

2D-3D electromagnetic simulation approaches

[ABCD] single-ended matrix of the contact [16x16]

$$[S]_{se} = \begin{bmatrix} \{[A] + [B] * Z_0^{-1} - [C] * Z_0 - [D]\} * den^{-1} & 2 * ([A] * [D] - [B] * [C]) * den^{-1} \\ 2 * den^{-1} & \{-[A] + [B] * Z_0^{-1} - [C] * Z_0 + [D]\} * den^{-1} \end{bmatrix}$$

$$den = [A] + [B] * Z_0^{-1} + [C] * Z_0 + [D]$$

[S] single-ended matrix of the contact [16x16]

$$[S]_{mm} = P_{mm} * [S]_{se} * {P_{mm}}^{-1}$$

$$[S]_{mm_{16X16}} = \begin{bmatrix} [S]_{dd_{8X8}} & [S]_{dc_{8X8}} \\ [S]_{cd_{8X8}} & [S]_{cc_{8X8}} \end{bmatrix}$$

$$P_{mm} = \begin{bmatrix} \frac{1}{\sqrt{2}} & -\frac{1}{\sqrt{2}} & 0 & 0 & \cdots & 0 & 0 & 0 \\ 0 & 0 & \frac{1}{\sqrt{2}} & -\frac{1}{\sqrt{2}} & 0 & 0 & \cdots & 0 \\ \vdots & \vdots & \vdots & \vdots & \ddots & \ddots & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & \frac{1}{\sqrt{2}} & -\frac{1}{\sqrt{2}} \\ \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & 0 & 0 & \cdots & 0 & 0 & 0 \\ 0 & 0 & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & 0 & 0 & \cdots & 0 \\ \vdots & \vdots & \vdots & \vdots & \ddots & \ddots & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \end{bmatrix}_{16X16}$$

[S] differential mode matrix of the contact [8x8]

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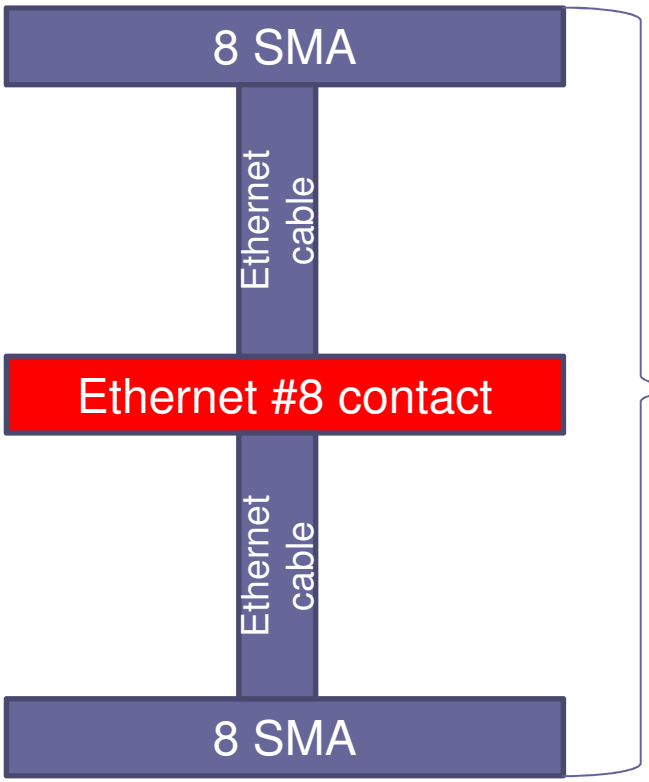
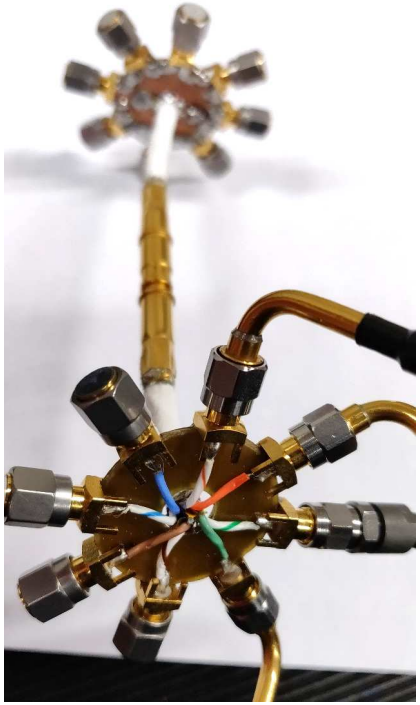
Prototype #1: validation of measurements & simulation tools



NEXT loss & Return loss measurement configuration



Insertion loss measurement configuration

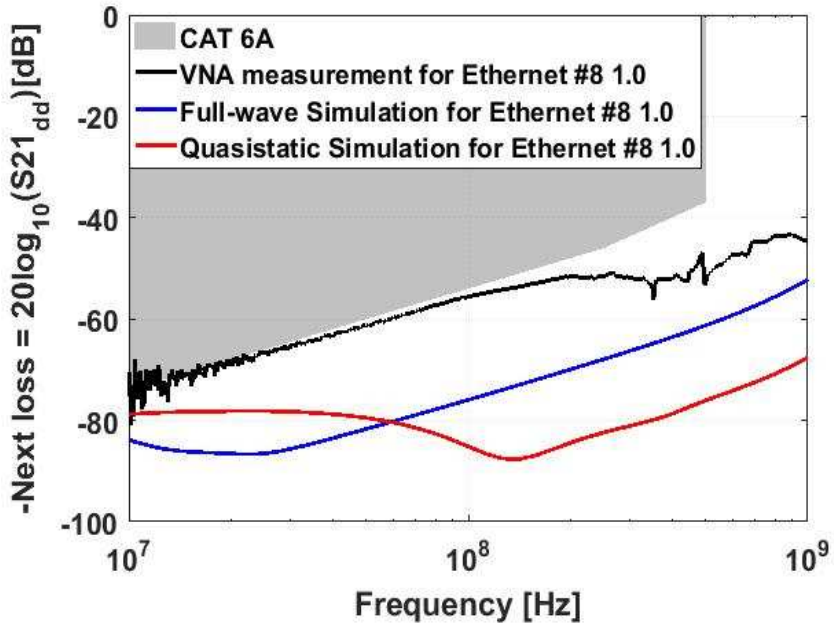
Diapositive 11

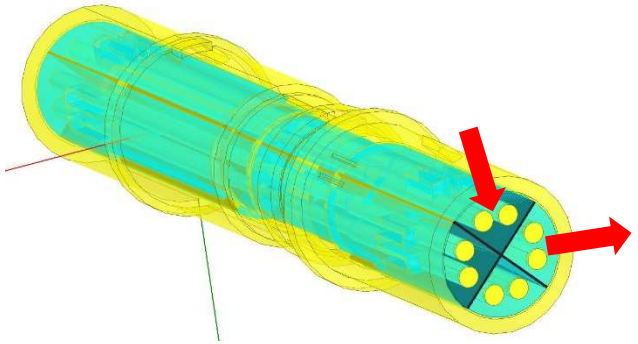
YB1 soudé = welded

Younes Boujmad; 03/06/2019

Prototype #1: validation of measurements & simulation tools

NEXT loss :





Measured NEXT > Simulated NEXT

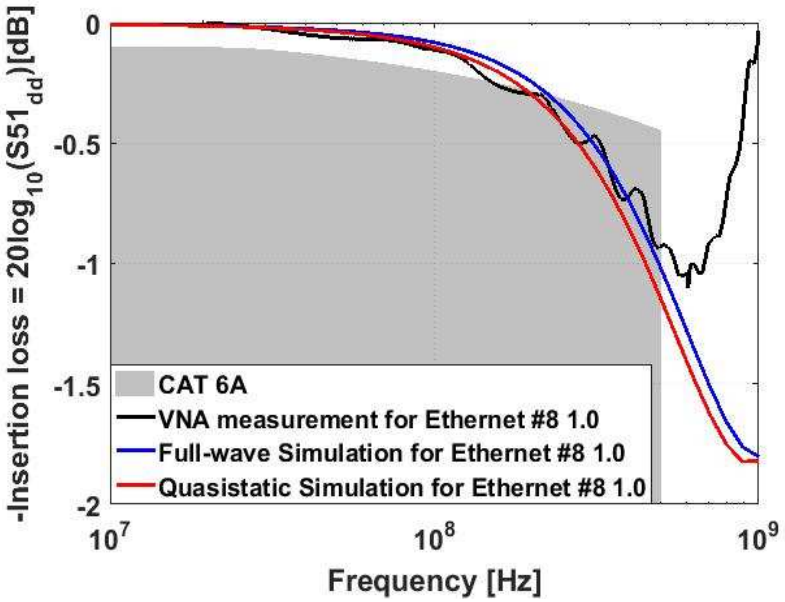
Improve the test fixture

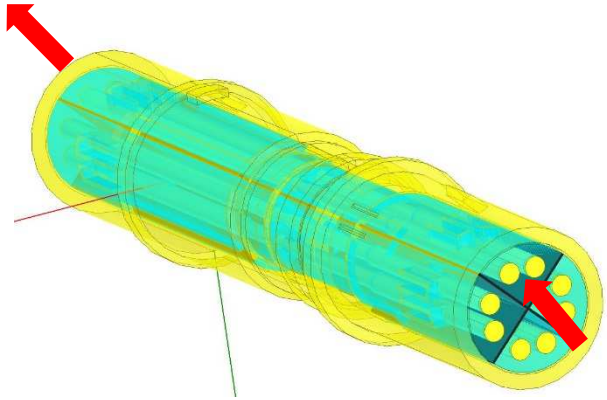
The NEXT is in accordance with the category 6A standard

Complex assembling of the metal cross

Prototype #1: validation of measurements & simulation tools

Insertion loss :



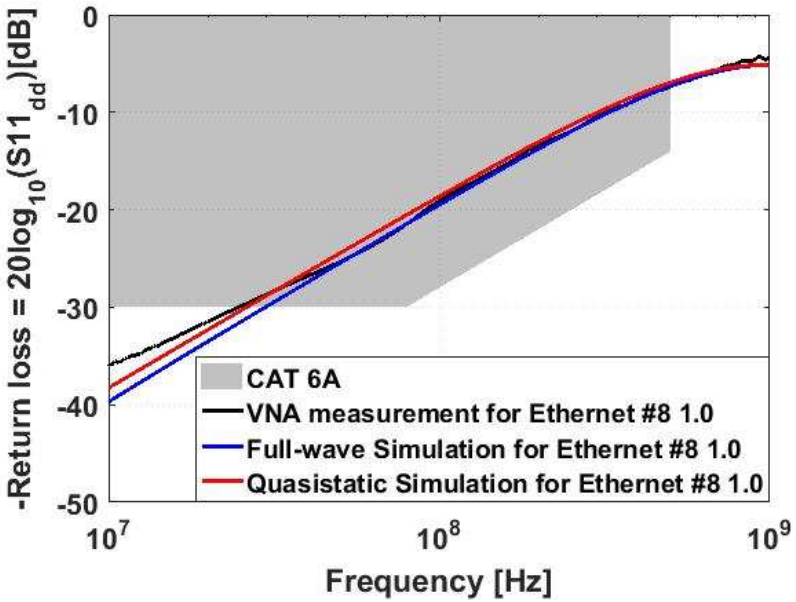


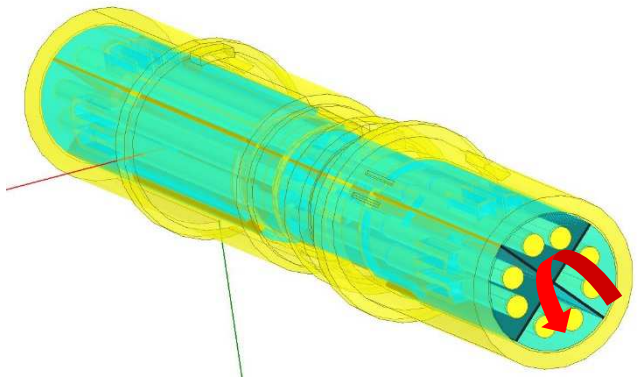
IL results: 2D segmentation approach ≡ 3D full wave simulation ≡ VNA measurement

The IL is not in accordance with the category 6A standard

Prototype #1: validation of measurements & simulation tools

Return loss :

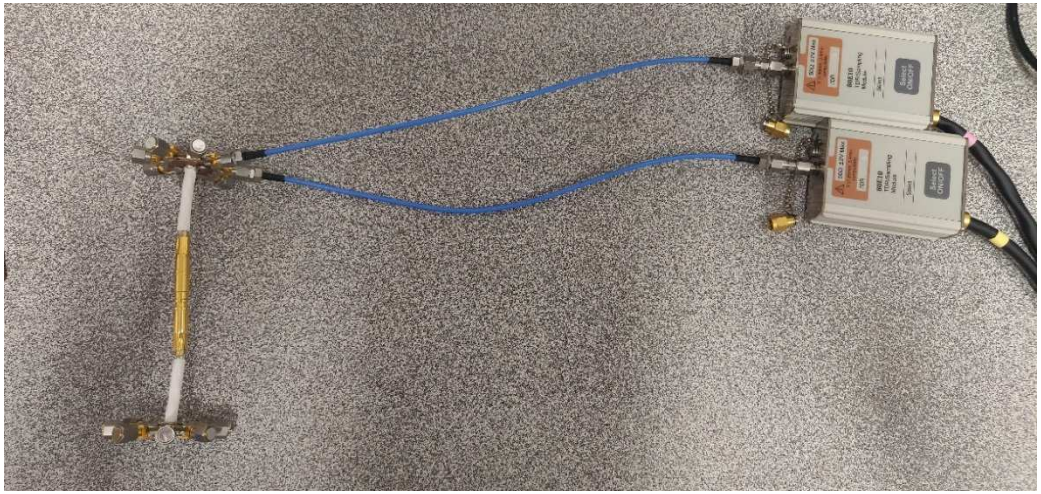


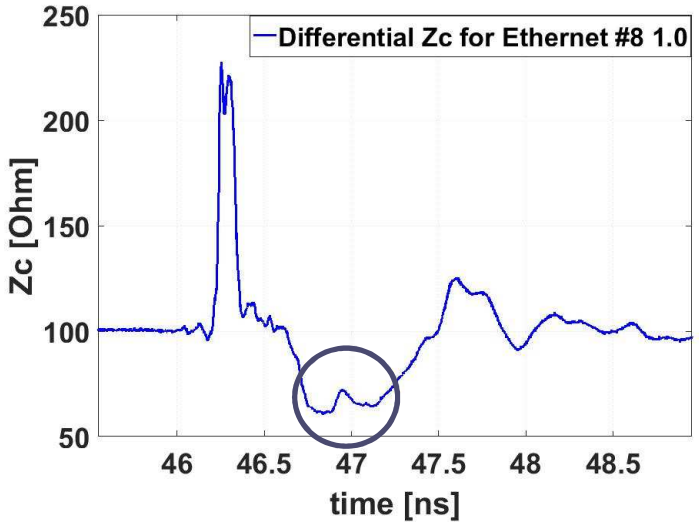


RL results: 2D segmentation approach ≡ 3D full wave simulation ≡ VNA measurement

RL level is 8.5 dB higher than the value imposed by the Ethernet cat 6A standard

Prototype #1: validation of measurements & simulation tools





- TDR measurement:
60Ω<Zc<70Ω for the contact #1

Conclusion 1

- The 2D modeling tool can be used for the optimization procedure
- The first prototype doesn't meet the category 6A standard

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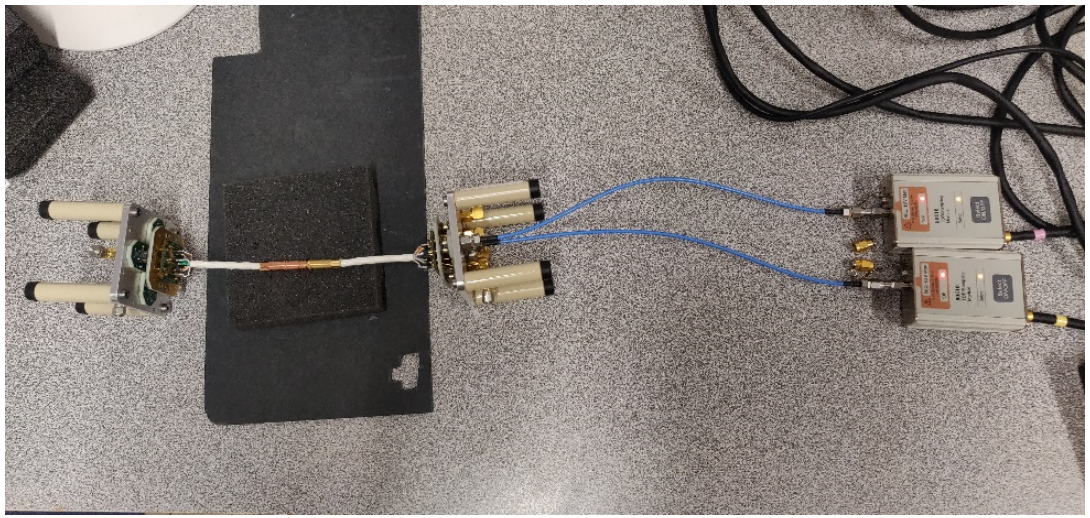
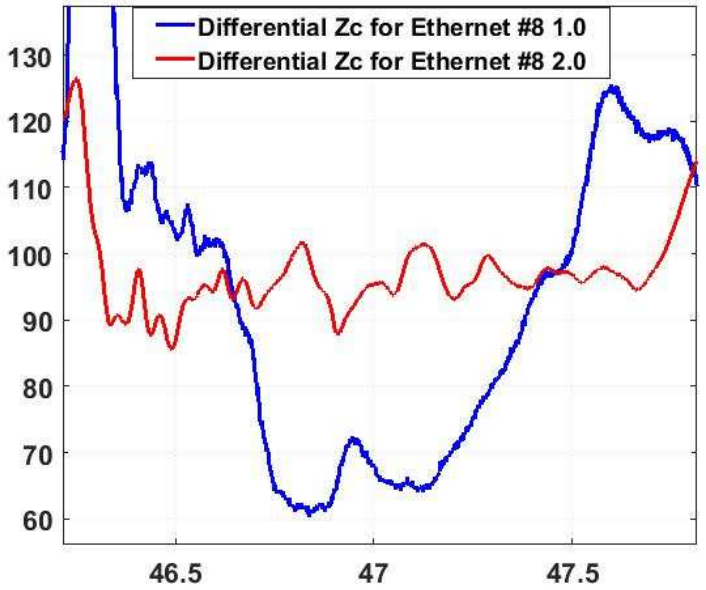
Prototype #2: optimized Ethernet contact

- Optimization of the impedance matching by:
  - Including air gaps in the dielectric
  - Modifying the shielding
  - Decreasing the diameter of the pins

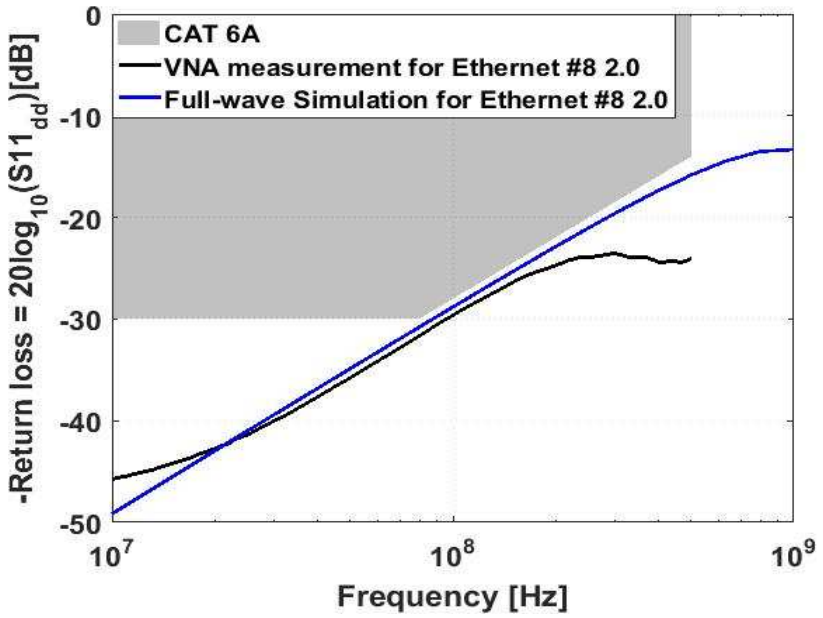


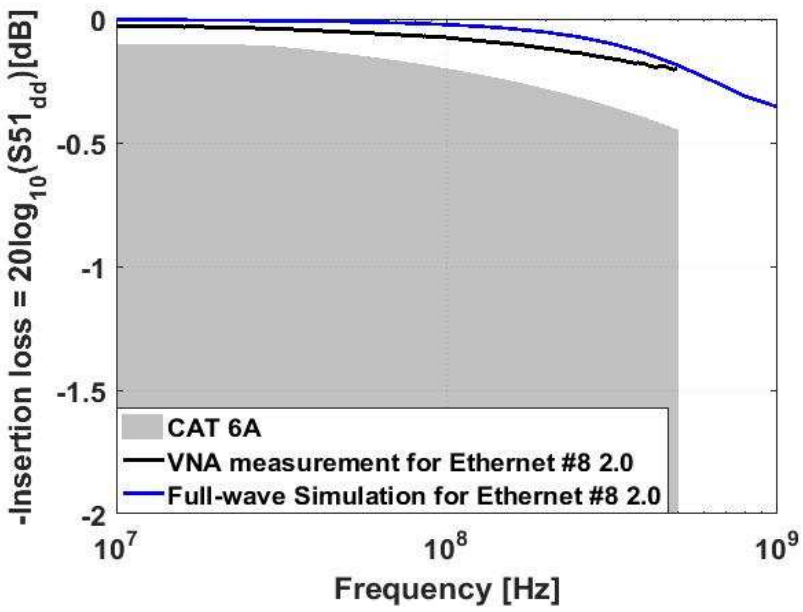


- TDR measurement :

90Ω<Zc<100Ω for the optimized contact (prototype #2)

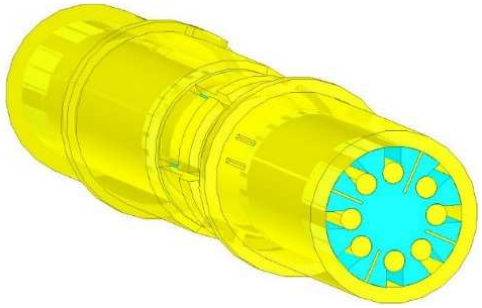
Prototype #2: optimized Ethernet contact

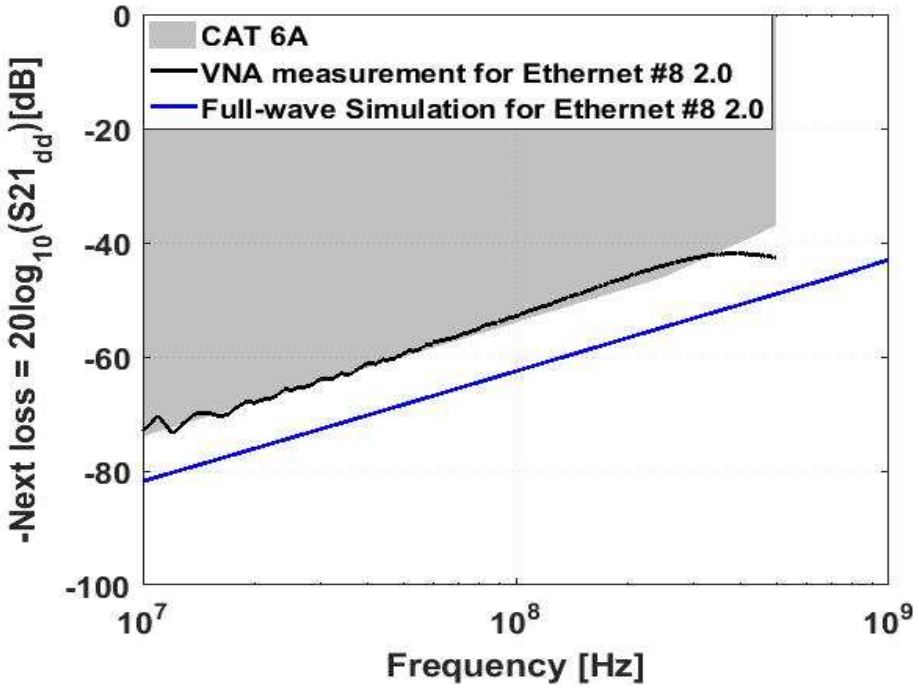




Characteristic Impedance Optimization => Improves the IL and RL compared to the category 6A standard

Prototype #2: optimized Ethernet contact





- Integrating the shield in a single piece of dielectric
- The NEXT in accordance with cat 6A

Conclusion 2

- The optimized prototype #2 meets the category 6A standard
- The optimized contact #2 is designed with a single piece of dielectric which facilitates contact assembly

Perspectives

- Broadband characterization of the dielectric polymer using coaxial lines [10 MHz - 12 GHz]
- Harsh environment qualification (temperatures and vibrations)
- Meet the industry standard for fabrication
- Conception of a mold for the dielectric part
- Final optimization leading to Ethernet #3 contact

THANK YOU FOR YOUR ATTENTION

This project is supported by the Rhône-Alpes region