ScuDo

Scuola di Dottorato ~ Doctoral School

WHAT YOU ARE,TAKES YOU FAR

XXXIV Cycle

Physical-Based Models for the Computer Aided Design of Cable Bundles

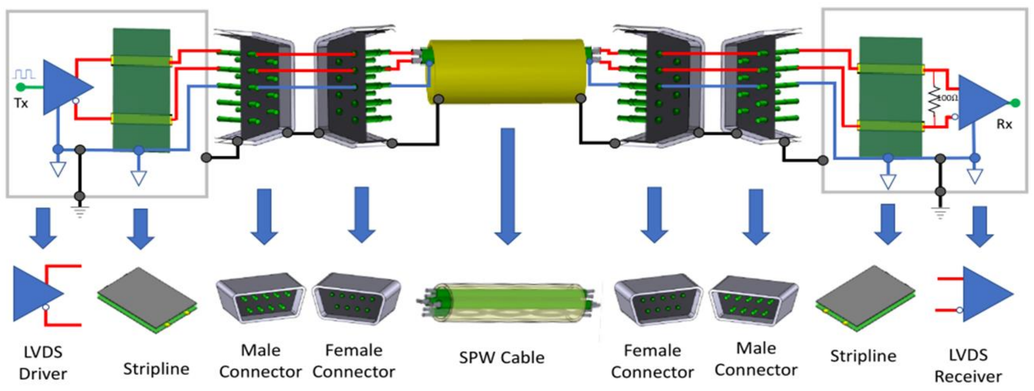
Felipe Treviso

Supervisor: Prof. Flavio Canavero

Co-supervisor: Prof. Riccardo Trinchero

Research context and motivation

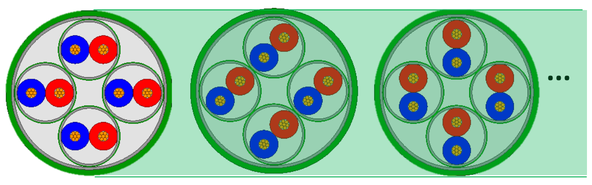
- **Electrical interconnections** are generally electrically **long and consist of multiple components with different geometries and characteristics.** As an example, in a SpaceWire link, transceivers and receivers are connected by a multi-section channel, made of printed circuit board segments, cable assemblies and connectors



- **Susceptibility and signal integrity of the link** must be carefully investigated during the design phase. There are two possible approaches **for the assessment of** link reliability:
  - **Experimental tests** are **expensive** and **slow**, requiring prototypes of ad-hoc test setups
  - **Simulations** are **faster** and **cheaper**, but they **require accurate models**

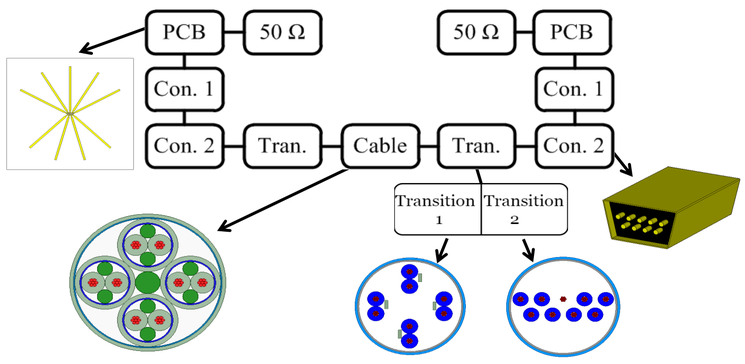
- Specifically, the availability of **accurate models of the channel components and structures** can be extremely useful for the assessment of the link performance and the noise margin within the simulation environment without requiring expensive and time-consuming prototyping.

- **How much of that complexity should be accounted for within the simulation framework?**
  Particular attention must be paid to the **discontinuities**, the **asymmetries** and **impedance mismatches** arising by the interconnection of the different structures of the link, since they can be the sources of mode conversions (e.g., differential-mode to common-mode conversion), potentially disrupting the communication channel performances and/or compromising the reliability of the application. However, the link may have a **complex geometry**, for example, a multiconductor cable with twisted wires, multiple shields, etc. thus making the simulation expensive if all the details are accounted.



Adopted methodologies

- Development of **full-wave 3D models** for short components and **2D models** for transmission lines, with all blocks combined in SPICE simulations



Spice models

Connector & PCB: Lumped model that replicates a rational transfer function:

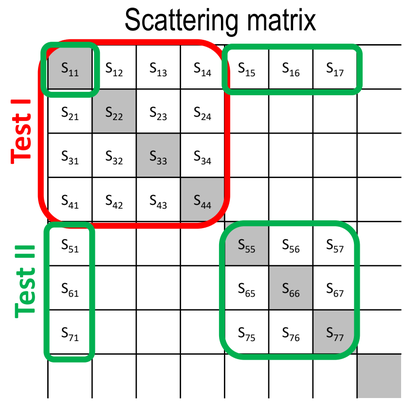
$$H(s) = \sum_n \frac{r_i}{j\omega - p_i} + r_0$$

Cable & Transitions: Coupled lossy transmission line model based on the per-unit-length parameters of the cross section

- **Model validation** by comparing the measured 18-port scattering matrix using a 4-port VNA.

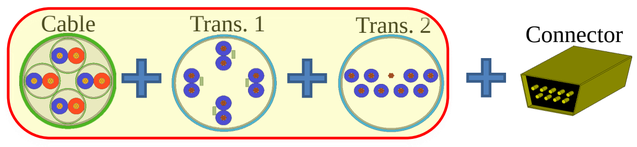
- Comparison of models with different detail levels, for example, using twisted wires for the cable or not and including non-abrupt transitions between cable and connectors.

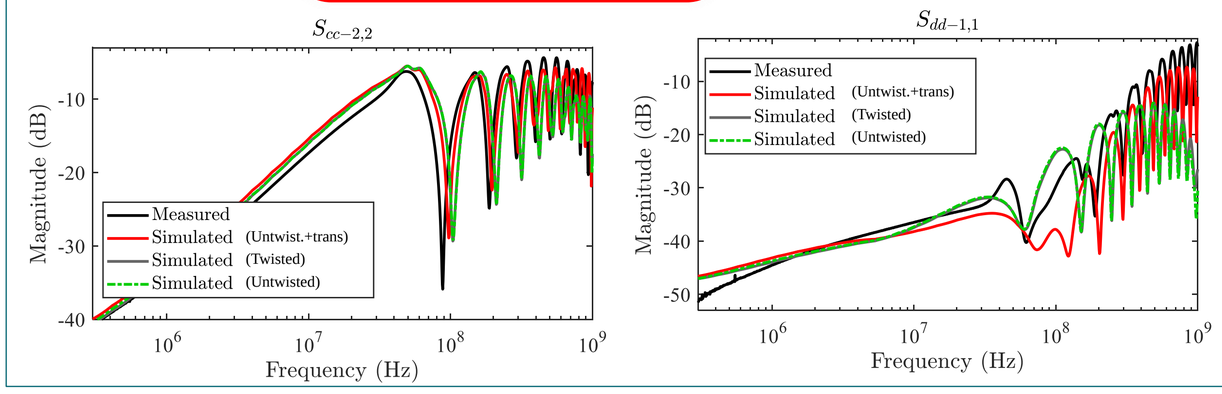
Scattering matrix



Novel contributions

- An **enhanced cable model** by considering the **transition** between the cable and the connector cross-sections
  - A cascade of blocks is used to represent this transition (instead of using an abrupt transition), making the model accuracy increase at higher frequencies



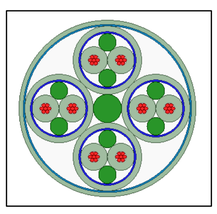


Addressed research questions/problems

- **Goal:**
  - Develop a **circuital model of a complex high-speed cable link** compatible with SPICE that is **reliable and provide fast and cheap simulations**.

- **Issues:**
  - **Connector:**
  - A complete 3D CAD model (connector geometry + material + wire connections) is not provided by the manufacturer and therefore it cannot be imported in an electromagnetic solver

  - **Cable:**
  - Electrically long electromagnetic structure
  - Physical dimensions are not fully provided
  - Position of the wires in the bundle changes along its length



- How can we **validate** the models?

Future work

- The **sensitivity** of the proposed model with respect to the **geometrical parameters** of the cable and the connector still need to be investigated, as the simulation results suffer larger variations with small changes in the parameters of the model.
- Alternative **models including all components** at once will be developed to increase the efficiency of the simulations

List of attended classes

- 01LCPRV – Experimental modeling: construction of models from experimental data (4/9/2019, 33 hours)
- 02QUBRS – Statistical data processing (13/3/2019, 20 hours)
- 01TCORV – Surrogate and compact modeling: theory for the user (3/9/2019, 20 hours)
- 01QFFRV – Innovative optimization techniques (8/3/2019, 20 hours)
- 01QCEIW – Advanced aspects of the finite element method (evaluation pending, 20 hours)
- 02LWHRV – Communication (17/12/2018, , 5 hours)
- 01RISRV – Public speaking (21/1/2019, 5 hours)
- 01SYBRV – Research Integrity (5/9/2019, 5 hours)
- 01SWQRV – Responsible research and innovation, the impact on social challenges (1/8/2019, 5 hours)
- 01SWPRV – Time management (7/12/2018, 2 hours)

Submitted and published works

- Treviso F. , Trinchero R. ; Canavero F. G. , "*Validation of a Physical-Based Model for a Spacewire Cable*", 2019 ESA Workshop on Aerospace EMC (Aerospace EMC), Budapest, 2019.

POLITECNICO DI TORINO

PhD program in

Electrical, Electronics and Communications Engineering