3D EM Simulation in the Design Flow of High-Speed Multi-Pin Connectors

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This article describes the design flow for a high speed connector using several simulation tools. The goal is to enable its first pass design without time-intensive and costly iteration steps. In addition to other simulation tools, CST MICROWAVE STUDIO® (CST MWS) is used during various stages of the design process to find fundamental design parameters and to predict the behavior of a complete telecommunication system.

A new high speed multi pin connector has to enable a data transmission rate of at least 10Gbit/s in a communication system (Figure 1), where two daughter cards are connected via a backplane. The connections should be point-to-point connections applying differential signal trace layout. Other technical requirements include:

- 100 Ohm differential impedance.
- SMT interface to printed circuit board.
- Extreme shielding to achieve a minimum of crosstalk between differential signal pairs.
- Minimum signal skew between the two contacts of a differential signal pair.
- Economical and easy trace routing.

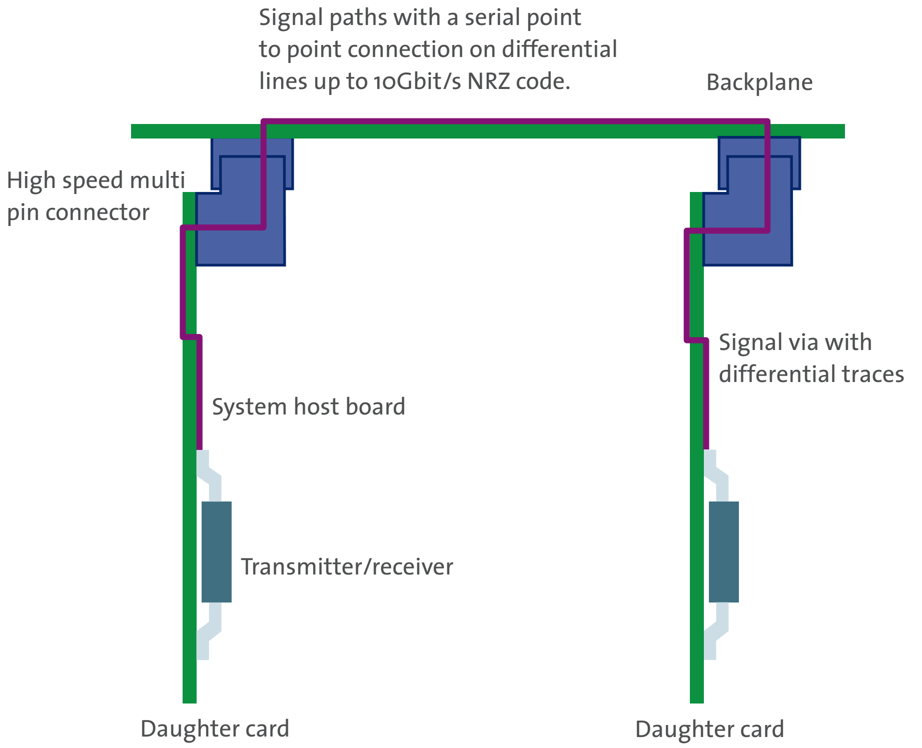

Figure 1: Backplane and daughter card system

EM simulation can be used in the early stages of the design process to help determine the main dimensions of the connector and how it will behave in the aforementioned system. The prototyping process is shown in Figure 2.

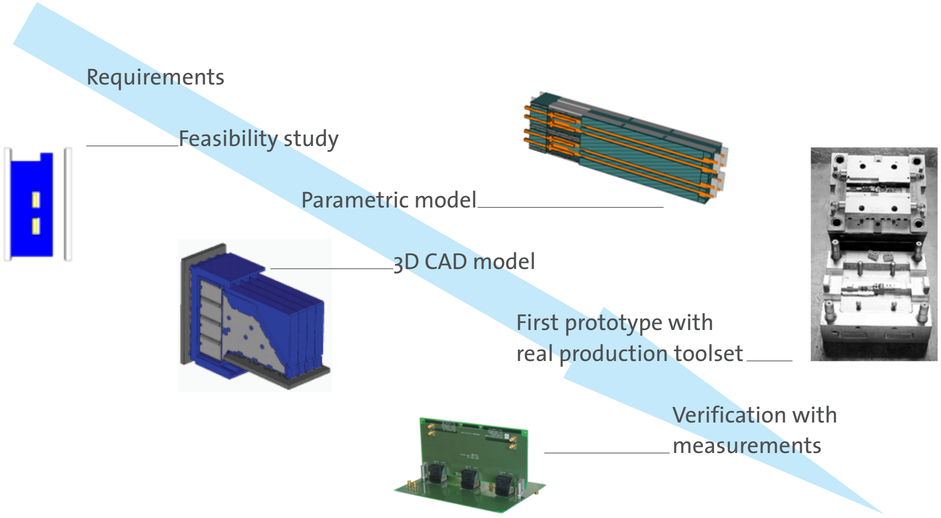

Figure 2: Design and prototype process flow

Once the requirements have been defined, a study is performed to establish the conductor dimensions. The main parameters are the trace width and the distance between the differential signal pair of the connector in addition to the distance between the 2 signal pairs inside the wafers. In the design process it is necessary to obtain a realistic prediction of the overall communication system performance. The s-parameters of the parametric connector model were exported in touchstone format and used in a 3rd party circuit simulator for further analysis. An accurate analysis must include the behavior of not just the connector but also the connector to PCB board interface, the backplane, daughter cards and signal path vias. This approach allows the performance of the complete communication system to be established and not just the connector. The CST MWS model is shown in Figure 3. It consists of 3 wafers with 4 signal pairs per wafer. It was used to verify the impedance matching, reflection, crosstalk & multiline crosstalk, to generate a SPICE model and to determine the overall system behavior based on the obtained s-parameters.

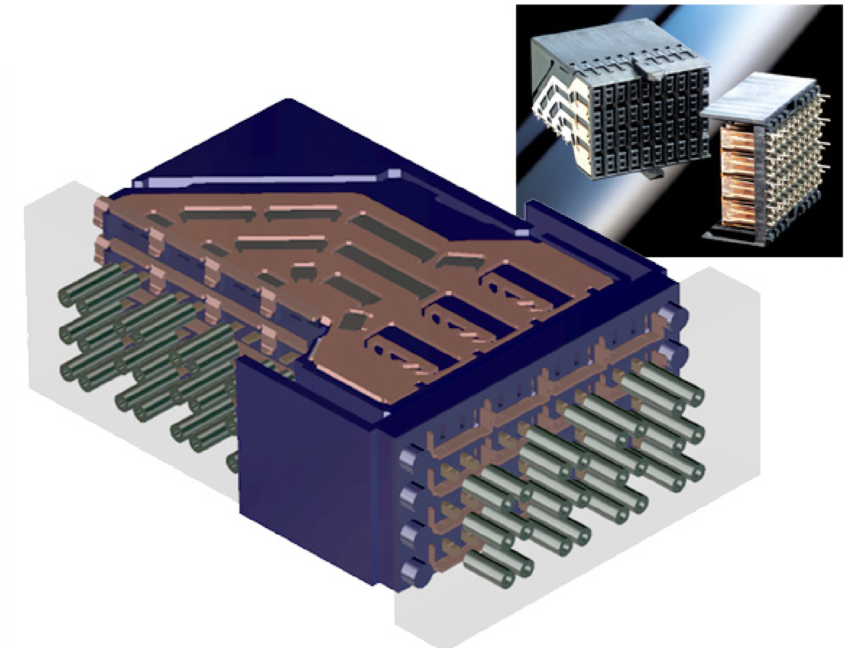

Figure 3: CST MWS 3D model and photo of the prototype connector

An accurate 3D simulation using CST MWS is vital for the highly critical and expensive manufacturing process of the cutting tools and plastic housing components. In addition to the investment costs, a major issue is the time at which the first sample is obtained since time consuming changes to the production tools may be necessary if the sample does not meet the required specifications. The overall time to market is an important factor that is heavily influenced by the design, prototype and test phases. The stamping and molding tools are designed and manufactured to allow high volume production of the connector system. The investment costs for those tools are in the range of 1 million Euros for one type of the connector, meaning that the prototyping stage is the most expensive part of the design process.

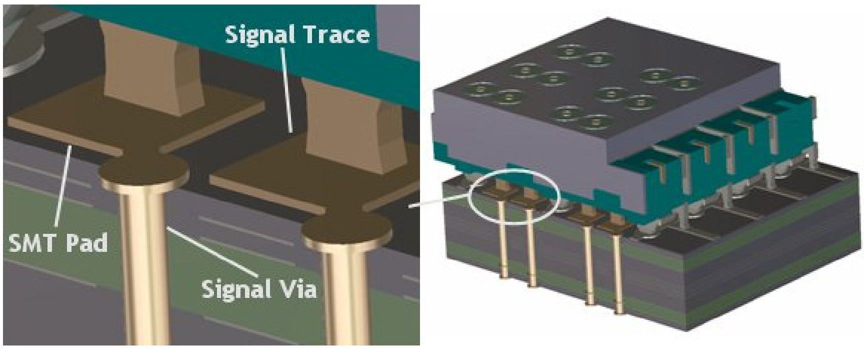

Figure 4: CST MWS model of the PCB-connector interface

A reliable 3D electromagnetic simulation (performed here using CST MWS) is therefore vital for obtaining accurate results during this process. The connector to PCB interface, shown in Figure 4, is one of the most limiting factors in speed performance. Parametric studies have been performed to optimize this interface with respect to the reflection and crosstalk behavior.

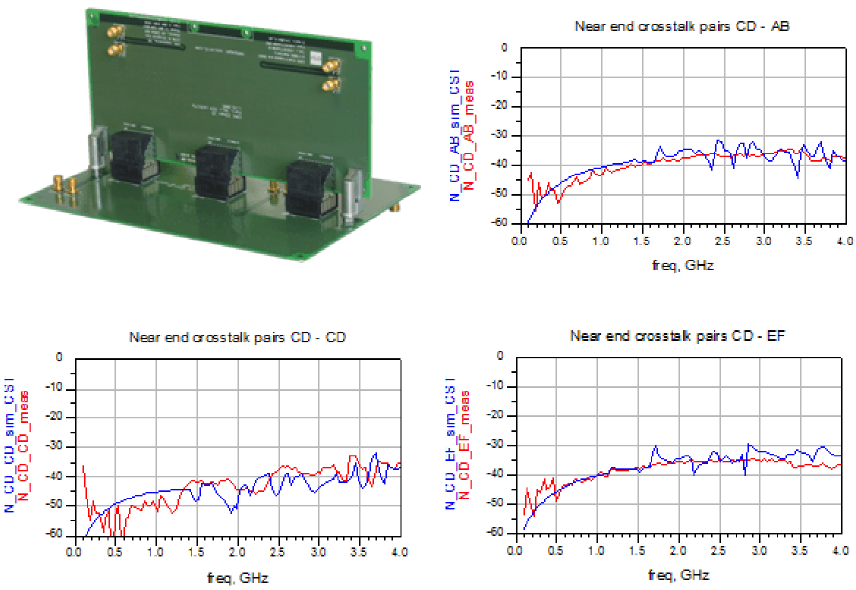

Figure 5: Test setup and measurement results

A test vehicle (PCB) was designed to verify the simulated connector behavior with measurements using a Time Domain Reflectometer and a Vector Network Analyzer. This testboard, shown in Figure 5, contains special de-embedding structures. The simulated results show excellent correlation with the measurement results proving the effectiveness of the simulation process, and moreover, the accuracy of the 3D simulations.

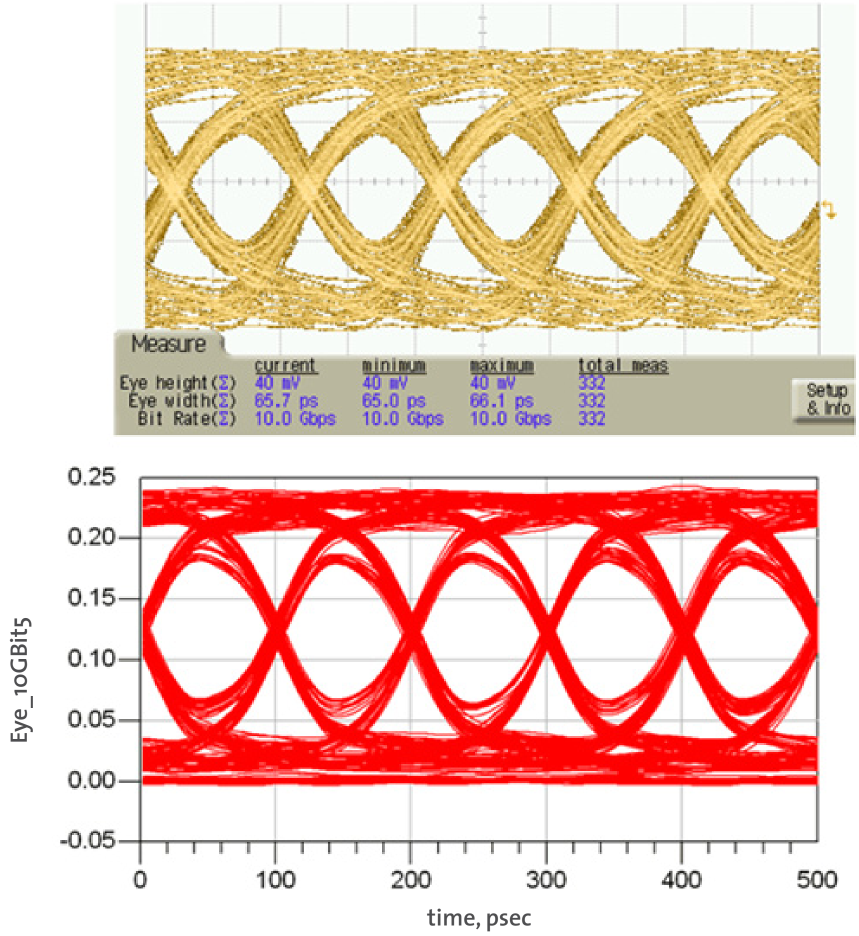

Figure 6: Eye diagram comparison between simulation and measurement

Figure 6 shows a comparison of the eye diagrams between a complete system simulation including the connector and test boards and the appropriate measurements done on the real system. The upper diagram shows the measured eye diagrams while the lower one shows the simulated ones. A data stream signal with 10Gbit/s of a NRZ 8B10B code was applied to both the real and the simulated systems. Good agreement between the simulated and measured results can be seen.

Conclusion

This article has shown the complete design flow of a complex electromechanical device including first rough estimations and ending in complete system simulations. This project demonstrates how the usage of modern simulation tools leads to the dramatic decrease in design time and an overall reduction in costs thanks to a one-pass design cycle. All molding and stamping tools for manufacturing this connector were produced without a major rework. SPICE / Touchstone models of the ERmet zeroXT connector were used in system feasibility studies before the first samples were produced.