3D Simulation of high-speed serial interface design

by

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Objective

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- Investigate package associated parasitic effects of a 64-pin Shrink Quad Flat Package (SQFP).

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- Package contains a test chip used as physical layer implementation of a high-speed serial link.
- Investigations have to be performed with the help of a 3D electromagnetic solver - CST Microwave Studio 5 -.

State of the Art

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  - → higher number of I/O pads.
- Systems becoming smaller leads to
  - → packages with higher complexity.
  - → closely spaced interconnects and narrow pitch interval.

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- First-order calculations by mathematical formulae.
- Direct measurements with Time - domain Reflectometry (TDR) techniques.

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Electrical Characterization

- First-order calculations by mathematical formulae.
- Direct measurements with Time - domain Reflectometry (TDR) techniques.
- **Computation of electric and magnetic fields using 3D field solver tools.**

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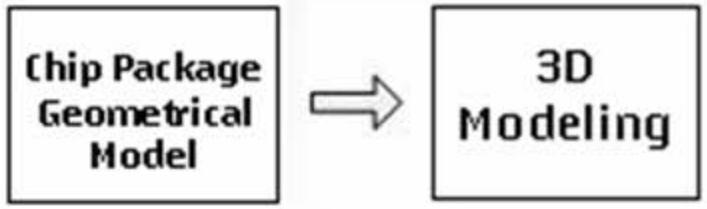
Modeling and Simulation Procedure

Modeling and Simulation Procedure

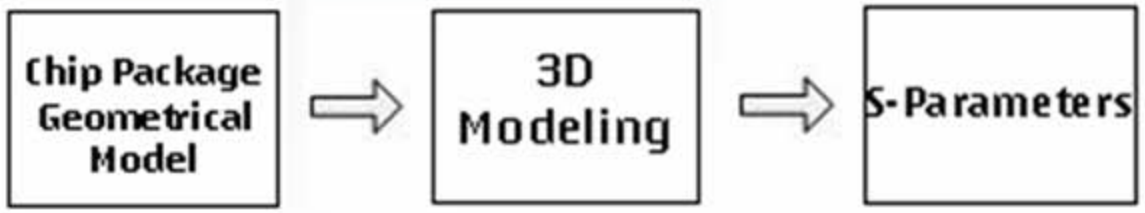
- Obtaining the package layout containing information regarding geometries and material parameters for the compound and firts and second level interconnects.

Modeling and Simulation Procedure



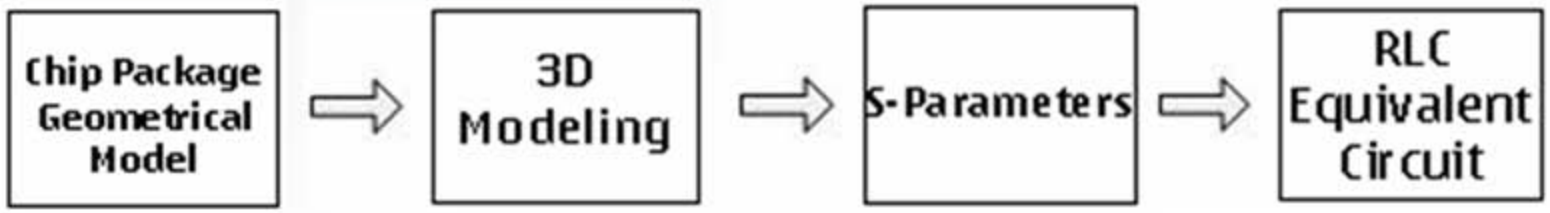
- Building the 3D model in CST MWS.

Modeling and Simulation Procedure



- Time- and Frequency simulators used to generate s-parameters.

Modeling and Simulation Procedure



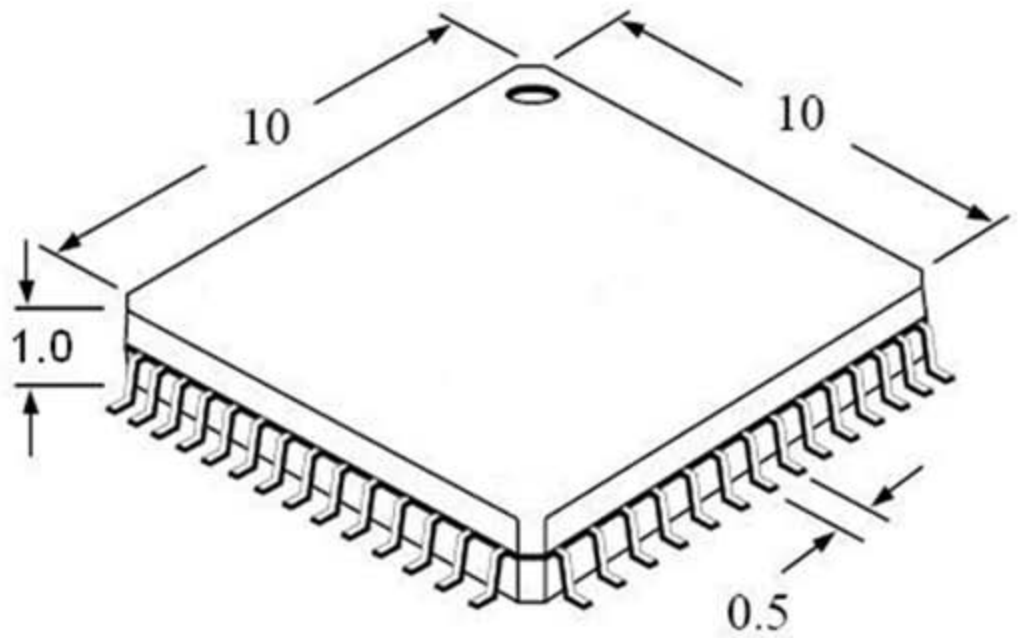
- Deriving SPICE compatible network model consisting of lumped R,L,C,G,K elements.

Modeling and Simulation Procedure

- Including the equivalent circuit into circuit simulator to identify the input of the package parasitics on the signal integrity.

Test Chip Package

- Package is 10x10 mm² small with body thickness 1 mm
- 1.4x1.4 mm² small IC with an active area of 0.01 mm² is mounted concentrically on silicon substrate
- Gold bond wire diameter is 20 µm with bond pad pitch of 70 µm
- Gull-wing shaped copper leads with lead pitch 0.5 mm



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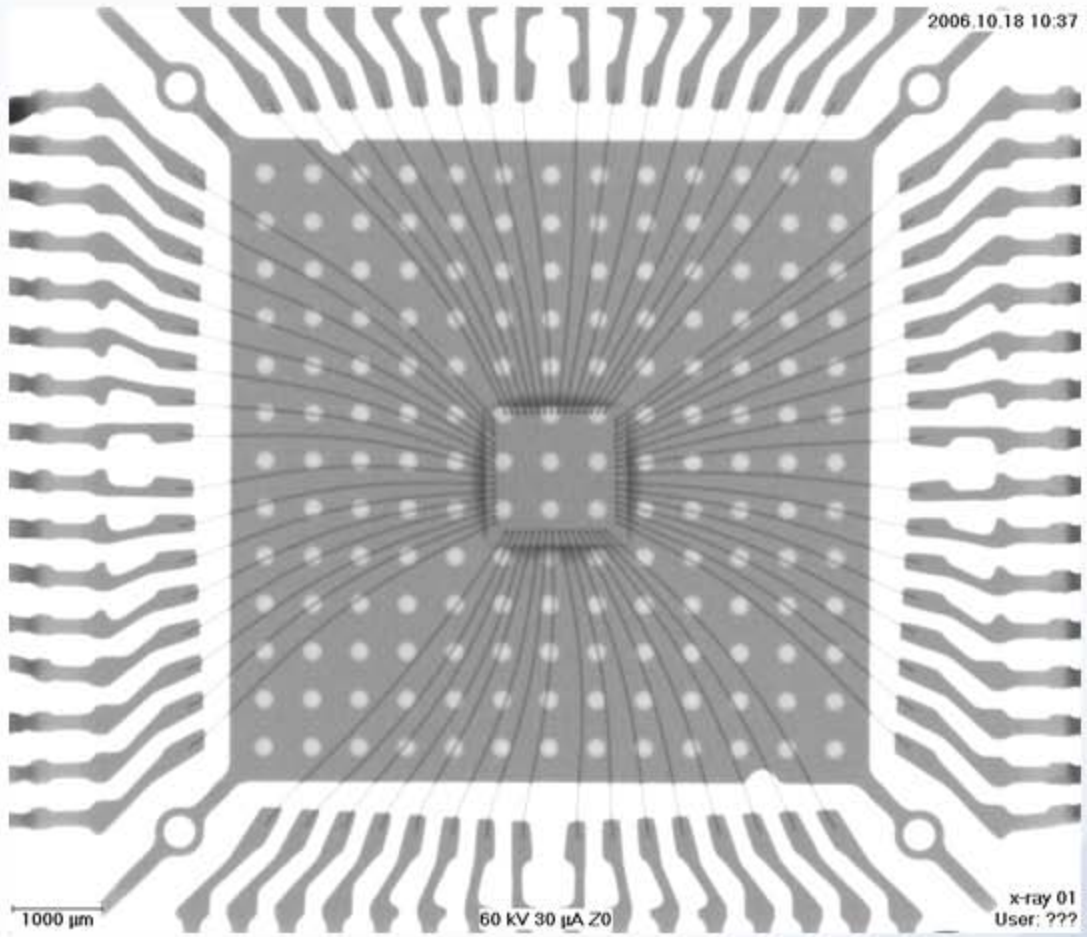

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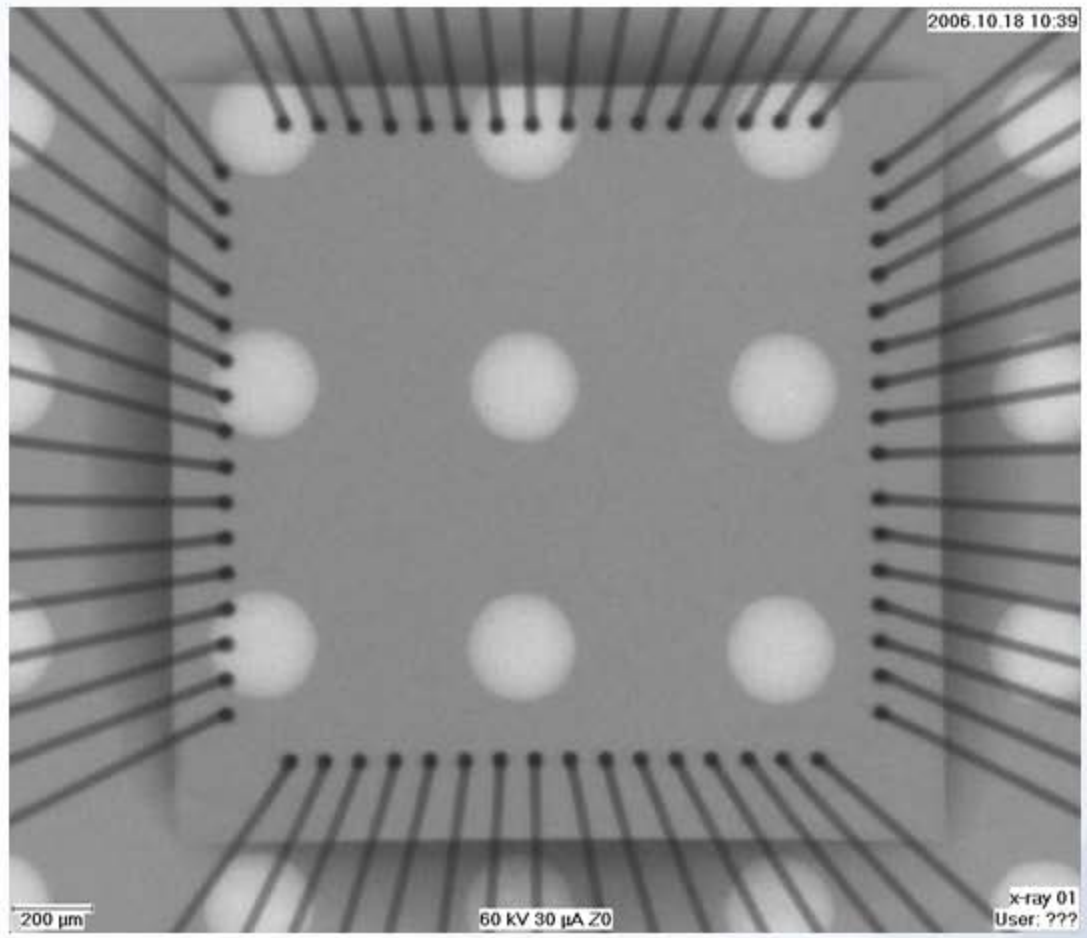

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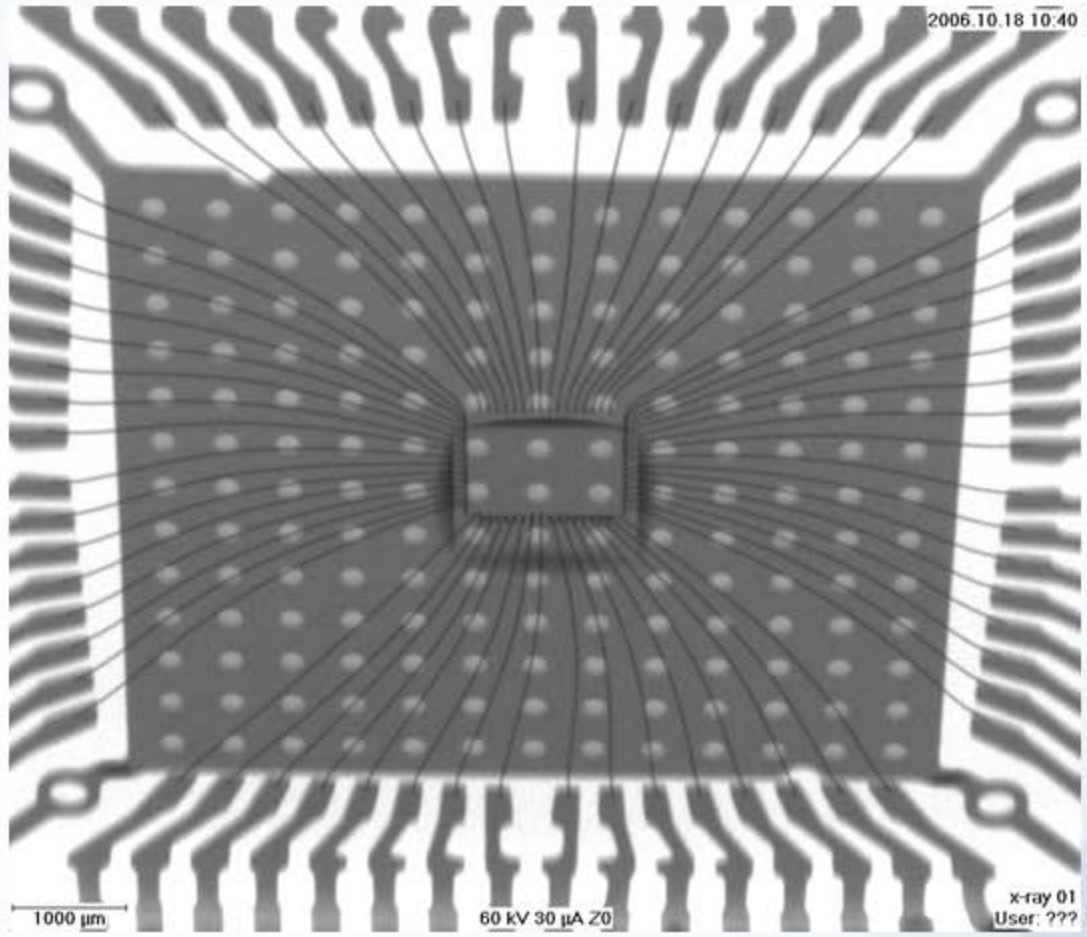

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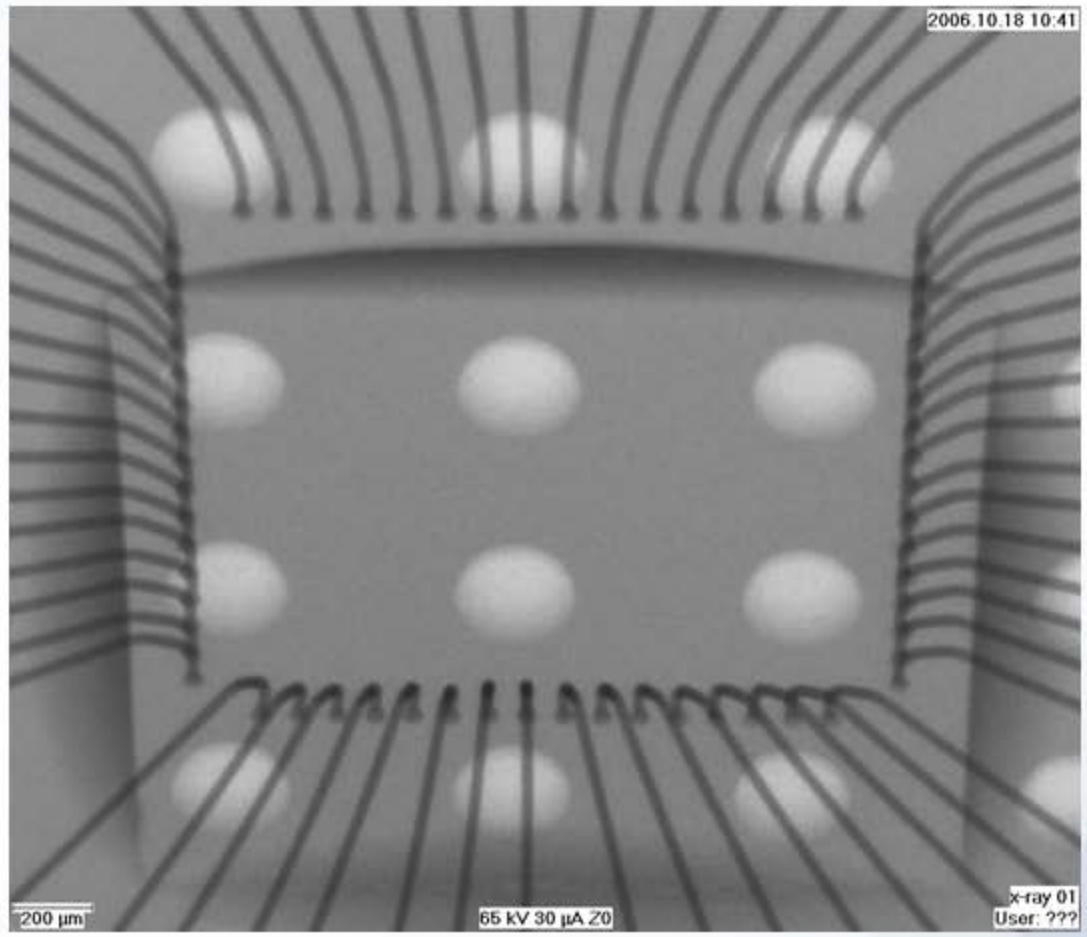

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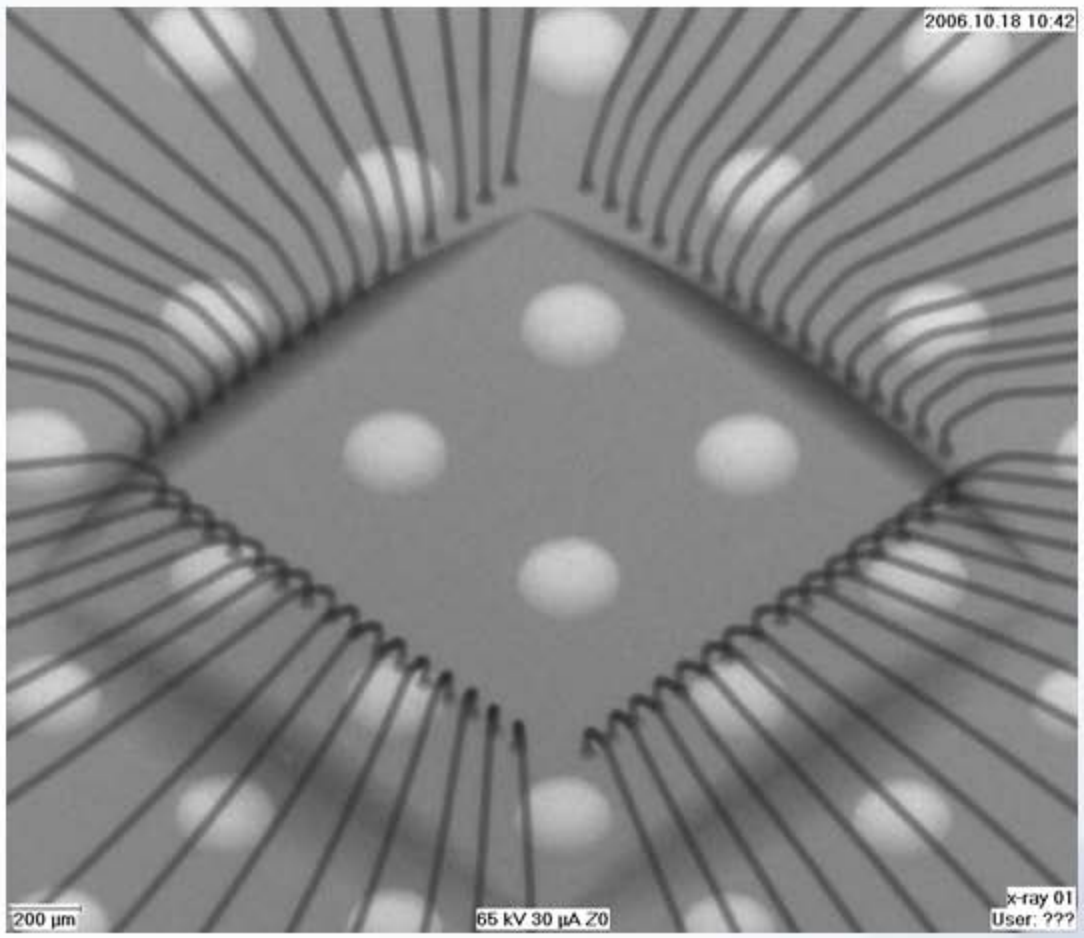

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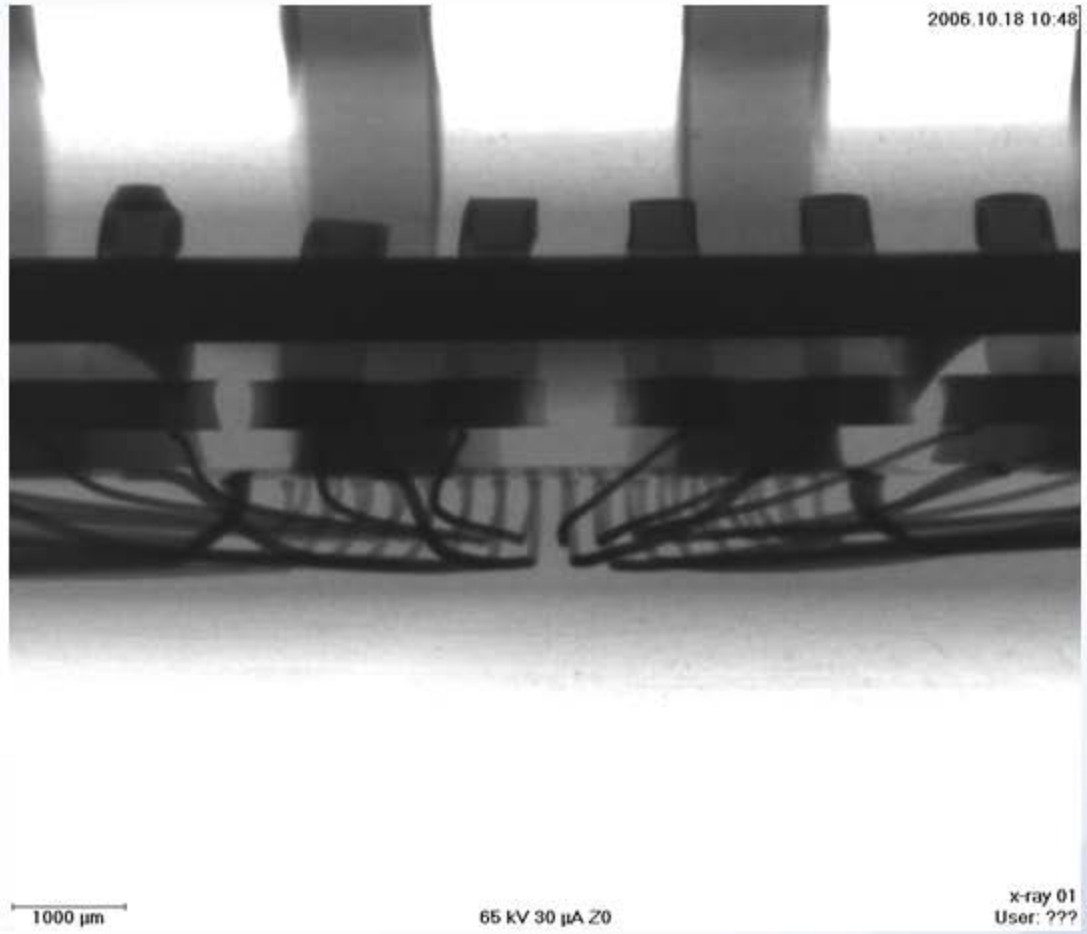

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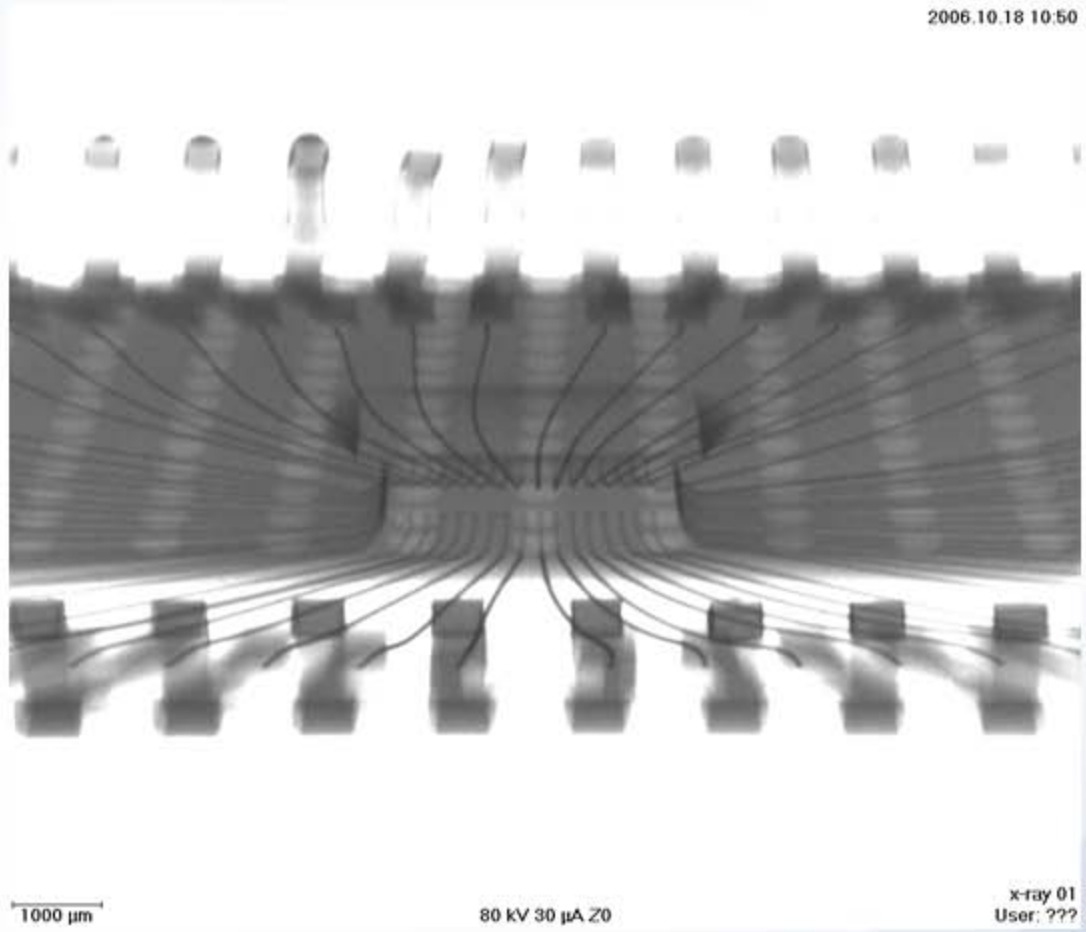

3D Model

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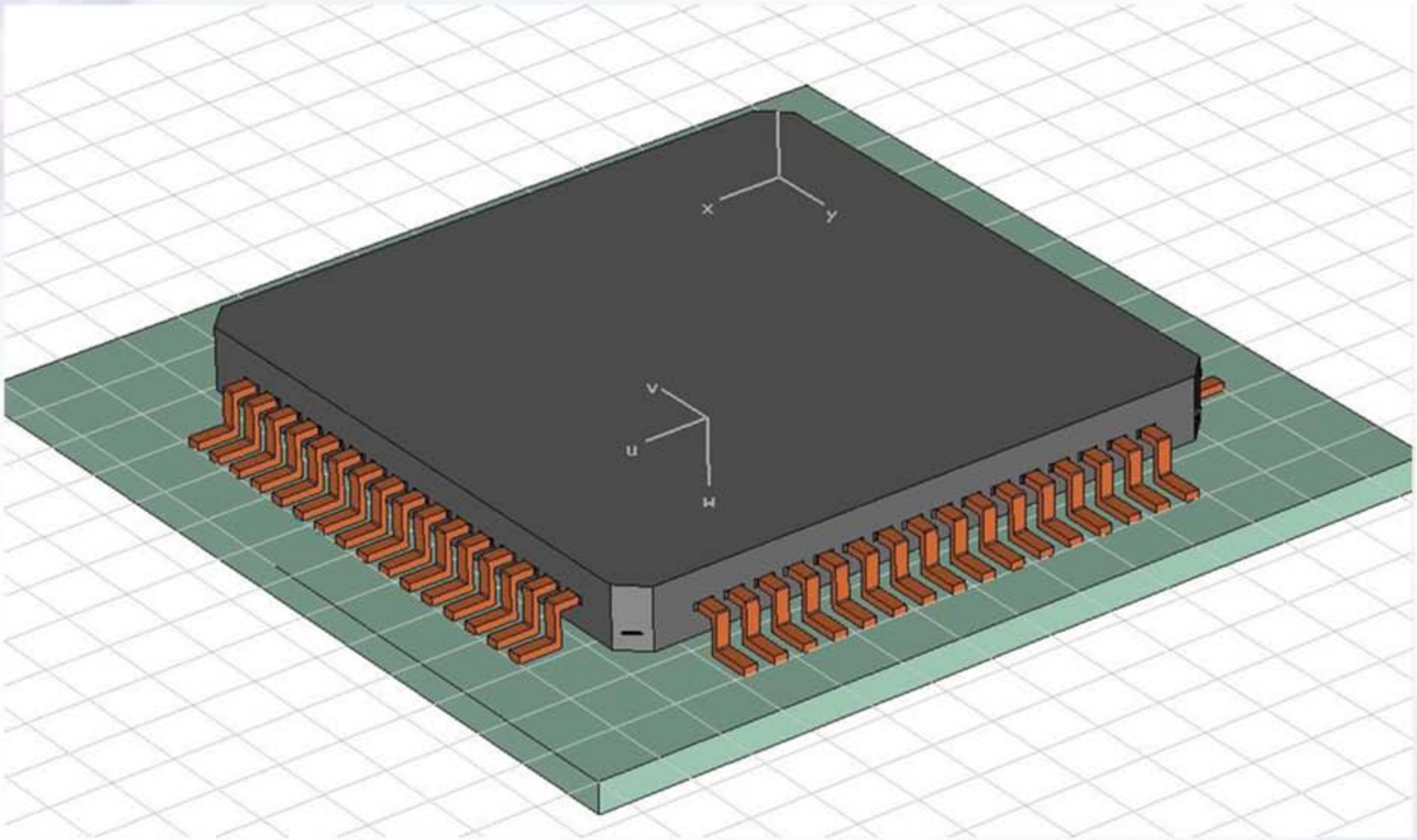

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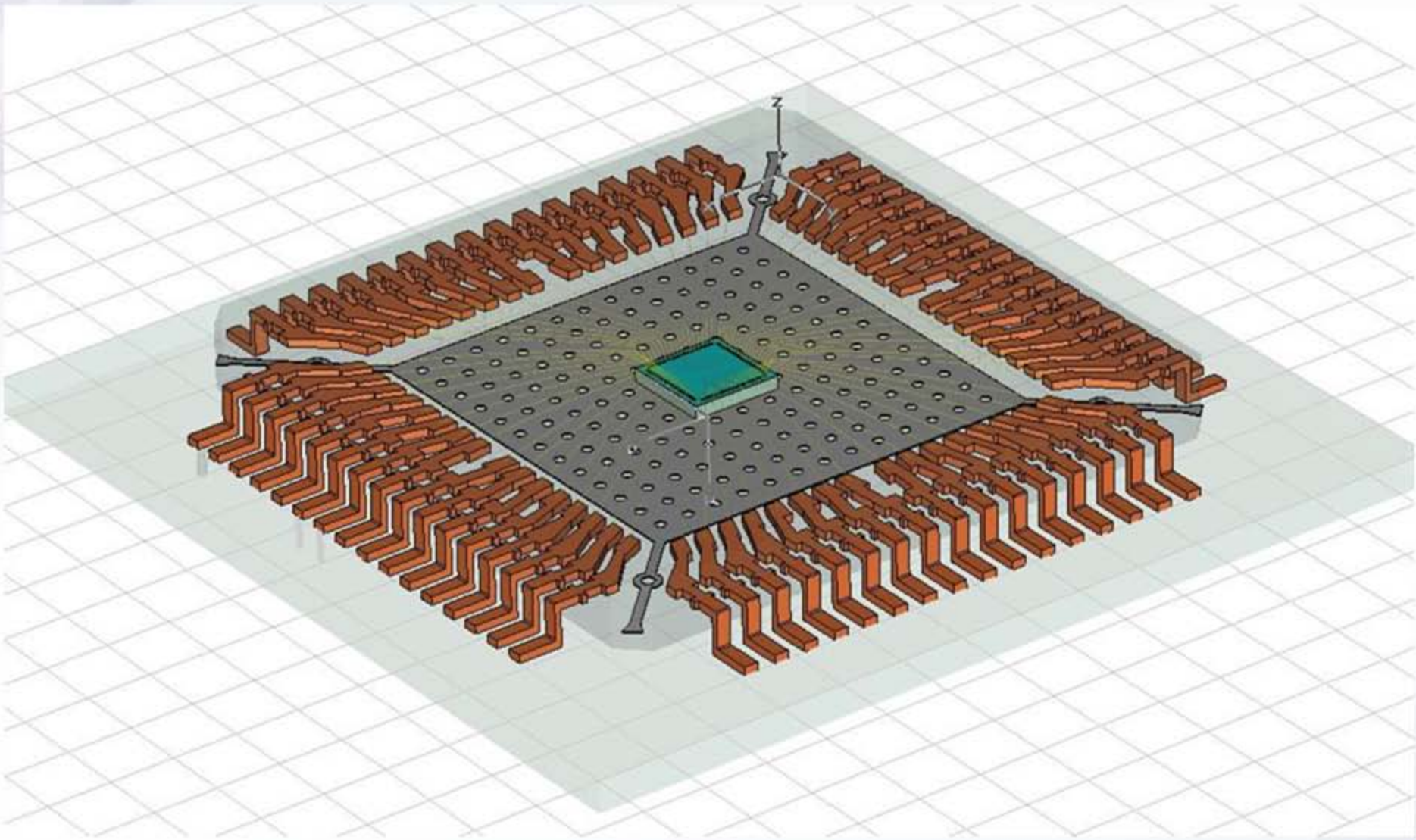

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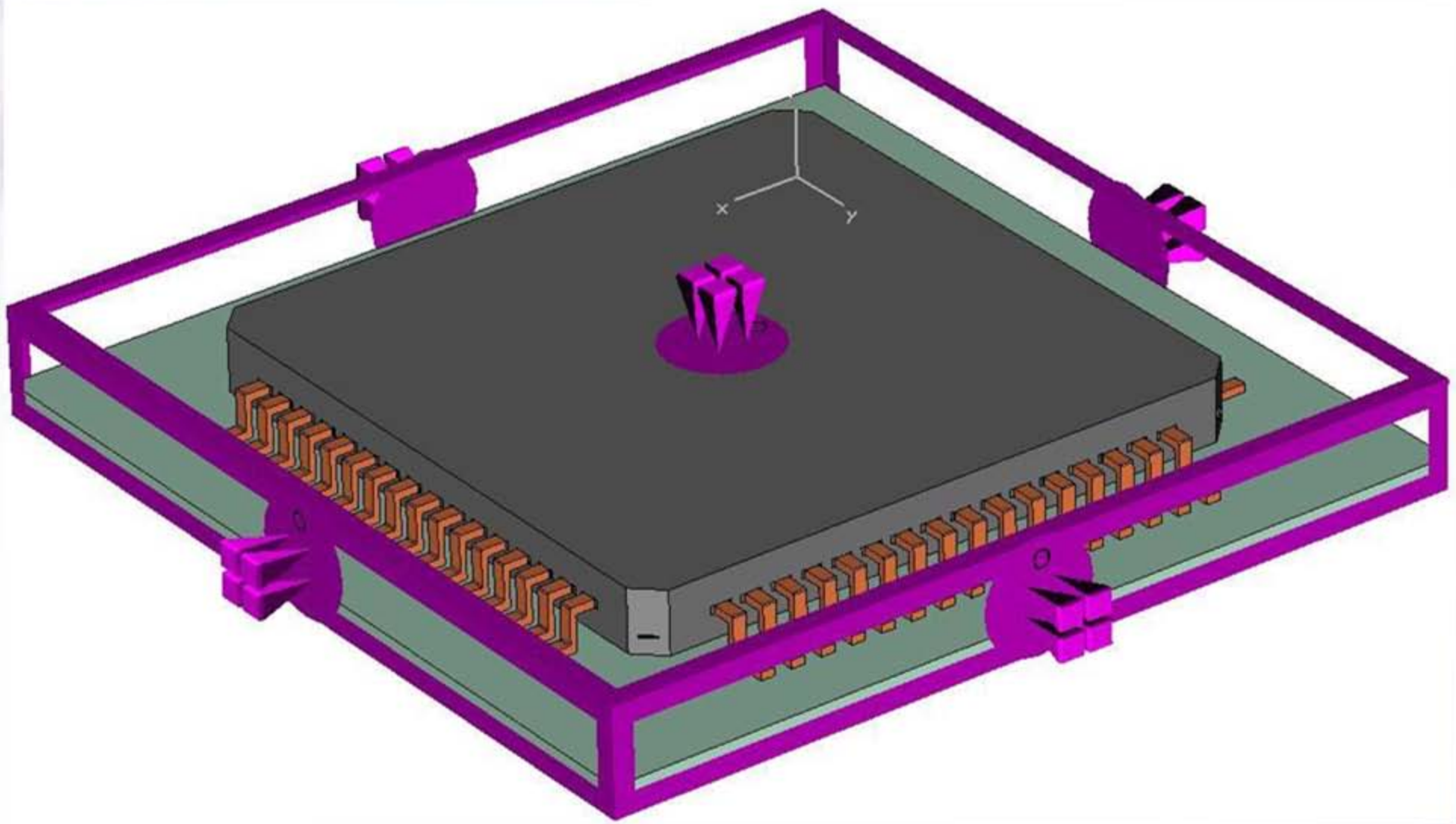

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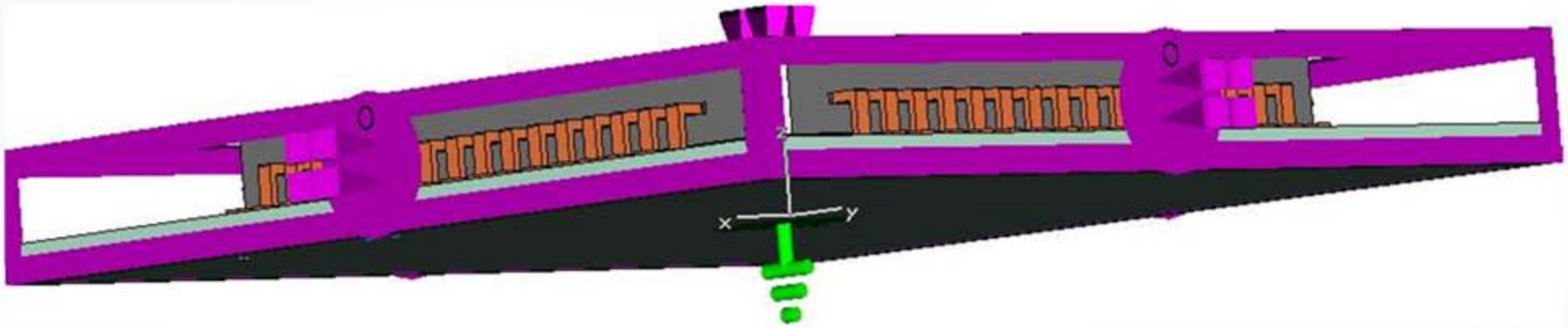

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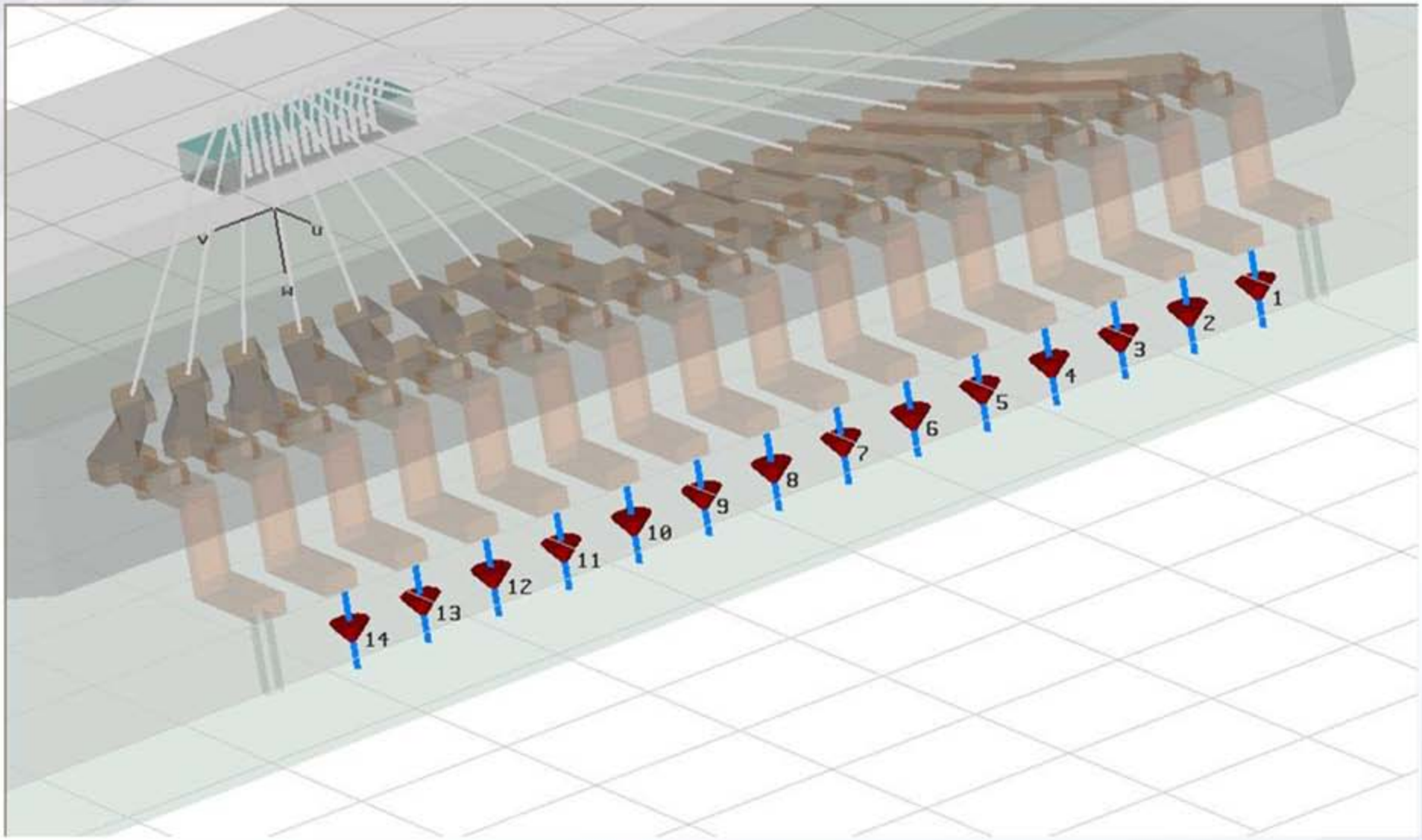

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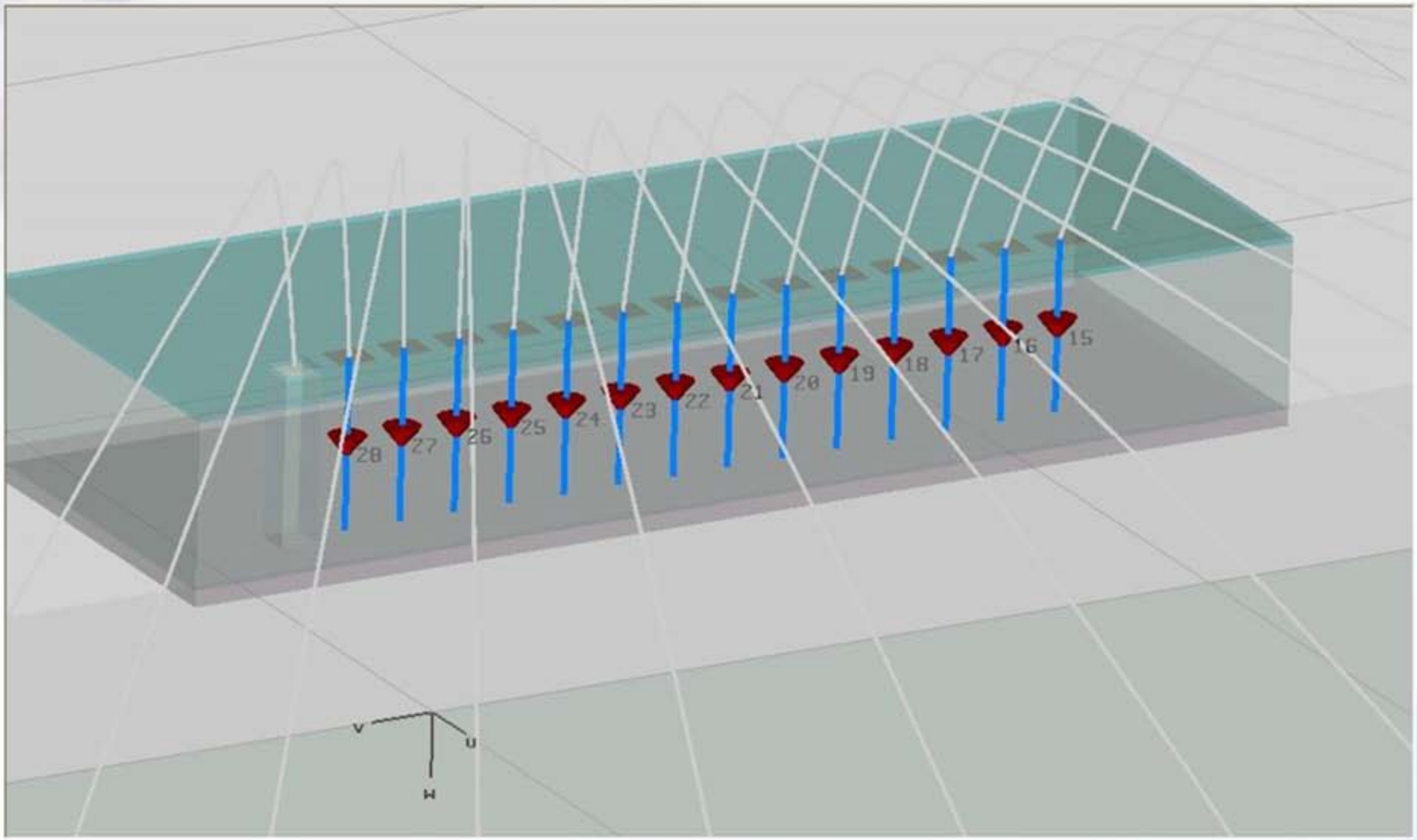
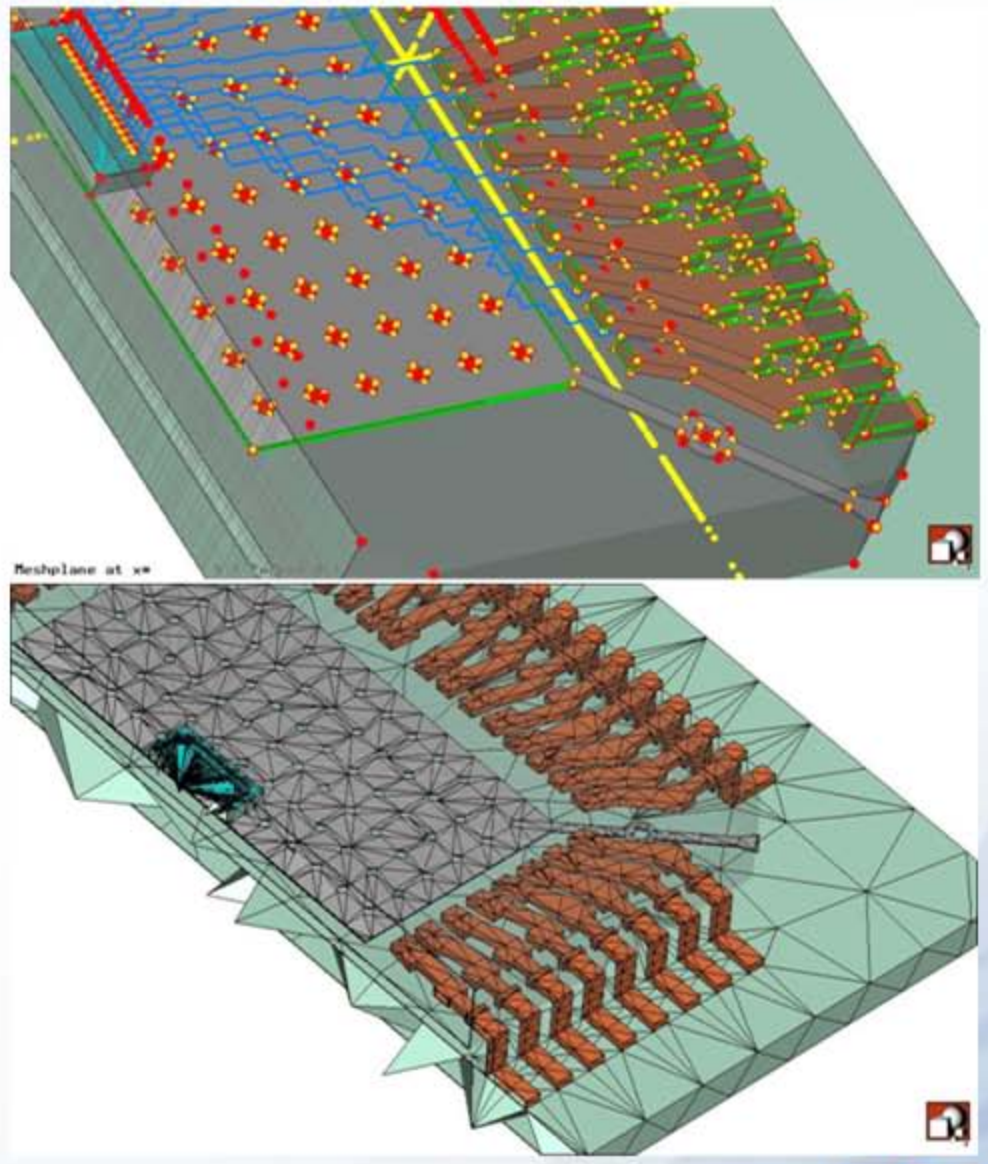


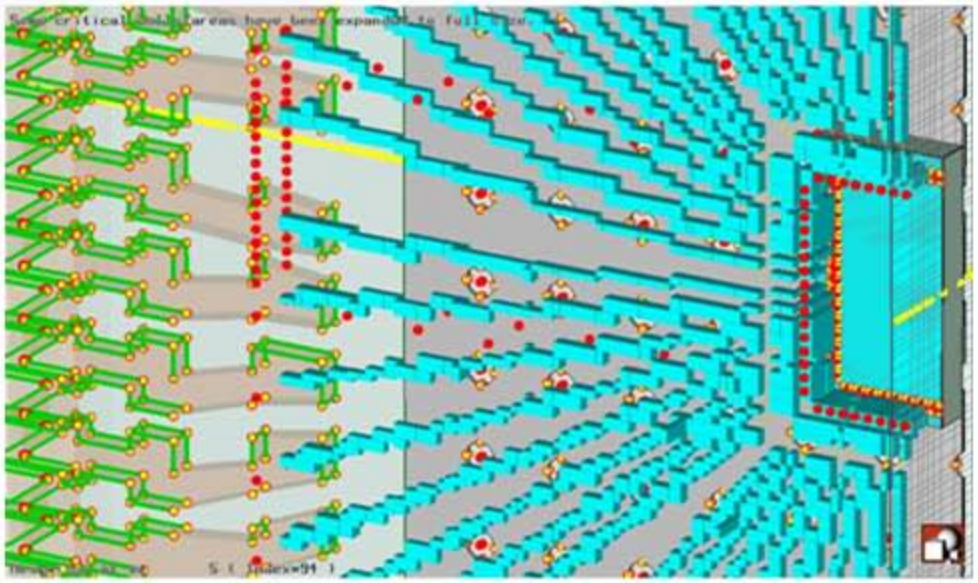
Meshing

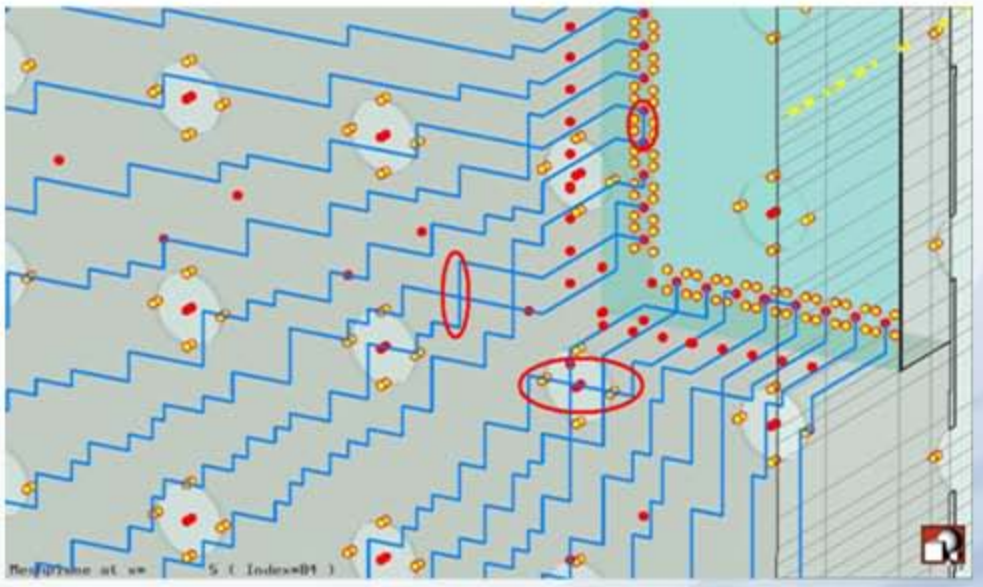
- To calculate electromagnetic properties, the structure has to be discretized
- Two different mesh types were utilised; hexahedral and tetrahedral
- Mesh density for both types can be generated automatically, adaptively or manually
- Finer mesh will lead to more precise values



Meshing Issue

- Choosing improper mesh settings will lead to coarse meshcells
- Cells will be filled with PEC material and produce numerous short circuits in the structure
- Solid wires transposed by infinetly thin wires
- Spatial sampling rate raised (20) and additional mesh step width (0.001 mm) specified for the wires => 10 mil. meshcells





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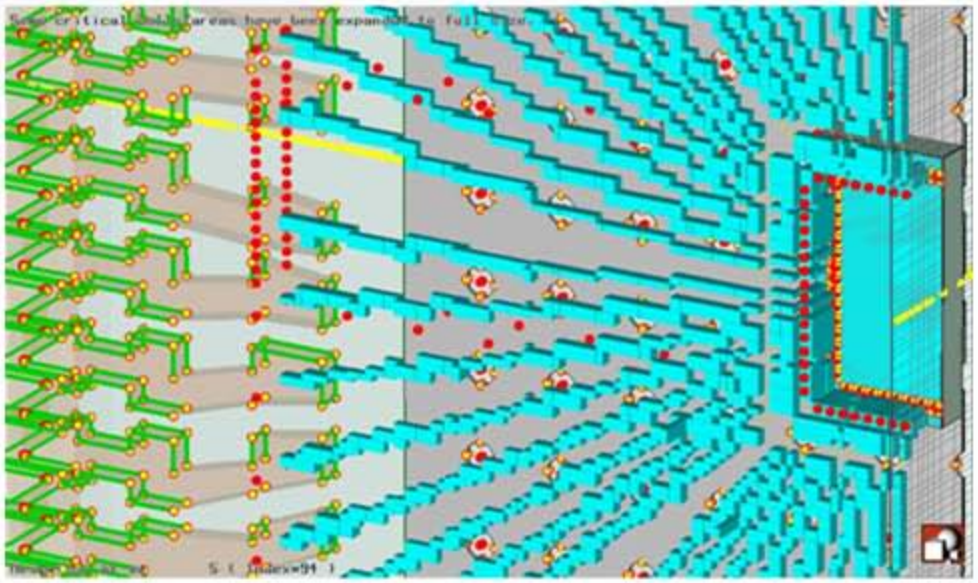

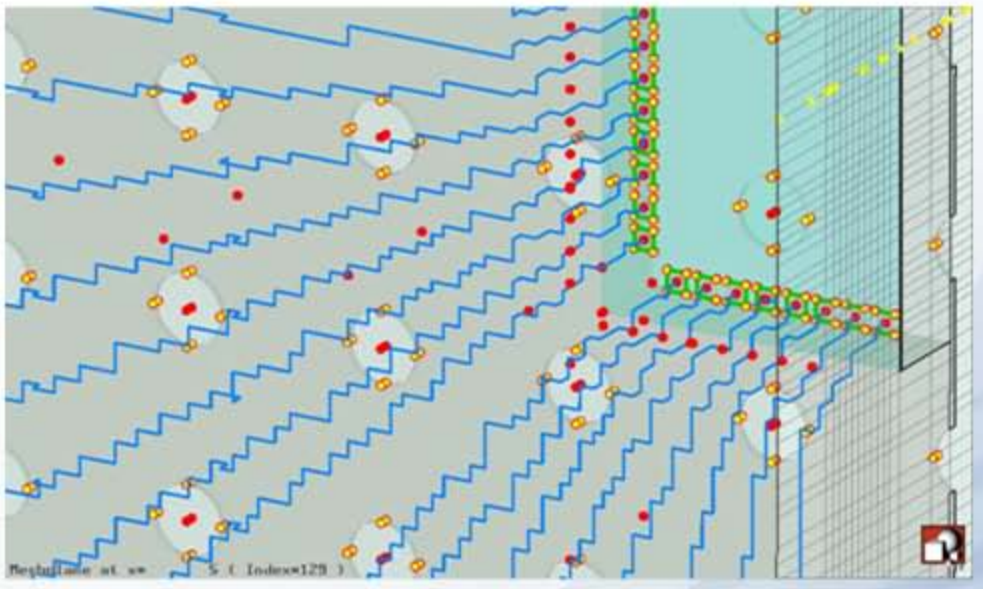

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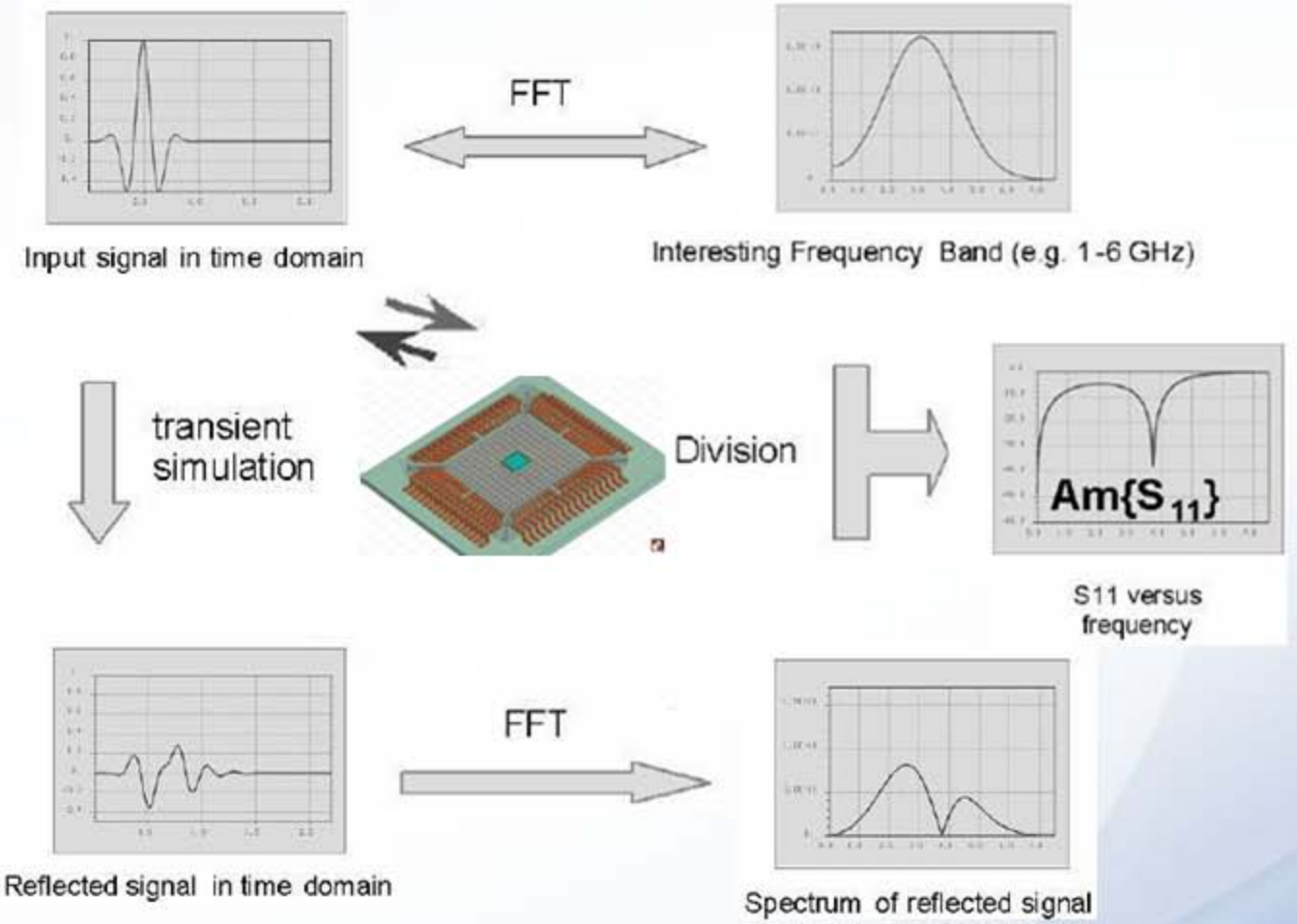
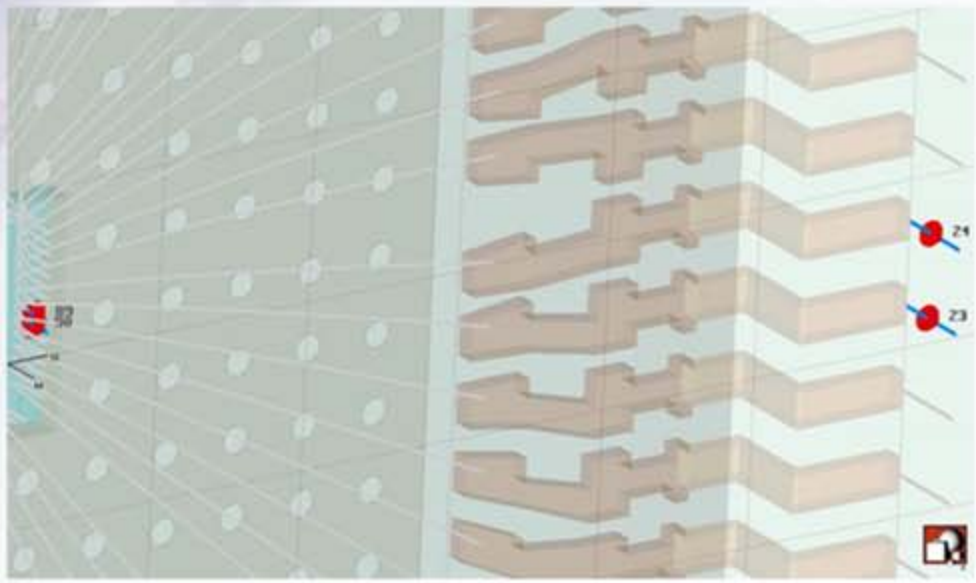
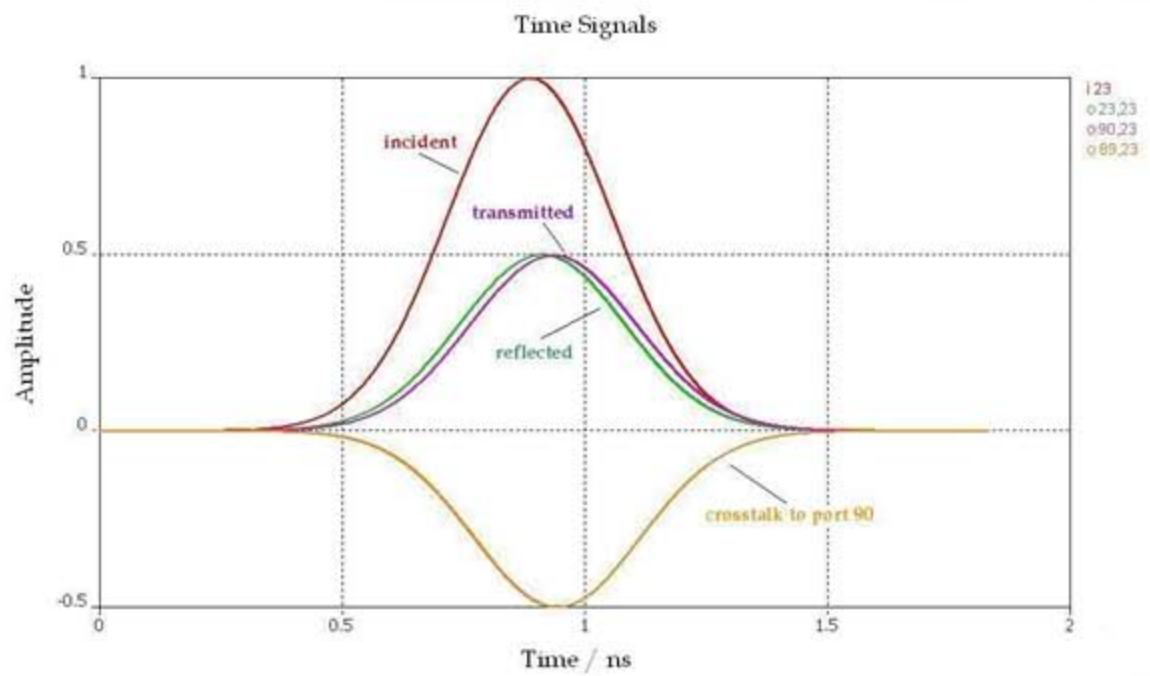
Solver Types

- Two different solver types were utilised
- Transient solver calculates propagation of electromagnetic fields over time at discrete locations and at discrete time samples
- Frequency solver solves the problem for a single frequency at time



Simulation Results of Whole Model





- Transient solver was used to analyze signal transmission and to obtain s-parameters
- Signal excitation was performed on two innermost ports and their opposite outermost ports
- Signal curves and s-parameters showed an unusual transmission behavior

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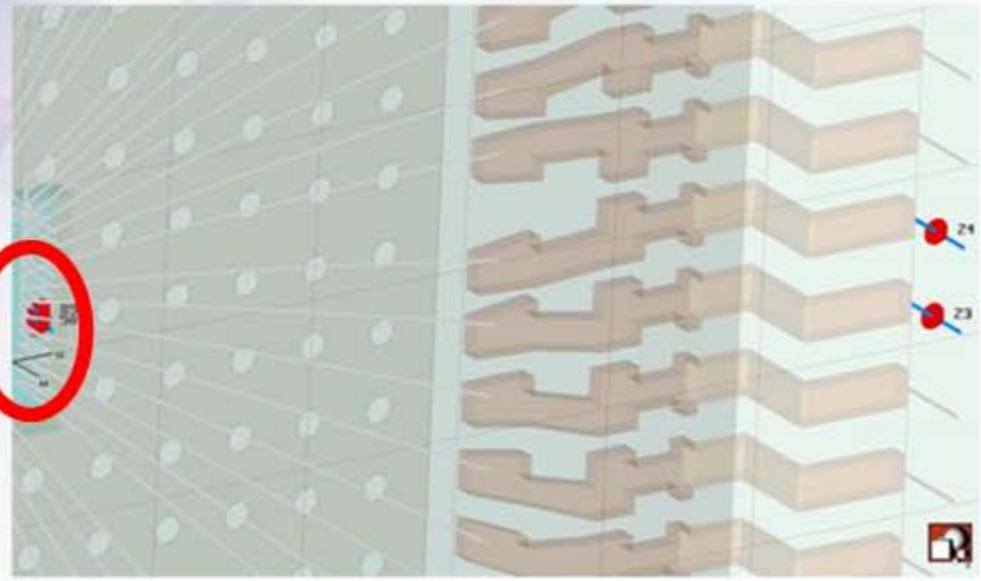

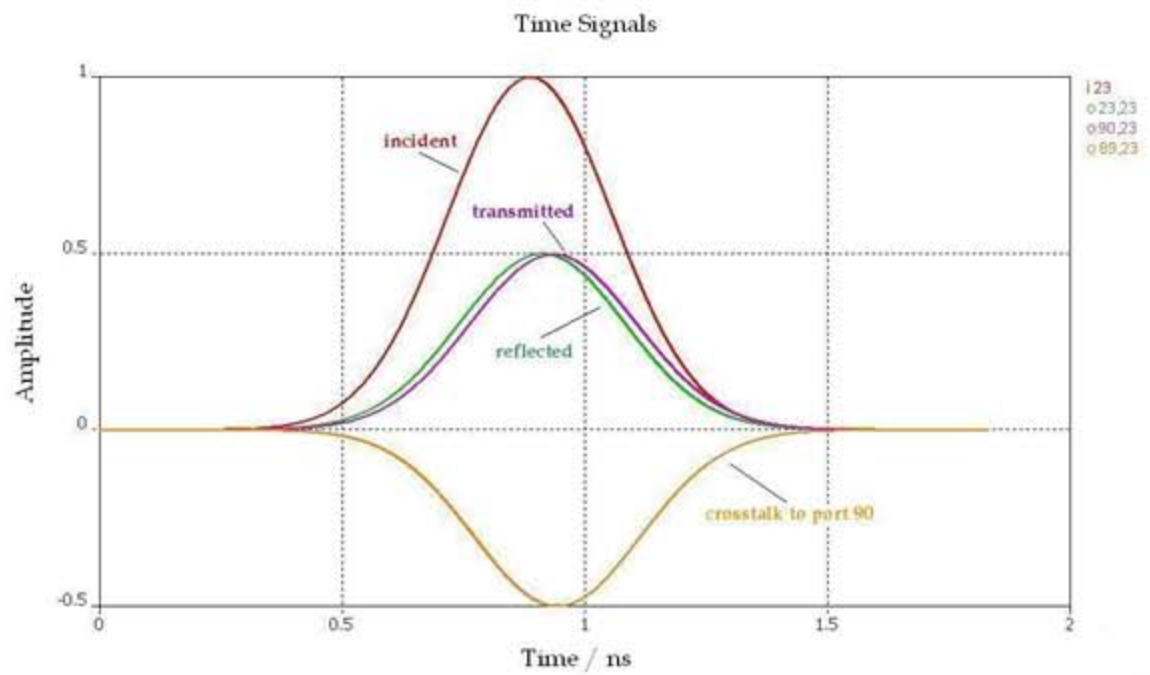

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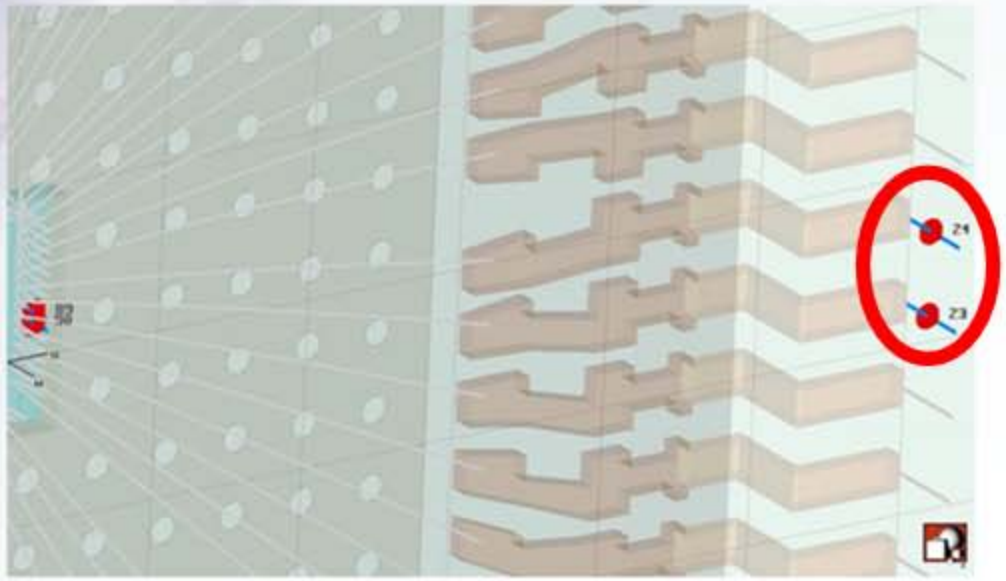

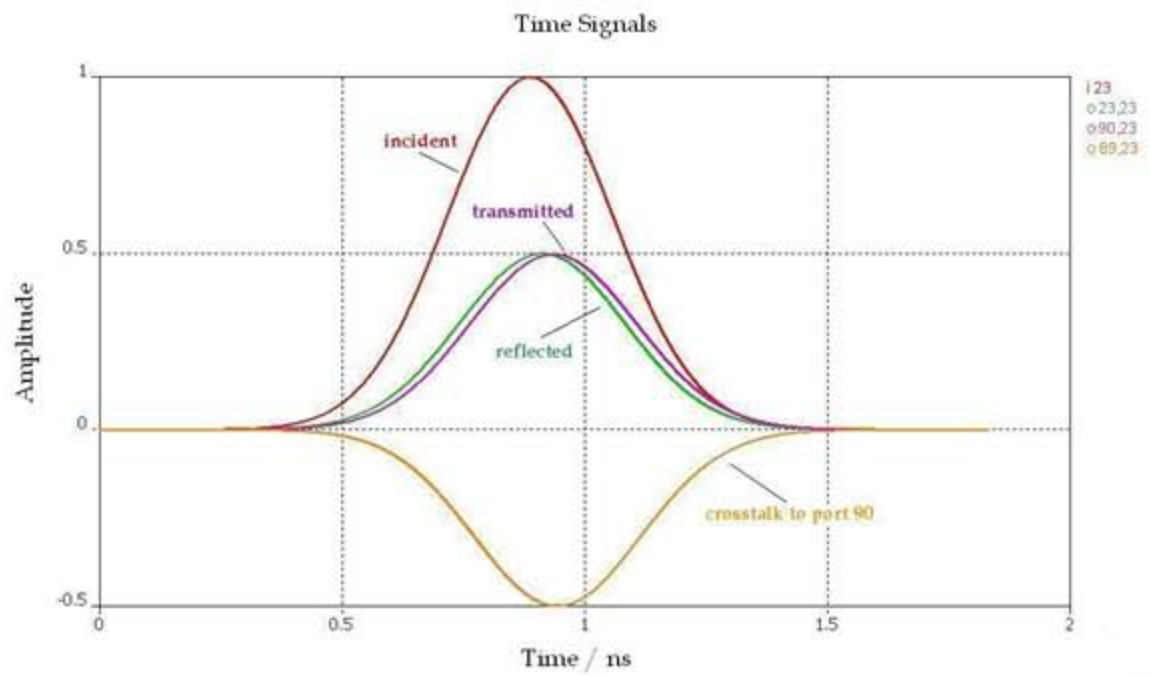

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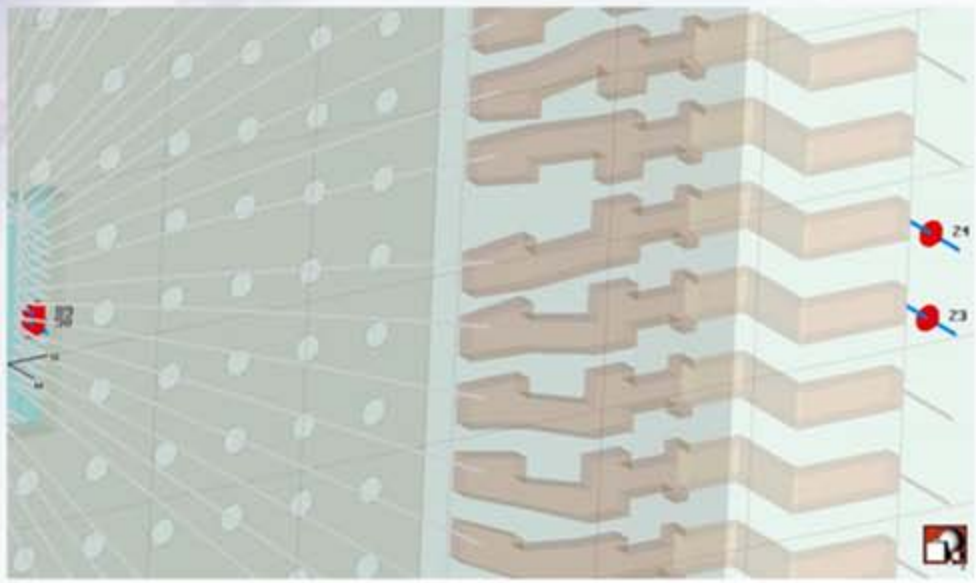

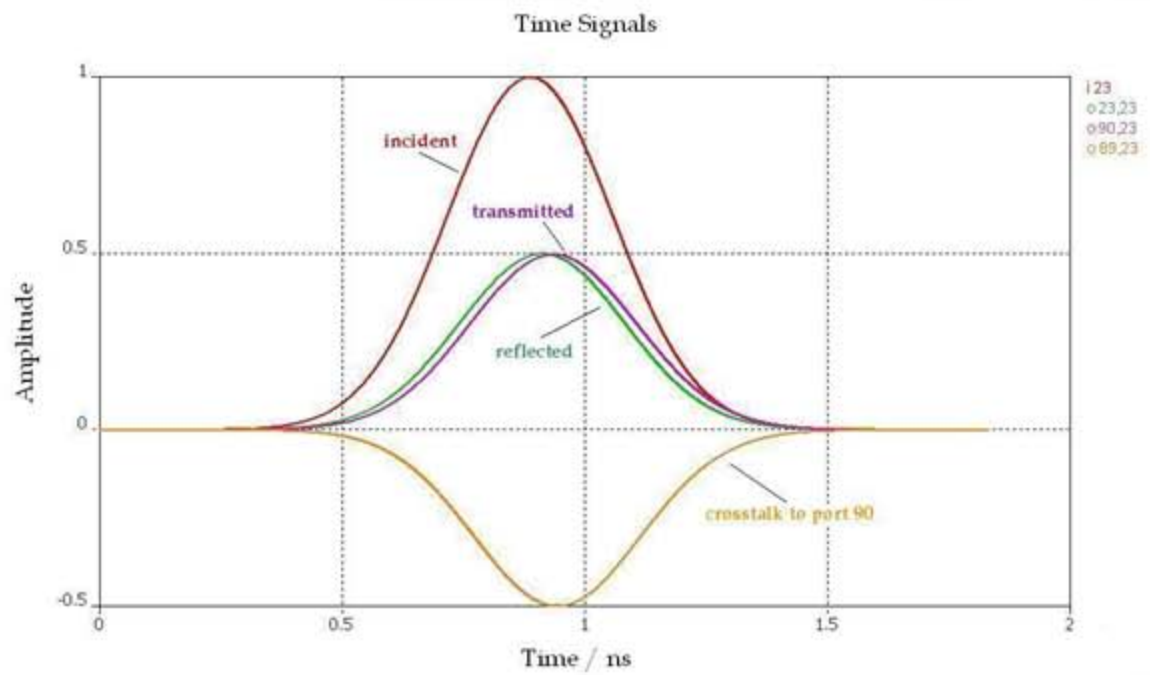

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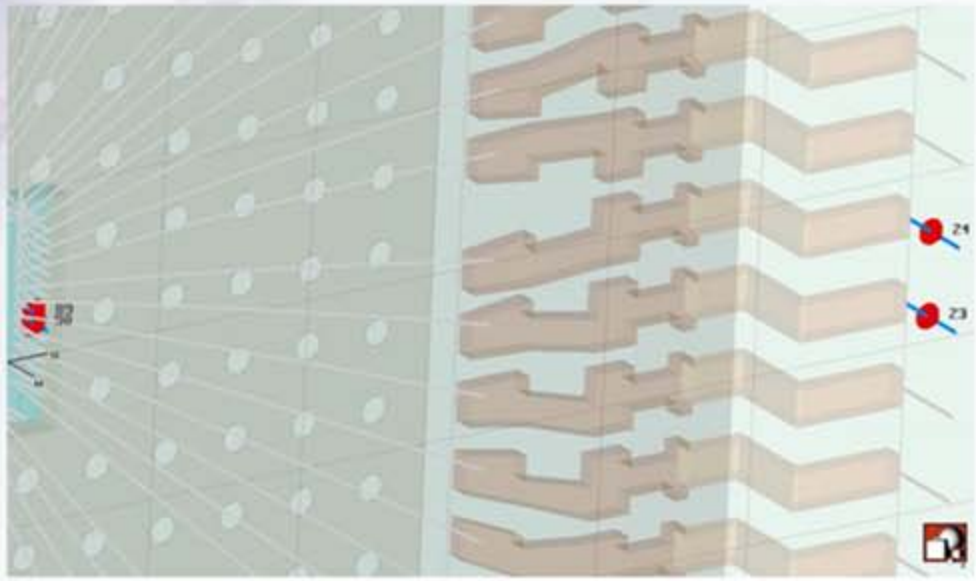

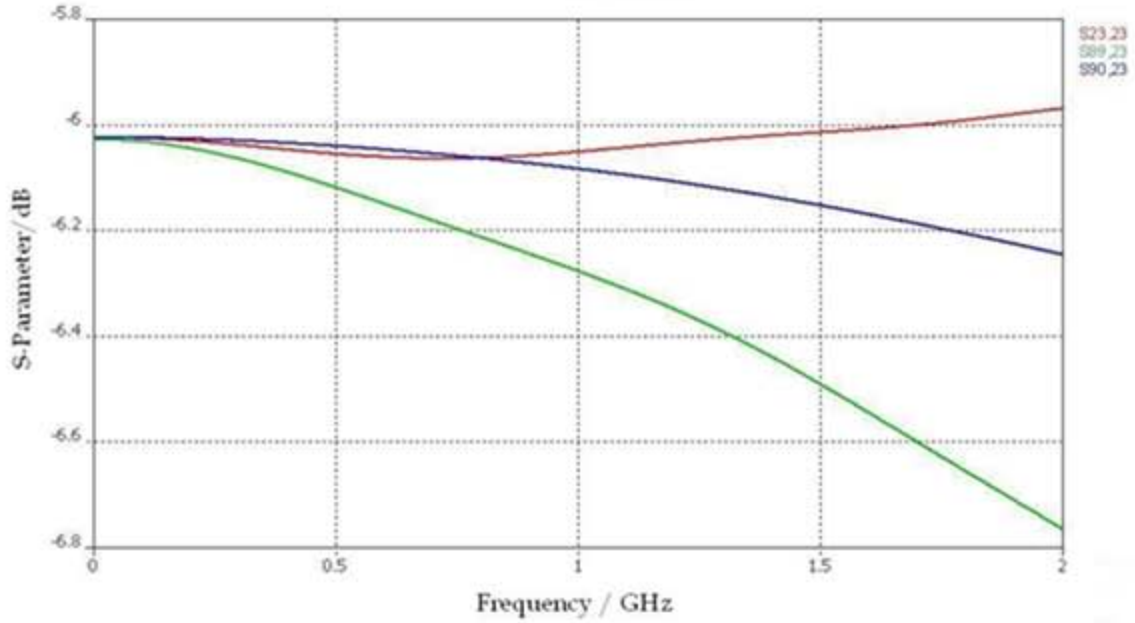

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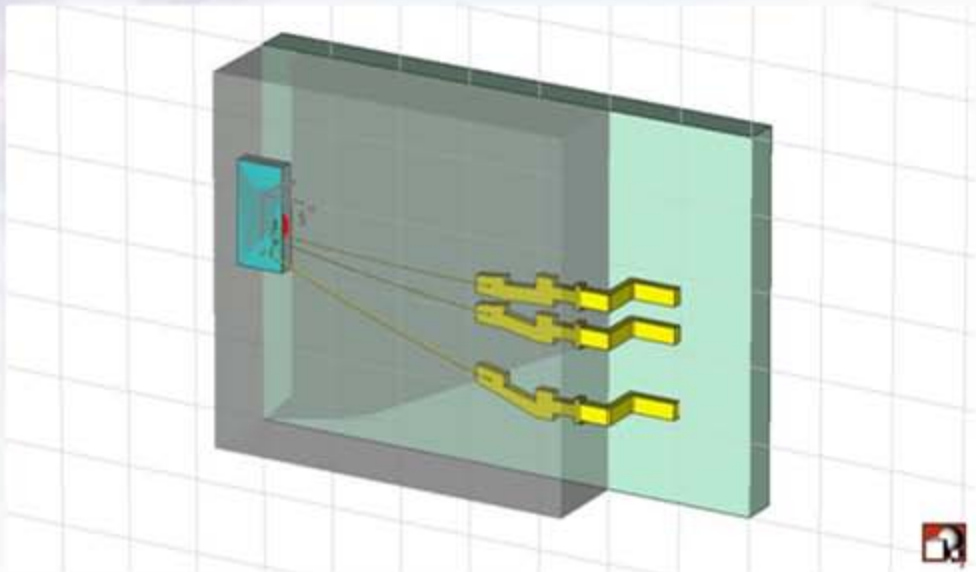
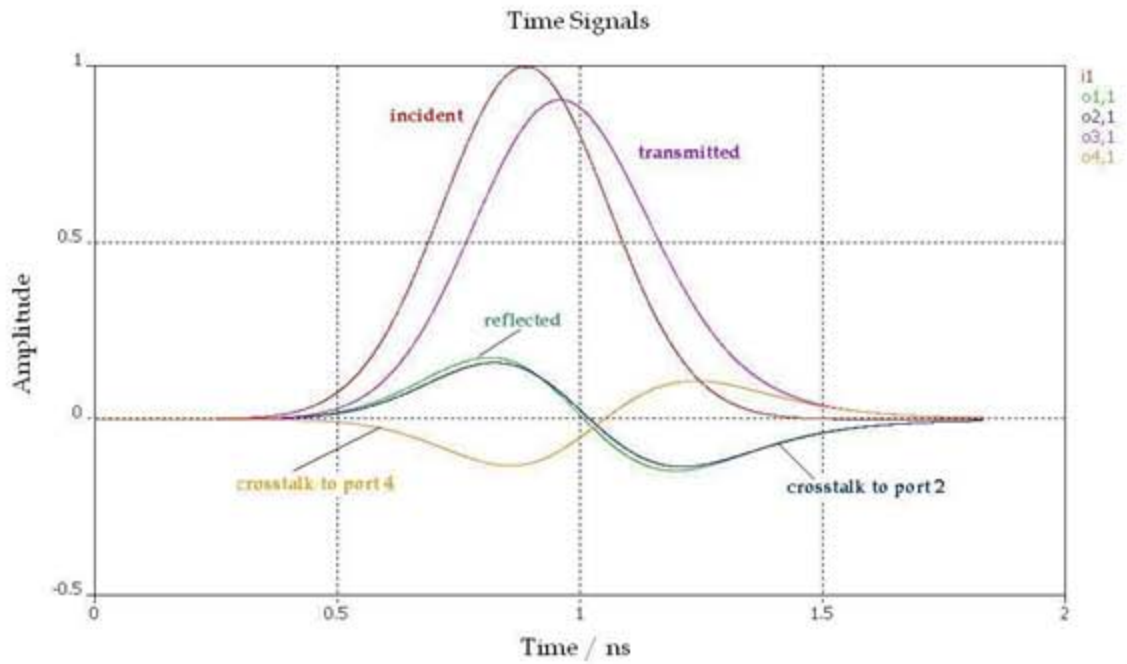
Simulation Results of Small Model





- Smaller model with dimensions of 5x5 mm² consist of a quarter of the whole package.
- Contains two signal leads and an additional lead which is used as a ground lead connecting both ground planes.
- Signal curves and S-parameters show a comprehensible transmission behavoir of the structure.

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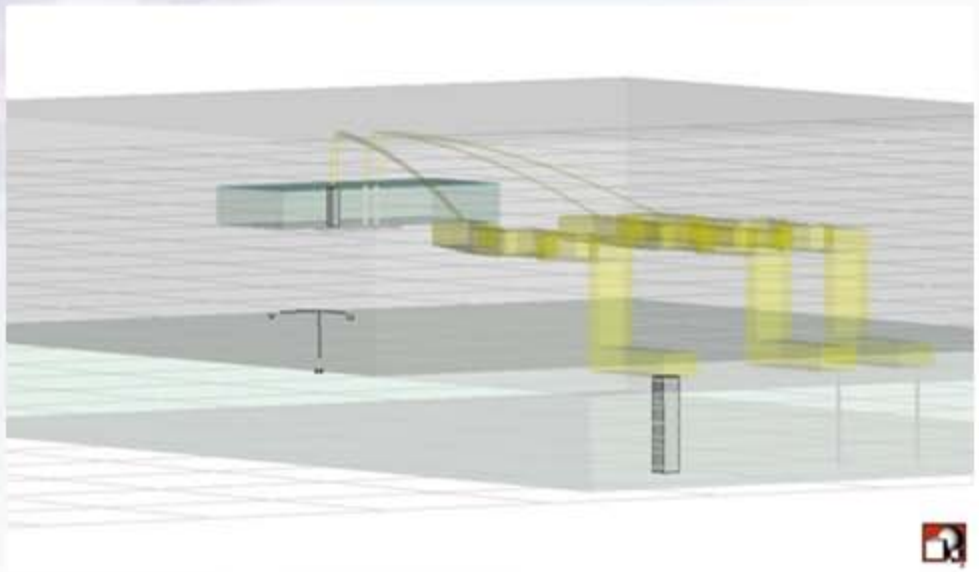

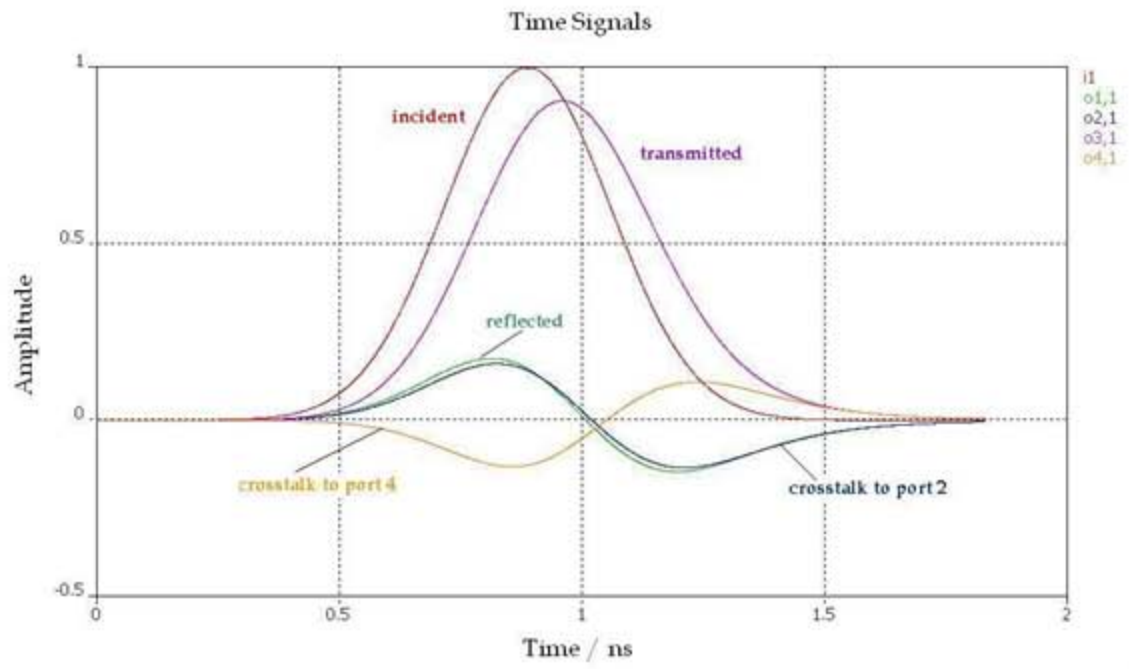

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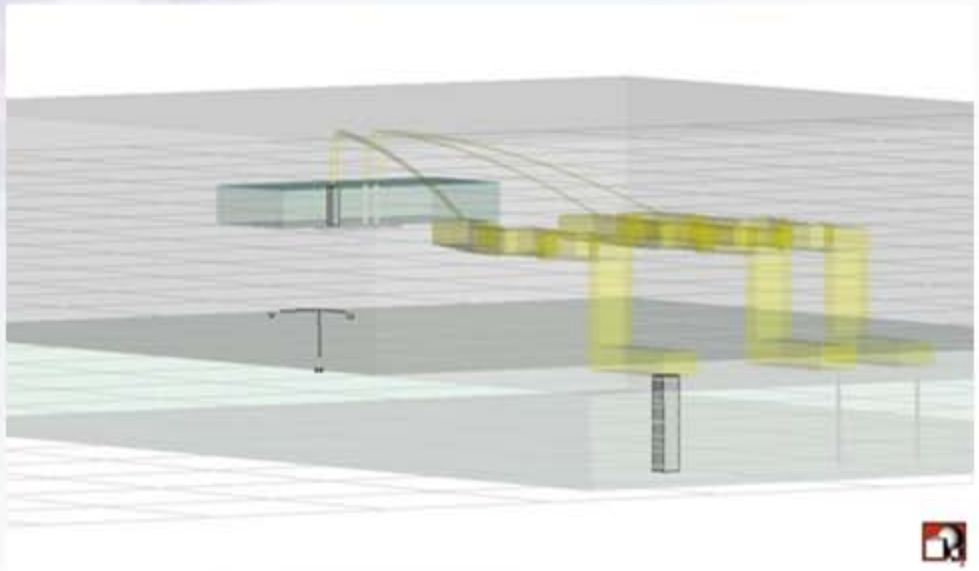

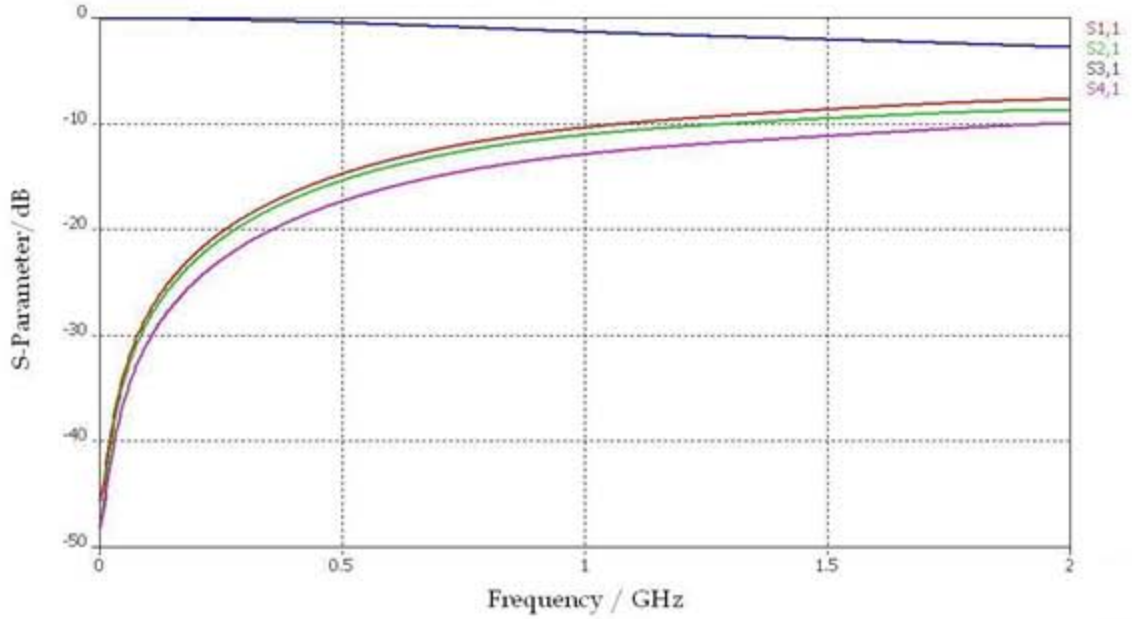

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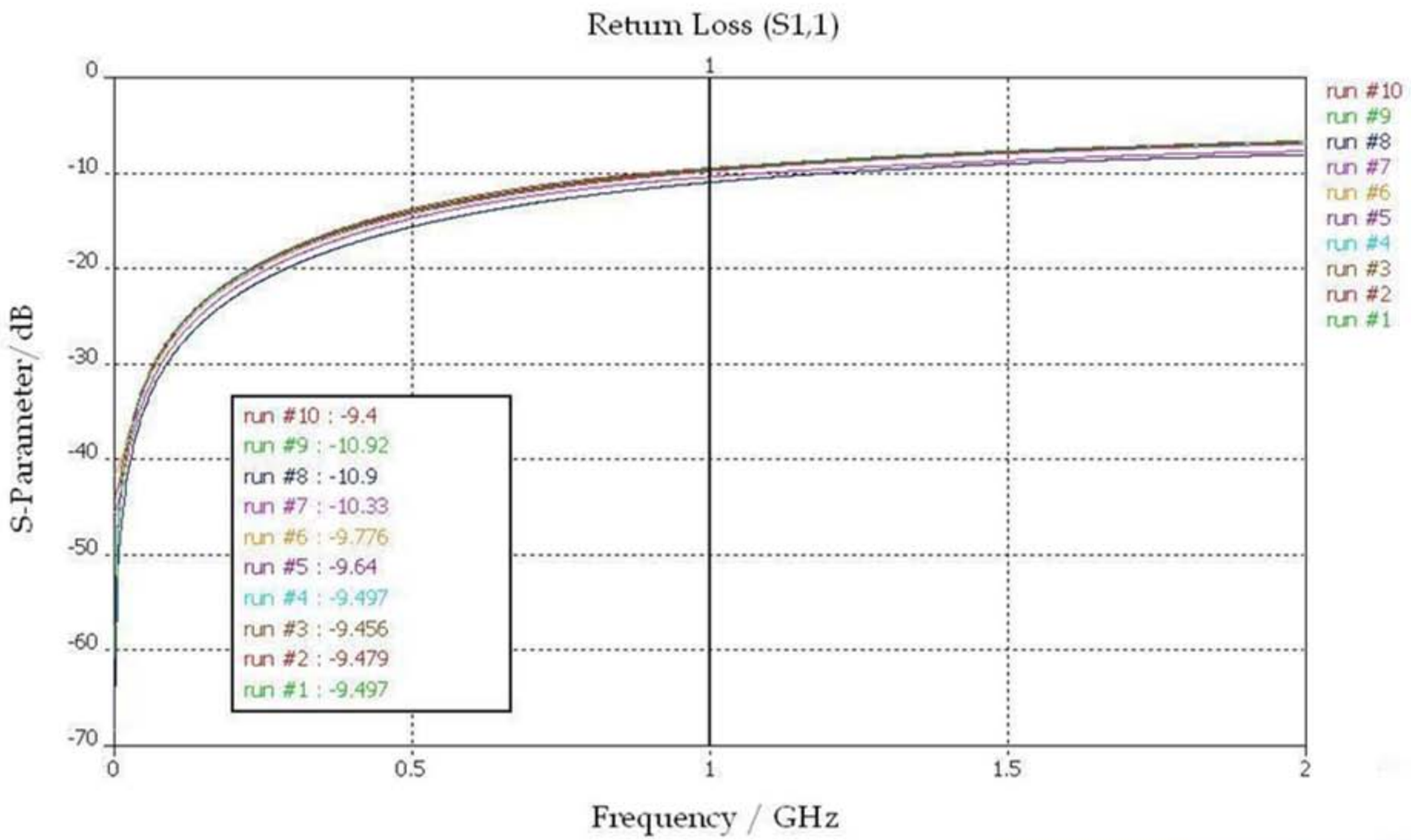
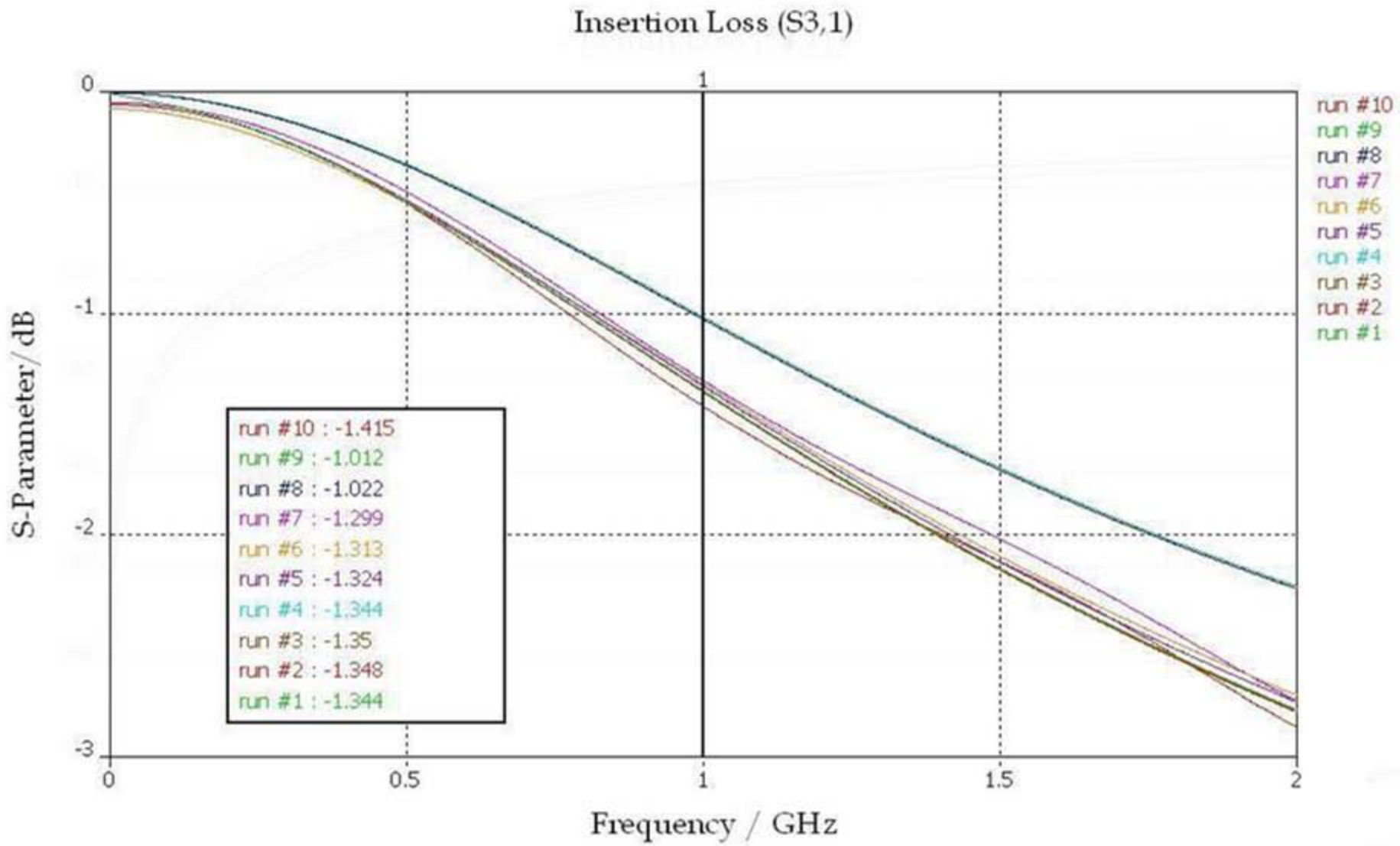
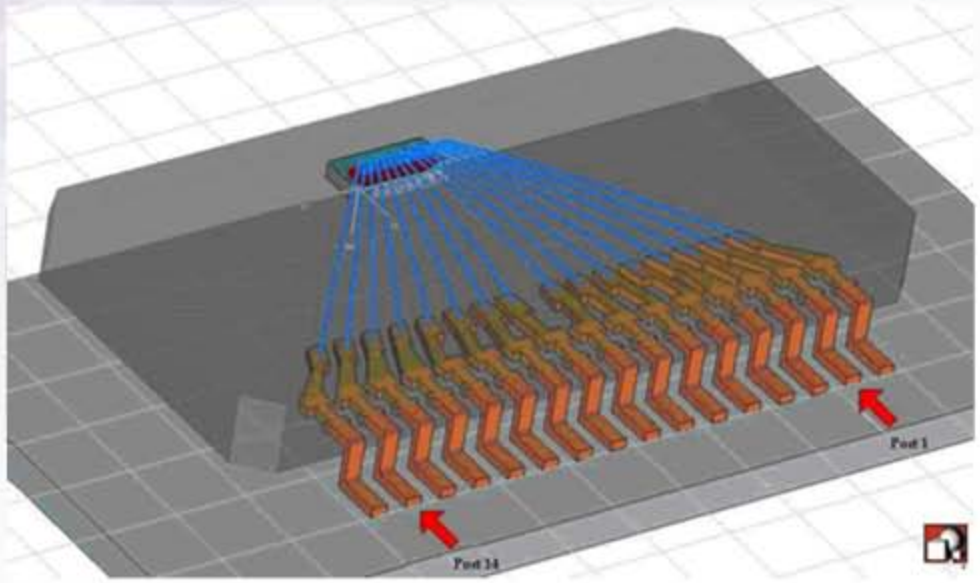
Different Simulation Runs

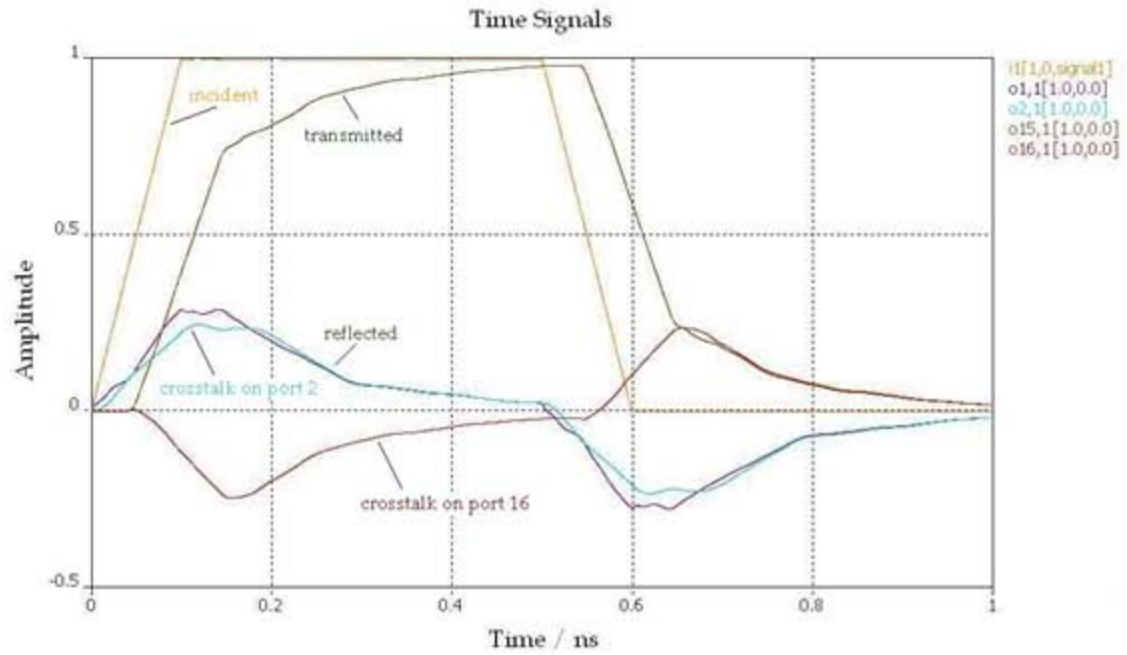


Different Simulation Runs



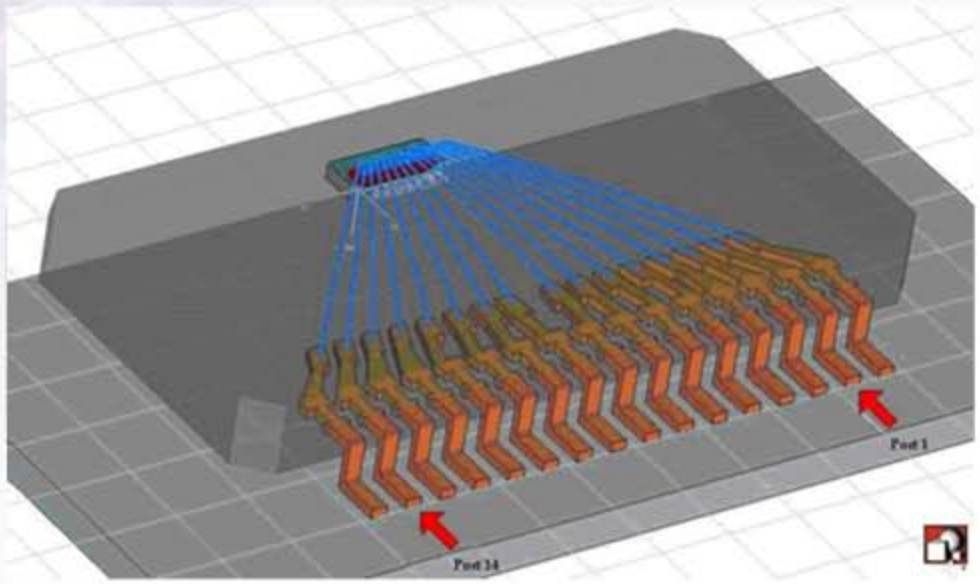
Simulation Results of Final Model

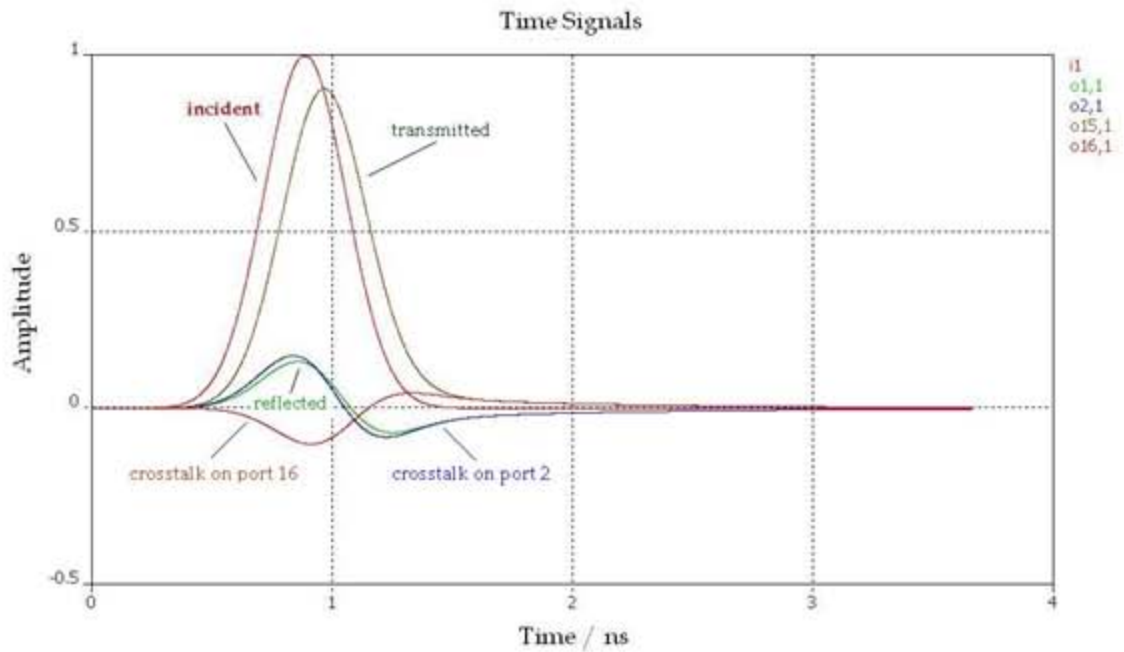




- Signal excitation was performed on 28 ports.
- Signal curves and s-parameters show a comprehensible transmission behavoir of the structure.

Simulation Results of Final Model





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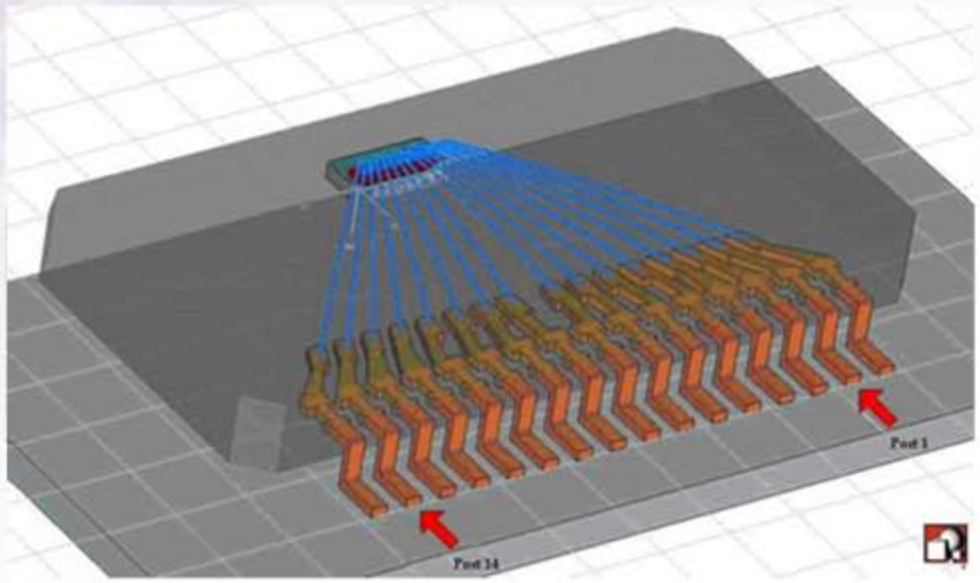

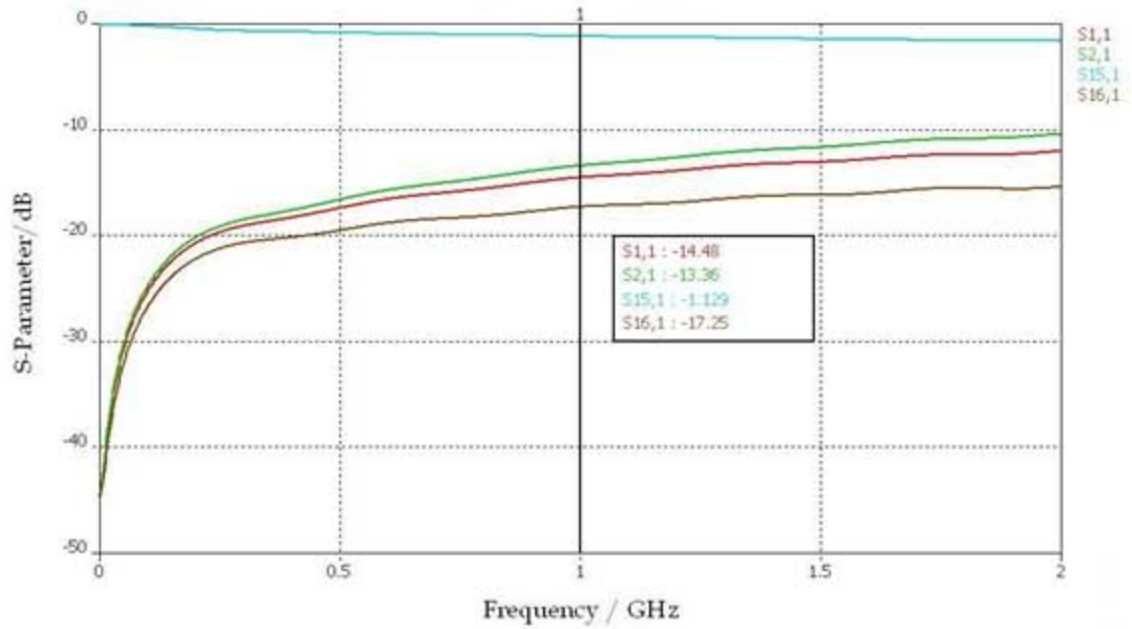

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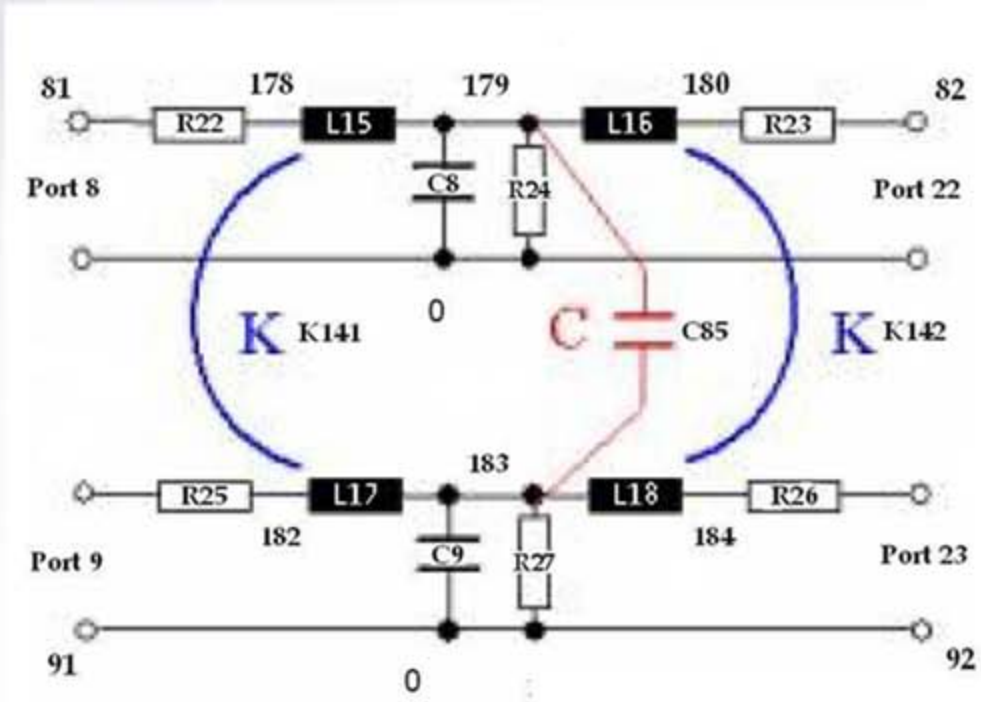
Simulation Results



Frequency	1 MHz		1 GHz	
Wire Type	Infinetly thin wires	Solid wires	Infinetly thin wires	Solid wires
R22-R23	0.02Ω	0.42Ω	2.13Ω	5.06Ω
L15-L16	3.8nH	4.3nH	2.19nH	3.8nH
C8	0.33pF	0.29pF	0.066pF	0.259pF
R24	0.4GΩ	1GΩ	10kΩ	4.1kΩ
R25-R26	0.02Ω	0.42Ω	2.20Ω	5.19Ω
L17-L18	4.2nH	4.71nH	2.2nH	4.21nH
C9	0.29pF	0.27pF	0.068pF	0.231pF
R27	0.7GΩ	2GΩ	10kΩ	3.7kΩ
K141-K142	2.5nH	2.8nH	2nH	2.7nH
C85	0.3pF	0.27pF	0.27pF	0.249pF

Structuring

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Summary & Outlook

Modeling :

- X-ray close-ups were taken in order to faciliate a precise modeling.
- Several 3D model were created using CST MWS.

Simulation :

- Meshing and ground issue was solved so that appropriate signal waveforms and s-parameters were facilitated. Most suitable trade-off was obtained, thus best one was chosen to perform a final simulation on a sufficient model.
- For each run T-shaped equivalent circuit was extracted at 1 MHz and 1 GHz.
- Results obtained for 1 MHz show good agreement with literature; no comparable results have been found for 1 GHz.

Outlook :

- Investigating the input of package parasitics on the signal integrity in SPICE.
- With the developed methodology more complex packages can be investigated.

H F T

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Thank you for your attention !