3D Package Model for Electromagnetic Field Solver used in More High-Speed Channel Simulation

Masaki Kirinaka
mkirinaka@fujitsu.com
FUJITSU INTERCONNECT TECHNOLOGIES LIMITED

Asian Virtual IBIS Summit
Tokyo, JAPAN
November 12, 2021
Agenda

• Background

• Verification of 3D Package model superiority

• Challenges for 3D Package model

• Summary
Background

In Optical Transmission System Board Development

Board configuration

OPTICAL FIBER

MODULE BOARD

BGA connection

MAIN BOARD

OPTICAL TRANSCEIVER

25Gbps

CPU

Copyright 2021 FUJITSU INTERCONNECT TECHNOLOGIES LIMITED
Against expectation, Simulation results were bad.
Review the Analog Channel Model.
Changed S-parameter extraction method.
By reviewing the S-parameter extraction method, good simulation results were obtained as expected.
The interconnect structure of the Optical Transmission System Board is like that of Chip, Package, and Board.

So, it seems that more accurate simulation results can be obtained by extracting the S-parameter with the Package integrated with the Board.

At that time, the Package requires a model for 3D ELECTROMAGNETIC FIELD SIMULATOR.

Therefore, we verified the superiority of using a 3D Model for Package by simulating with a simple 3D Model of Package and Board.

Also, we examined the issues of 3D Models.
Verification of 3D Package model superiority

Simple 3D Model for Verification

Package-only 3D Model

16 Layers
1.85 mm

View from A

View from B

View from C

BGA Ball

enlarge

C4 Pad

Board-only 3D Model

14 Layers
2 mm

View from D

View from E

View from F

Integrated Package and Board 3D model

View from E

View from F

1.85 mm
16 Layers

View from A

View from B

View from C

2 mm
14 Layers

View from D

View from E

View from F

1.85 mm
16 Layers

View from A

View from B

View from C

2 mm
14 Layers

View from D

View from E

View from F

Package

Board
Verification of 3D Package model superiority

Verification Case

- Case2 (More accurate simulation result) vs. Case1 (Simulation result by conventional topology)
- What is the difference between Case1 and Case2?

<table>
<thead>
<tr>
<th>Case</th>
<th>Analog Channel Model Configuration</th>
<th>Verification Items</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Insertion Loss</td>
</tr>
<tr>
<td>1</td>
<td><img src="image1.png" alt="Conventional Simulation Topology" /></td>
<td>SDD21 SDD11</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td><img src="image2.png" alt="Integrated Package and Board 3D model" /></td>
<td>SDD21 SDD11</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Verification of 3D Package model superiority

Simulation Results

Red: Case1 (Package-only + Board-only)

Blue: Case2 (Integrated Package and Board)

<table>
<thead>
<tr>
<th>Data Rate</th>
<th>f_{Nyquist}</th>
</tr>
</thead>
<tbody>
<tr>
<td>5Gbps NRZ</td>
<td>2.5GHz</td>
</tr>
<tr>
<td>10Gbps NRZ</td>
<td>5GHz</td>
</tr>
<tr>
<td>16Gbps NRZ</td>
<td>8GHz</td>
</tr>
<tr>
<td>28Gbps NRZ</td>
<td>14GHz</td>
</tr>
<tr>
<td>56Gbps NRZ</td>
<td>28GHz</td>
</tr>
<tr>
<td>56Gbps PAM4</td>
<td>14GHz</td>
</tr>
</tbody>
</table>

Copyright 2021 FUJITSU INTERCONNECT TECHNOLOGIES LIMITED
Verification of 3D Package model superiority

Simulation Results

[Case1] Package-only + Board-only

5Gbps NRZ

10Gbps NRZ

16Gbps NRZ

28Gbps NRZ

56Gbps NRZ

56Gbps PAM4

[Case2] Integrated Package and Board
Verification of 3D Package model superiority

- Case1 (Package-only + Board-only) has a larger Impedance mismatch than Case2 (Integrated Package and Board) at the connection between the Package and the Board.

- Therefore, Case1 has worse Insertion Loss and Reflection Loss than Case2.

- Also, the higher the Data Rate, the smaller the Eye opening in Case1 than in Case2.

- In the future, when the Data Rate becomes higher ($f_{Nyquist} \geq 28\text{GHz}$, for example, 112G, 224G), it may be necessary to simulate with the extracted S-parameter by integrated Package and Board in order to improve the analysis accuracy.

- Therefore, it may be necessary to add a standard for 3D Package model to IBIS specification in the future.
Verification of 3D Package model superiority

New Subparameter "FILE_3D" may be needed in the future.

Table 46 – Interconnect Modeling Keywords and Subparameters

<table>
<thead>
<tr>
<th>Keyword or Subparameter</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interconnect Model Set</td>
<td></td>
</tr>
<tr>
<td>Manufacturer</td>
<td>(note 1)</td>
</tr>
<tr>
<td>Description</td>
<td>(note 1)</td>
</tr>
<tr>
<td>Interconnect Model</td>
<td>(note 2)</td>
</tr>
<tr>
<td>Param</td>
<td></td>
</tr>
</tbody>
</table>

Existing model format

File_3D
Challenges for 3D Package model

- Package design and material property values are revealed.
- 3D ELECTROMAGNETIC FIELD SIMULATOR is required.
- The analysis result differs depending on the ELECTROMAGNETIC FIELD SIMULATOR settings (Number of meshes, Analysis frequency range, Boundary conditions, Port settings).
- Simulation time is longer than S-parameter.

etc.

There seems to be many challenges for realization.
Summary

• We investigated the superiority of the 3D Package model.

• At higher data rates (112G, 224G), the 3D Package model helps improve analysis accuracy.

• On the other hand, the 3D Package model has many challenges (standardization and usage).
References

• “IBIS (I/O Buffer Information Specification) Version 7.0”, IBIS Open Forum 2019
  http://www.ibis.org/ver7.0/
shaping tomorrow with you