

When Could PCB and PKG PDN Lumped Loop Inductance be Extracted Separately?

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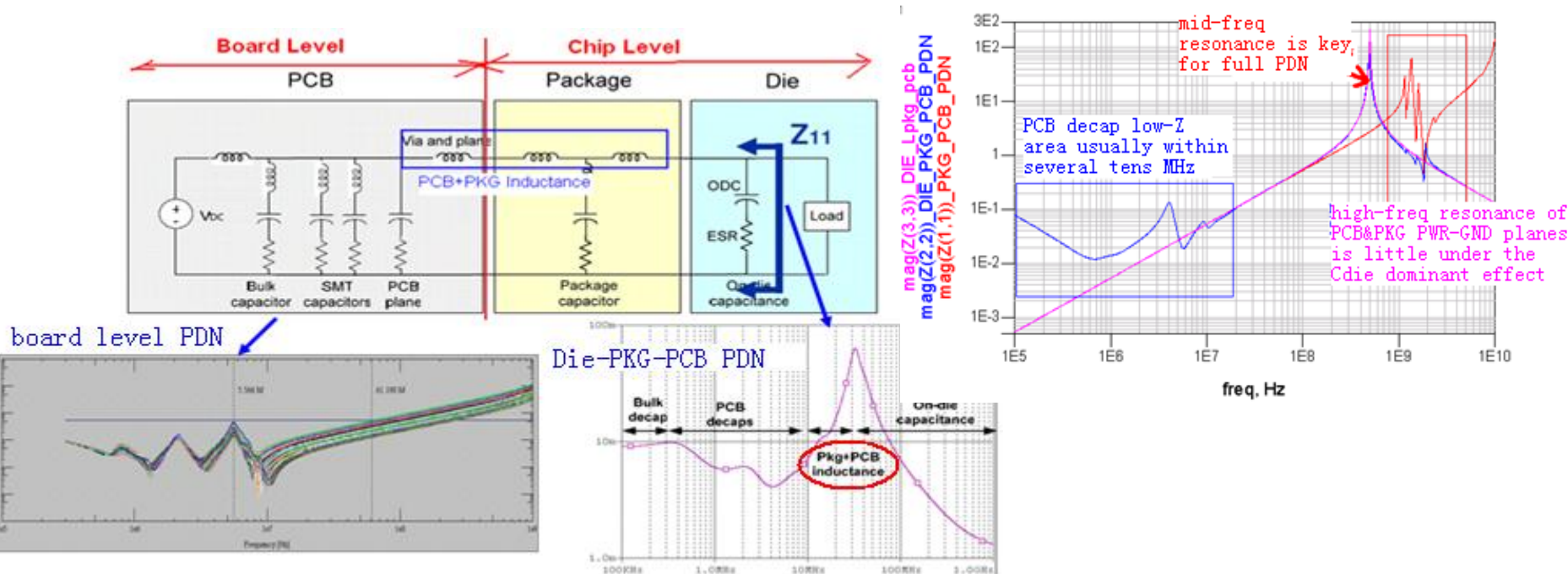
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Background: Importance of Lpkg-pcb Constraint

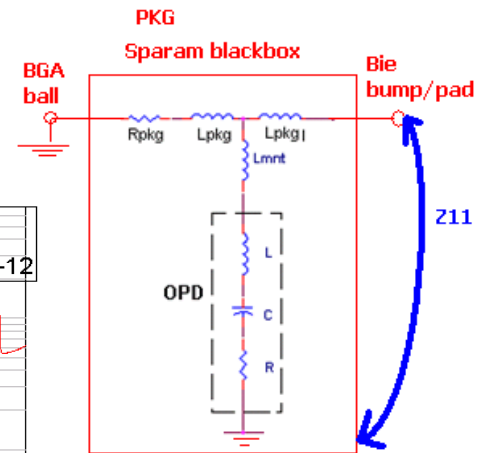
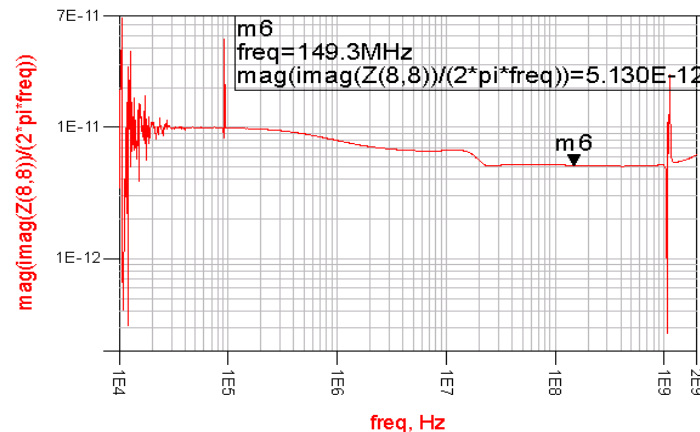
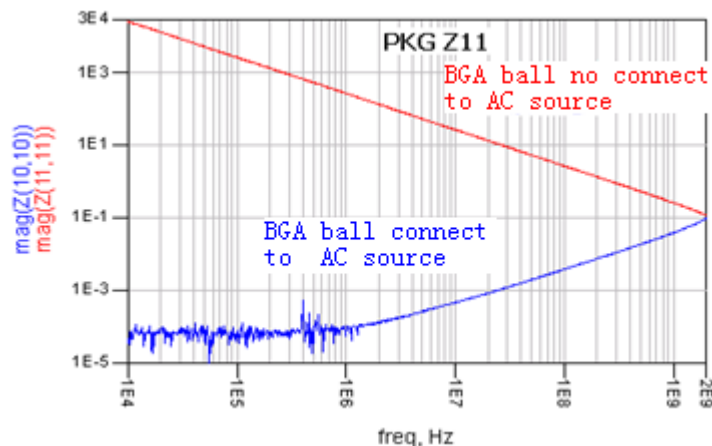
- Die-PKG-PCB PDN mid-freq resonance is the crucial factor in chip self-generated power supply noise
- PDN mid-freq resonance without On-Package-Decap(OPD) can be approximately treated as simple parallel resonance of lumped $R_{die-pkg-pcb}$, $L_{pkg-pcb}$, C_{die}
- Traditional target impedance and effective frequency requirement is to control the L_{pcb} in nature



Lpcb/Lpkg Extraction from Sparam

- PCB and PKG are belong to different teams or companies, so Lpcb/Lpkg is usually extracted from Sparam separately
- Inductance is dominant in high frequency, so it can be extracted from imaginary part of Zin in flat area

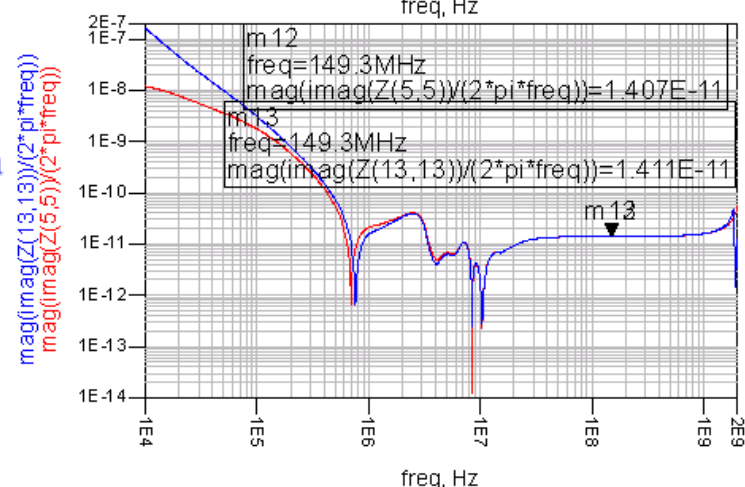
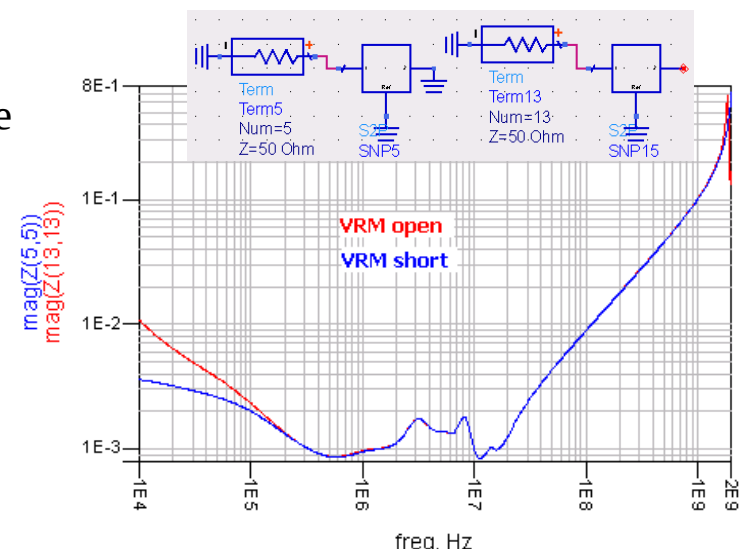
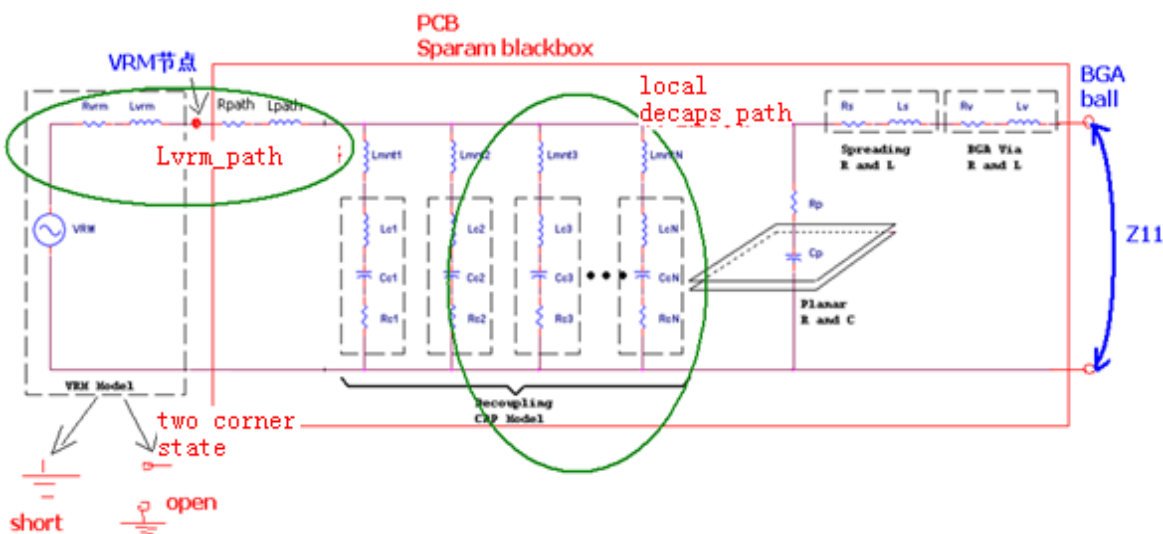
$$Z(f) = R + j\omega L + \frac{1}{j\omega C} = R + j(\omega L - \frac{1}{\omega C})$$
 in flat area
- For Lpkg extraction, BGA ball should be connected to AC ground or AC source to specify the source
- For Lpcb extraction, see next page
- Then $L_{pkg-pcb} = L_{pkg} + L_{pcb}$



PKG-only Lpkg Extraction

Lpcb/Lpkg Extraction from Sparam(Cont.)

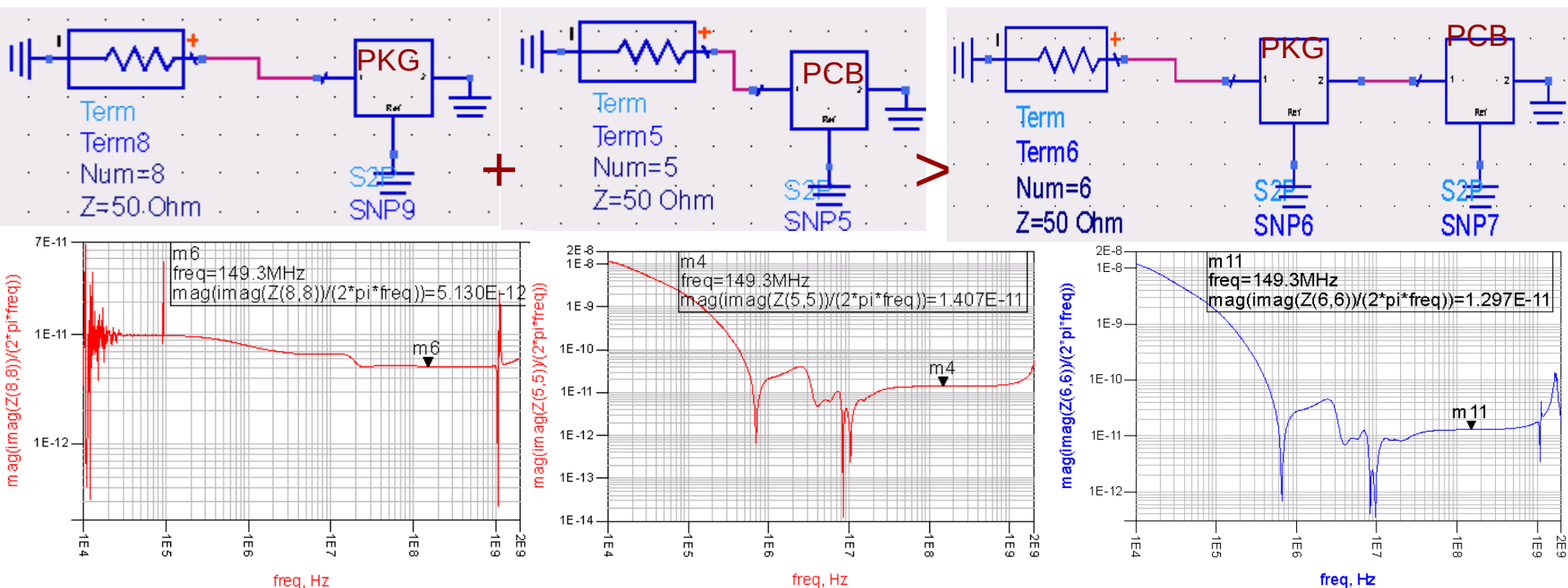
- For Lpcb extraction, VRM should be added as source
- For lack of accurate VRM model, both open and short state of PDN can be simulated to view the VRM effect on PDN and Lpcb
- VRM has little effect on Lpcb when PCB decaps provide good enough local low-Z bypass



Could Lpkg/Lpcb be Extracted Separately?

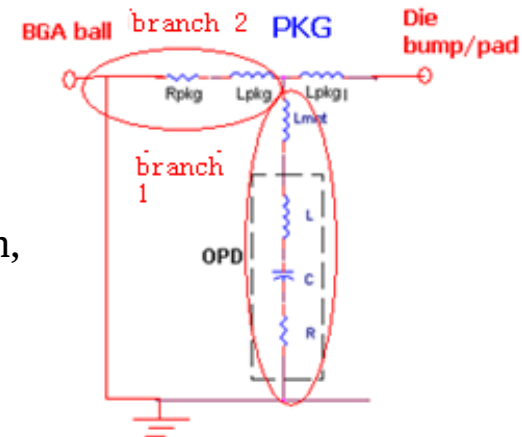
- An interesting example: It's weird that $L_{pkg} + L_{pcb} = 5.13 + 14.07 = 19.2 \text{ pF} > L_{pkg-pcb} = 12.97 \text{ pF}$, even if $L_{pcb} > L_{pkg-pcb}$
- It seems L_{pkg} and L_{pcb} can't be extracted separately. Is it right?

Why?

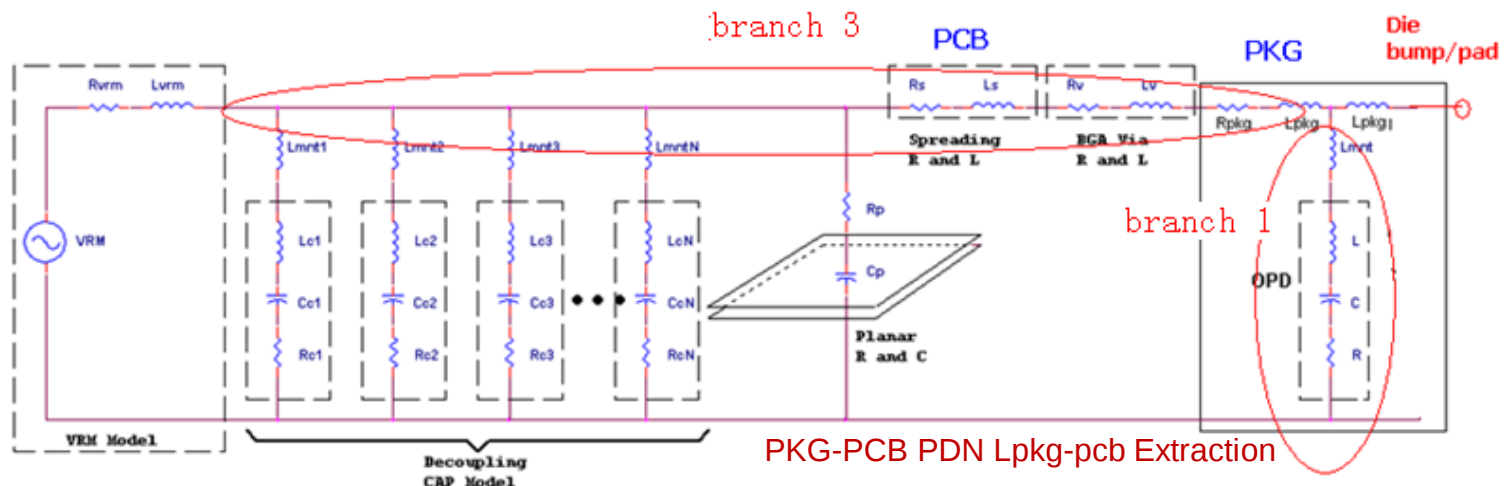


On-Package-Decap(OPD) Change the Loop Inductance

- With the increase of data rate, OPDs are more and more added for better PI performance
- OPDs add a local low-Z path and change feature of Lpkg-pcb
- PKG-only extraction doesn't include Lpcb into the parallel calculation, so $L_{pkg} + L_{pcb} > L_{pkg-pcb}$
- On one hand, OPDs improve the full PDN performance. On the other hand, PCB decaps take less effect on full PDN with OPDs and less PCB decaps are needed



PKG-only Lpkg Extraction

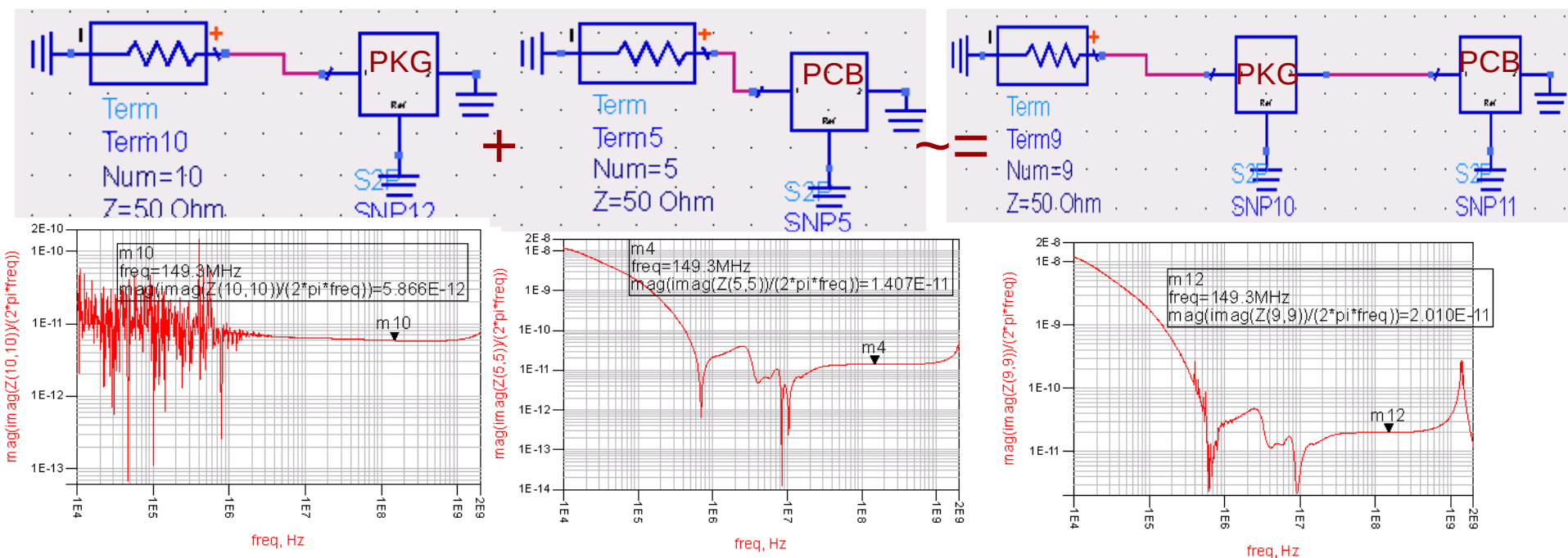


PKG-PCB PDN Lpkg-pcb Extraction

Could Lpkg/Lpcb be extracted Separately?(Cont.)

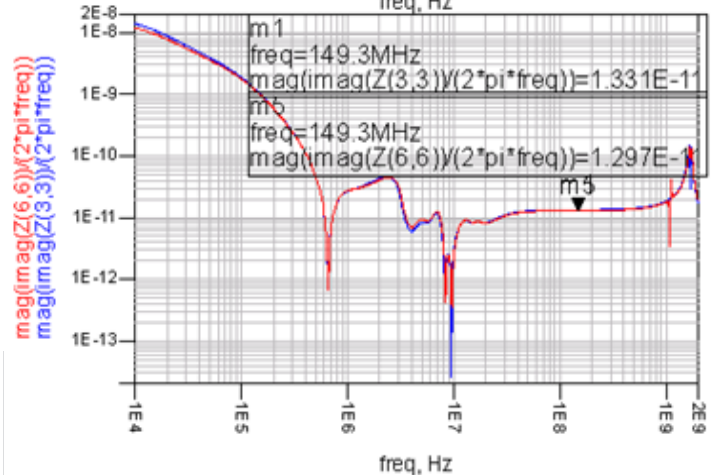
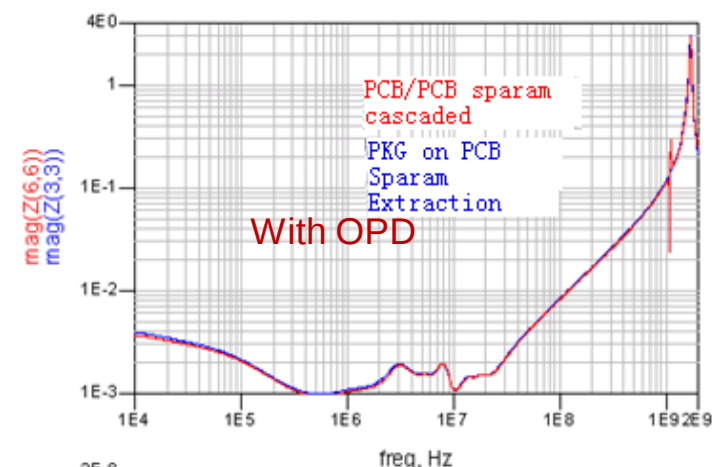
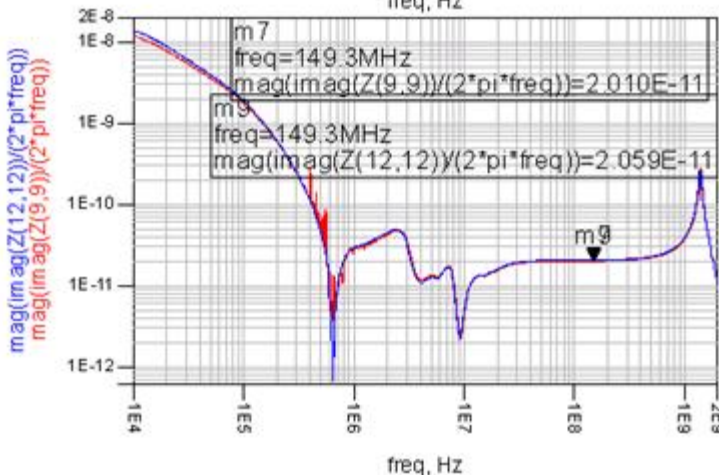
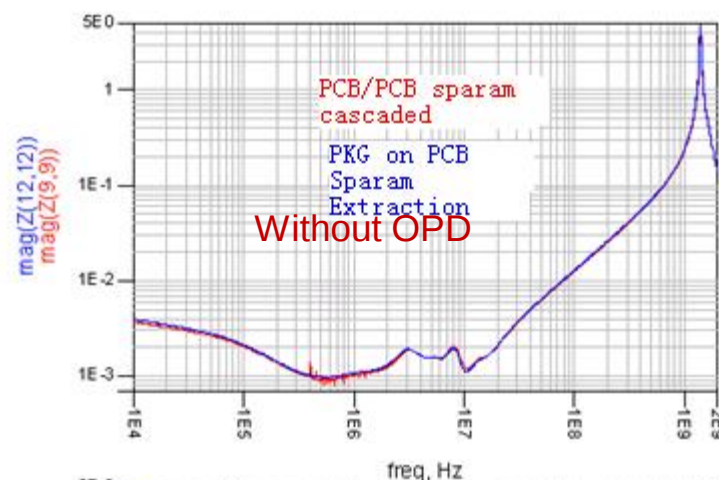
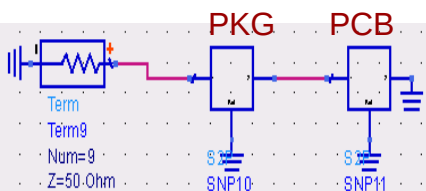
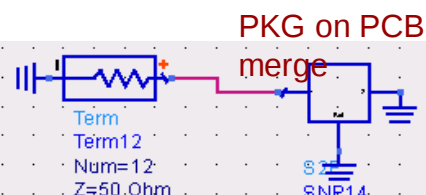
- If no OPD is added, Lpkg/Lpcb can be extracted separately and then sum both.

$$L_{pkg} + L_{pcb} = 5.86 + 14.07 = 19.93 \text{ pF} \sim L_{pkg-pcb} = 20.10 \text{ pF}$$



PKG/PCB Sparam Cascaded vs. PKG on PCB Merge Extraction

- When PKG/PCB have the integral pwr-gnd plane and can be treated as pin-group, there's almost no difference on full PDN impedance between PKG/PCB extraction separately and PKG on PCB extraction



The Limitation of IBIS PKG PWR/GND RLC Model

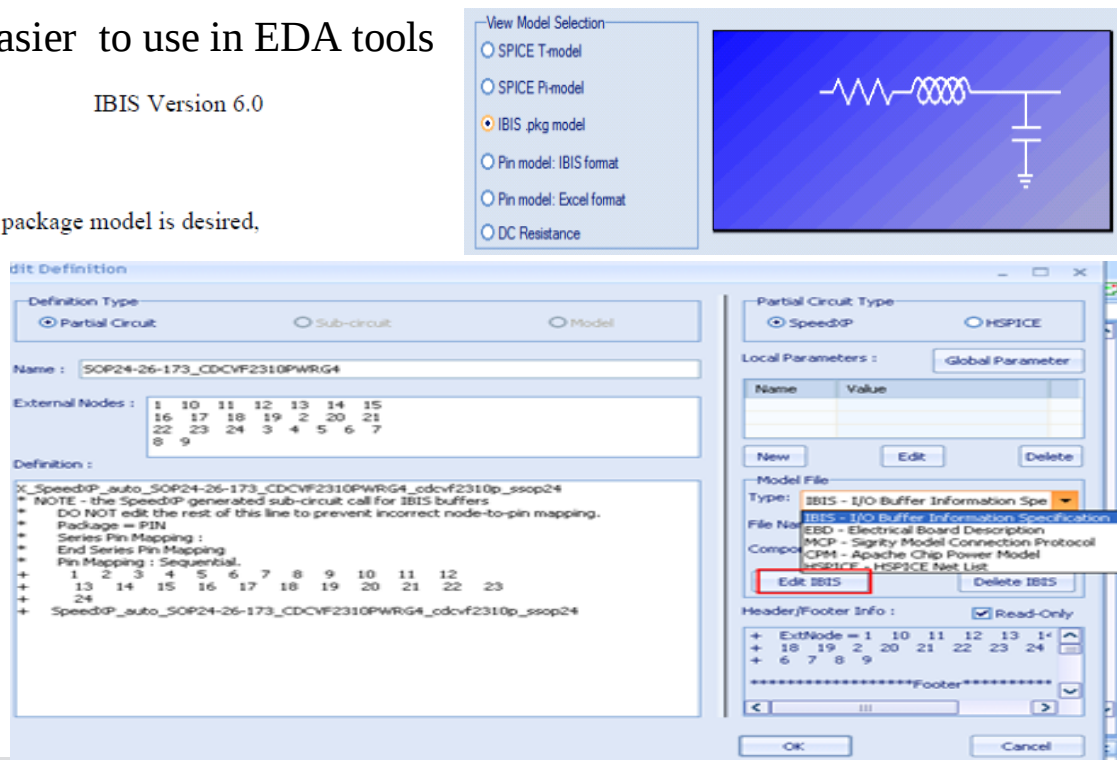
- As we discussed, with OPDs it is not suitable to use PKG-only Lpkg like IBIS RLC PKG model to do the full PDN simulation
- For the present, we have to edit the netlist manually to include IBIS with other format PKG model
- We propose that the IBIS grammar be compatible with more complex models based on Sparam or Spice(.ckt) to make IBIS models easier to use in EDA tools

IBIS Version 6.0

7 PACKAGE MODELING

The [Package Model] keyword is optional. If more than the default RLC package model is desired, use the [Define Package Model] keyword.

```
| The inductance matrix has sparse coupling
|
[Inductance Matrix]      Sparse_matrix
[Row]      Y21
Y21      1.88315e-009
AA26      1.62658e-012
AA22      3.03324e-012
AA10      1.66893e-012
AC20      2.4359e-011
AC21      1.19519e-011
AJ21      1.2311e-012
AB20      1.91878e-011
AA21      1.08181e-010
AA20      4.80607e-011
AB21      3.45745e-011
[Row]      AA26
AA26      1.55486e-011
AC20      2.14604e-012
```



Summary

- With OPDs, Lpkg-pcb can't be summed with Lpkg and Lpcb extracted from sparam separately, but should be extracted from PKG-PCB sparam cascaded
- OPDs not only improve the full PDN performance, but weaken the PCB decaps effect on full PDN as well, which make PCB decaps more simplified
- IBIS PKG RLC model is not suitable for PDN simulation with OPDs. We propose the IBIS grammar be compatible with Sparam or Spice(.ckt) models to make IBIS models easier to use in commercial EDA tools

Thank you

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