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Using S-parameters for behavioral interconnect modeling

Asian IBIS Summit

Zhu ShunLin 朱顺临

High-Speed System Lab, EDA Dept. ZTE Corporation

Zhu.shunlin@zte.com.cn

October 27, 2006

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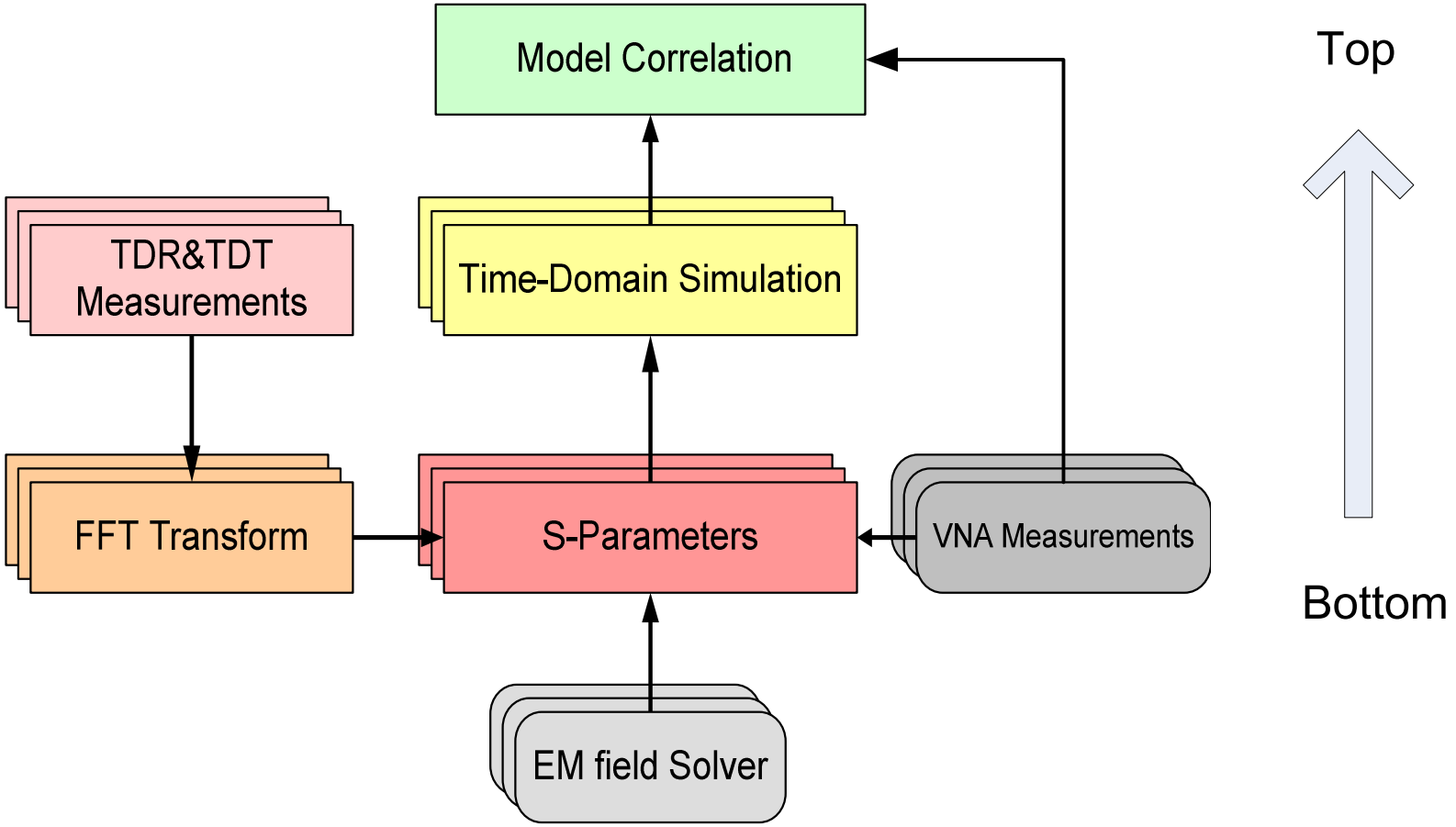
Agenda

- Using S-parameters for high-Speed digital design
- Describing passive interconnects in ICM
- ICM&IBIS
- A solution for package modeling using S-parameters
- Summary

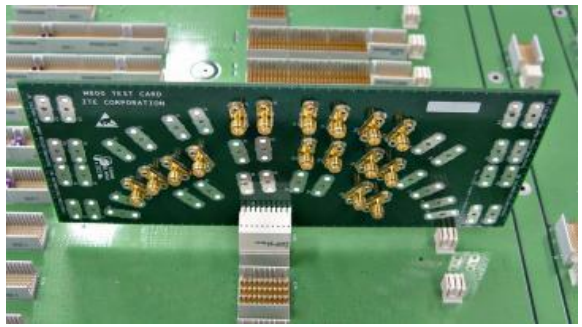
Using S-parameters for high-Speed Digital Design

- The signal integrity simulation of high-speed digital design requires that the interconnect modeling must be valid over a wide bandwidth.
- S-parameters can be generated by 3D EM field solver or by VNA and TDR/TDT measurements.
- S-parameters can be used to generate distributed models for transmission line and vias.
- S-parameters model can be easily correlated with VNA measurements.
- Circuit simulators can run both S-parameters and RLGC models together in time-domain.

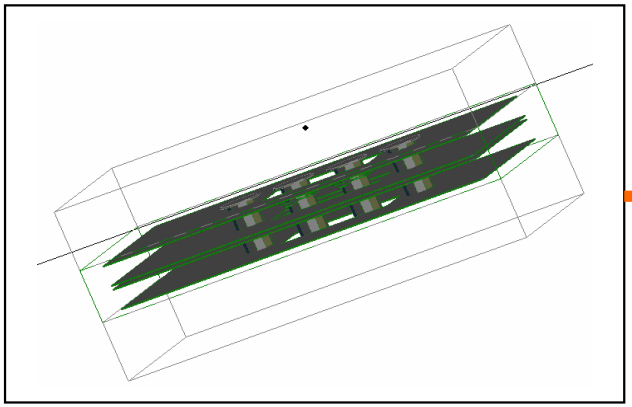
S-parameters Extraction and Correlation



Measurement and 3D EM Solver Modeling



Measurement setup



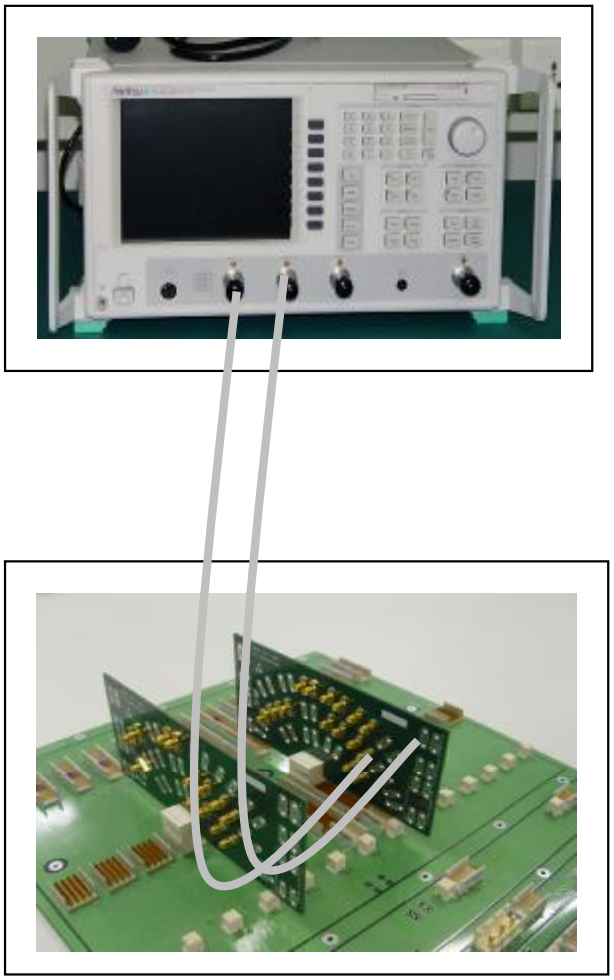
3D EM Solver Modeling

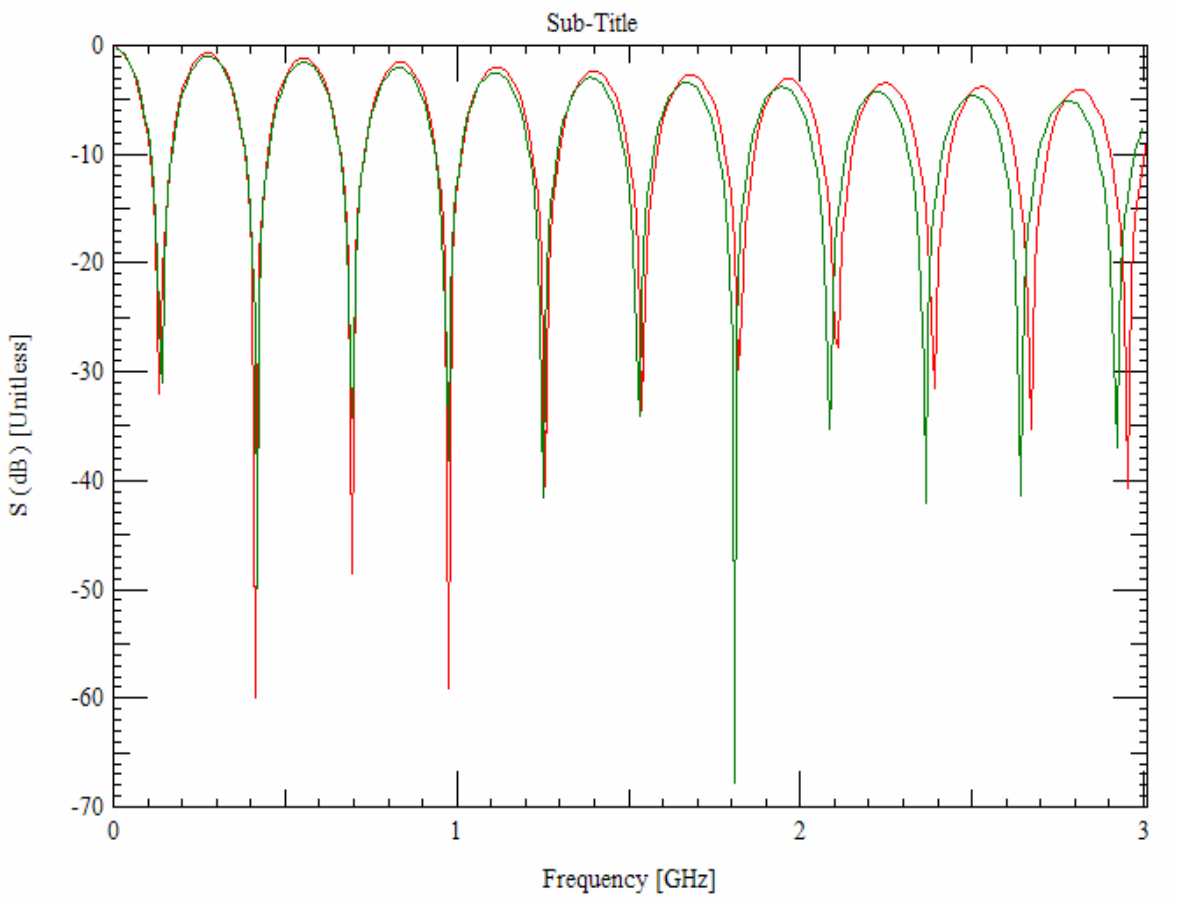
S-Parameter touchstone file

```
! FILE NAME
! DATE 10/20/05   22:27
! CORRECTED   DATA
# GHz   S      MA     R    50.00
 0.010000000 3.217487E-02  25.539 1.433922E-02  73.163 7.022051E-04 -164.797 9.721752E-01  -14.501
         1.437112E-02  73.522 8.342298E-02  21.247 9.721735E-01  -14.643 1.031352E-03  152.923
         6.869677E-04 -166.566 9.750083E-01  -14.799 3.180707E-02  24.806 1.426077E-02  73.110
         9.757603E-01  -14.762 1.043164E-03  148.597 1.442420E-02  73.191 3.261170E-02  27.190
 0.019987500 4.338055E-02  24.741 2.759167E-02  60.757 1.264493E-03  172.773 9.619784E-01  -28.320
         2.753260E-02  60.598 5.663544E-02  -7.471 9.629115E-01  -28.078 8.262120E-04  130.485
         1.252529E-03  171.672 9.652648E-01  -28.414 4.342042E-02  20.989 2.762920E-02  60.190
         9.660442E-01  -28.600 8.369133E-04  130.697 2.751868E-02  59.706 4.591656E-02  22.958
 0.029975000 5.279364E-02  19.352 3.940318E-02  47.550 1.777378E-03  145.369 9.554404E-01  -42.013
         3.933148E-02  47.604 3.671105E-02  -9.347 9.577851E-01  -41.765 7.441007E-04  136.632
         1.751164E-03  143.245 9.584093E-01  -42.077 5.350023E-02  13.120 3.941780E-02  46.306
         9.575923E-01  -42.330 7.423362E-04  133.941 3.934892E-02  46.433 5.596628E-02  14.271
 0.039962500 6.059968E-02  11.269 4.905304E-02  34.608 2.323297E-03  117.191 9.492754E-01  -55.661
         4.906615E-02  34.594 3.431321E-02  15.544 9.519293E-01  -55.371 1.174888E-03  136.972
         2.295646E-03  114.989 9.529339E-01  -55.758 6.189575E-02  3.980 4.901626E-02  33.024
         9.517830E-01  -55.968 1.161010E-03  136.920 4.896336E-02  33.055 6.299231E-02  3.407
 0.049950000 6.662585E-02  1.555 5.628981E-02  21.659 2.841726E-03  90.468 9.434645E-01  -69.209
         5.633547E-02  21.883 5.111281E-02  22.288 9.453543E-01  -68.928 1.940923E-03  116.840
         2.788556E-03  88.049 9.454238E-01  -69.373 6.795117E-02  -5.423 5.627455E-02  19.599
         9.449649E-01  -69.579 1.899390E-03  117.875 5.611407E-02  19.671 6.618402E-02  -7.747
 0.059937500 7.025610E-02  -9.871 6.094978E-02  8.924 3.319784E-03  63.903 9.380775E-01  -82.793
         6.093212E-02  8.964 6.989614E-02  11.224 9.395743E-01  -82.342 2.770354E-03  88.655
         3.227467E-03  61.858 9.384965E-01  -82.888 7.212381E-02  -15.124 6.077348E-02  6.385
         9.384112E-01  -83.188 2.774367E-03  89.391 6.085816E-02  6.319 6.634015E-02  -18.404
 0.069925000 7.160252E-02  -22.097 6.273439E-02  -3.632 3.720456E-03  37.930 9.326985E-01  -96.370
         6.272058E-02  -3.522 8.357295E-02  -6.331 9.355087E-01  -95.783 3.570472E-03  57.951
         3.599259E-03  36.141 9.323274E-01  -96.278 7.376438E-02  -24.634 6.278425E-02  -6.705
         9.336231E-01  -96.646 3.602008E-03  58.589 6.281382E-02  -6.657 6.448640E-02  -28.081
 0.079912500 7.081175E-02  -34.685 6.182219E-02  -16.100 4.040125E-03  12.437 9.270003E-01 -109.843
         6.178188E-02  -15.966 8.959131E-02  -26.534 9.309905E-01 -109.271 4.262746E-03  27.041
         3.903036E-03  11.300 9.269238E-01 -109.574 7.376363E-02  -34.289 6.182057E-02  -19.660
         9.282665E-01 -110.146 4.314952E-03  26.898 6.182886E-02  -19.667 6.259895E-02  -35.944
```

S-Parameter

Lab Correlation for S-parameters

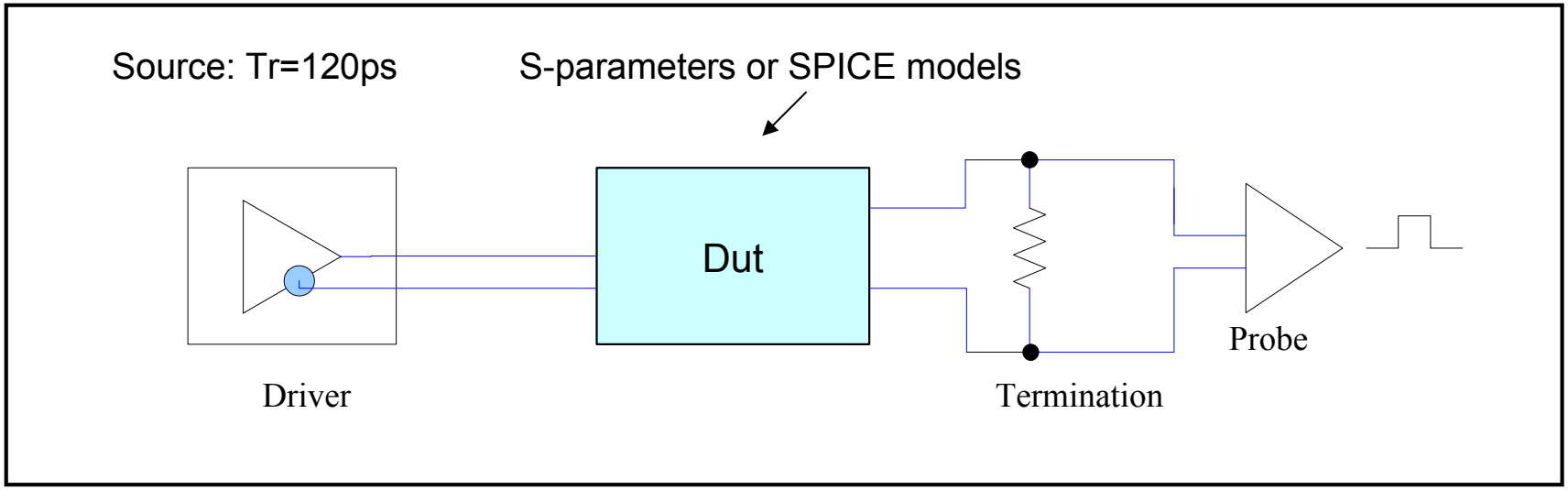




S21 data comparison between VNA measurement and Simulation

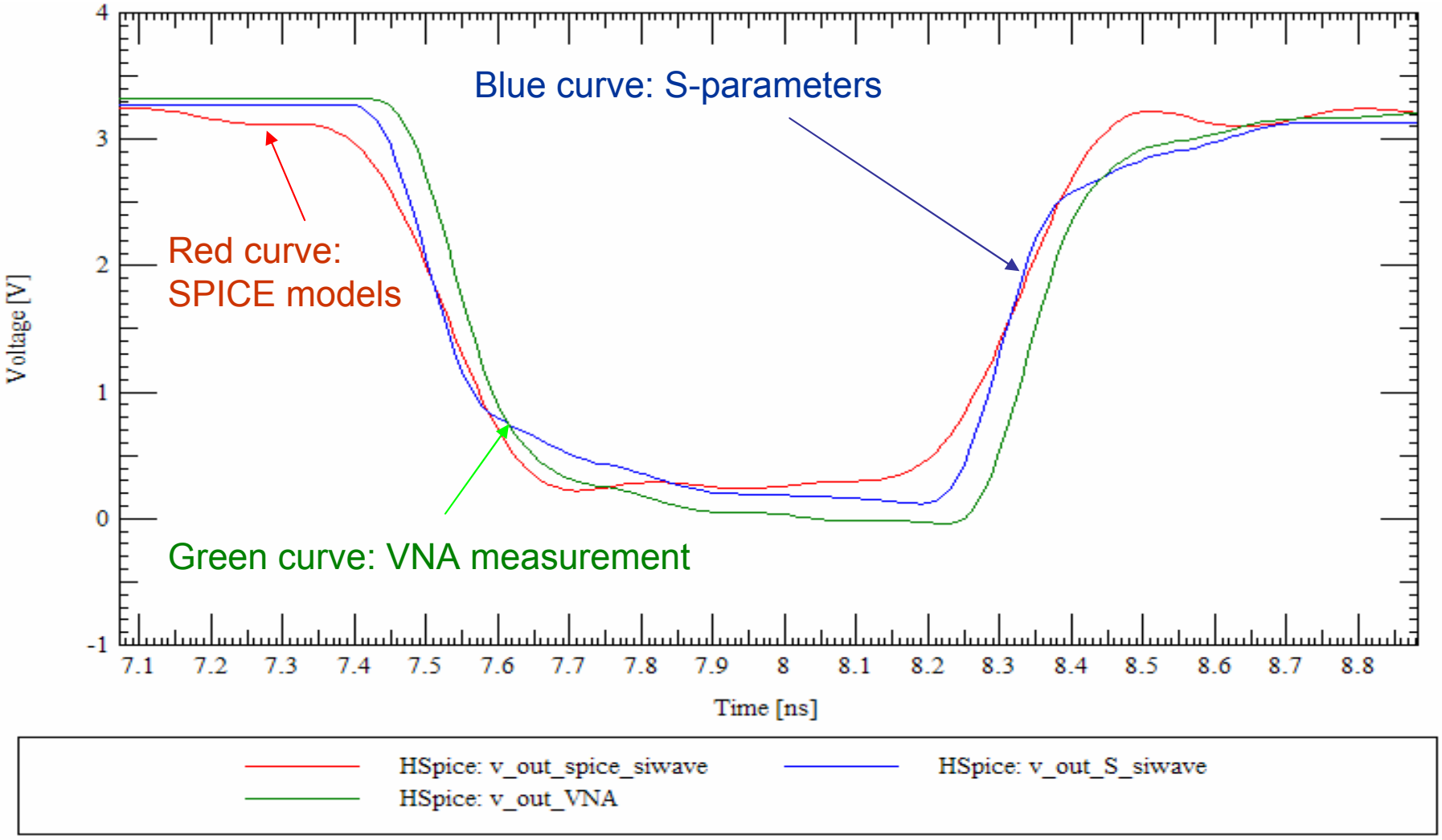
Simulation using S-parameters and SPICE models

1 Simulation using S-parameters extracted by EM field solver
2 Simulation using RLGC models
3 Correlate with laboratory measurements



Measurement versus Simulation

Lab Correlation for S-parameters and SPICE models

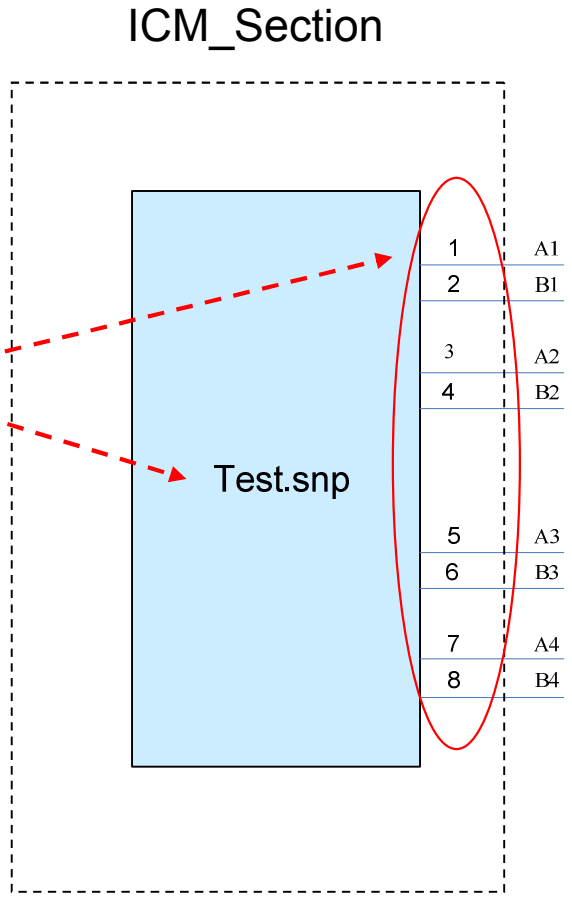


ICM&IBIS

- IBIS Interconnect Modeling Specification (ICM) permits model authors to describe passive interconnects in a tool-neutral, behavioral, human-readable way similar to IBIS.
- ICM supports S-parameter data.
- ICM supports RLGC frequency-dependent matricies.
- ICM does not include connections between IBIS [Model], IBIS [Pin] and ICM ports today.

Describing passive interconnects in ICM

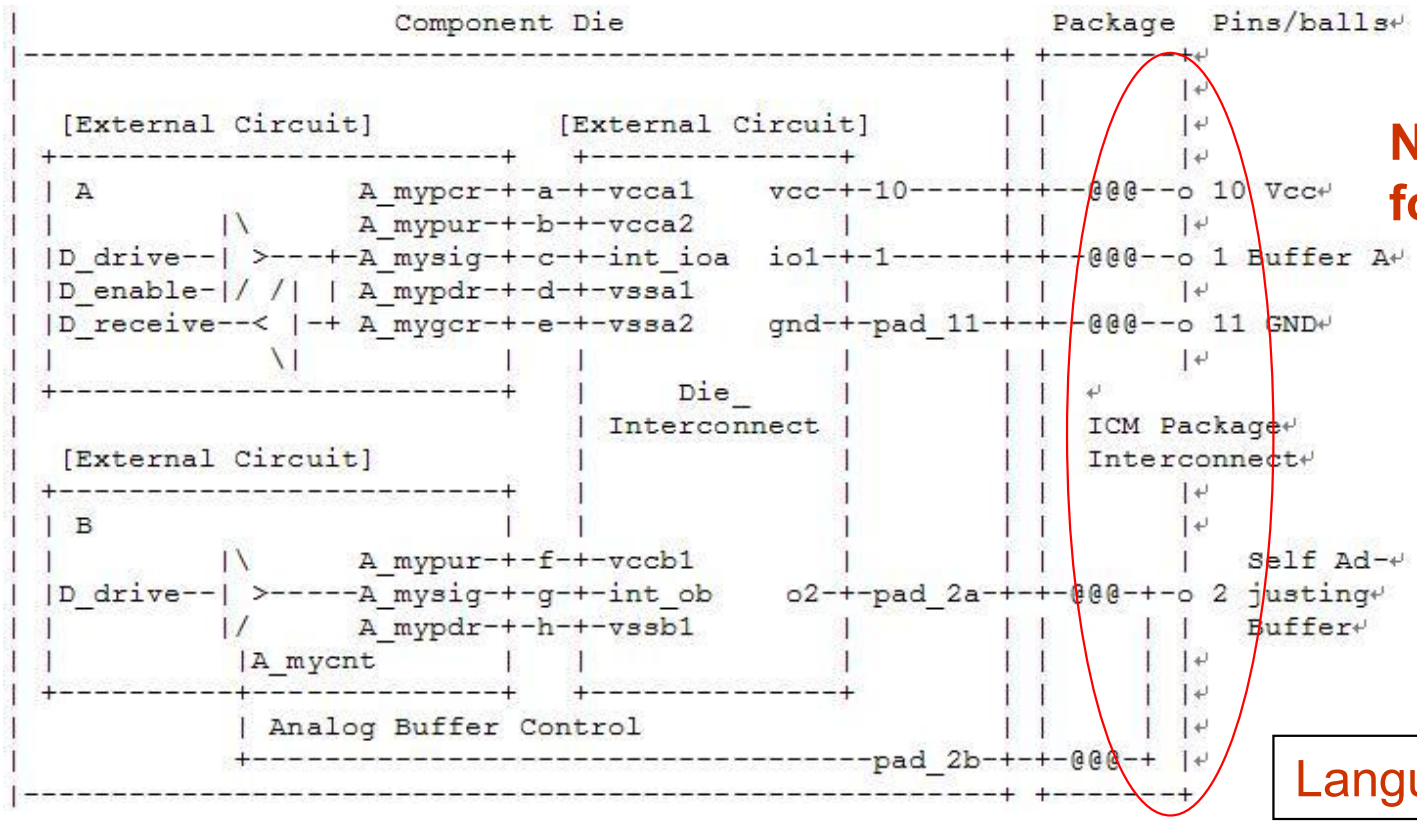
```
[Begin_ICM_Section]  S_para_example
[Derivation Method] Lumped
[ICM S-parameter]
File_name  test.snp
Port_assignment
|Port    Node
 1       A1
 2       B1
 3       A2
 4       B2
 5       A3
 6       B3
 7       A4
 8       B4
[End ICM Section] S_para_example
```



How do we link ICM to IBIS?

[External Circuit] in IBIS ver4.2

- Accepting SPICE, VHDL-AMS, Verilog-AMS, VHDL-A(MS) or Verilog-A(MS) as arguments.



New syntax required for arbitrary ports

Language→Touchstone ?

A proposal for IBIS package modeling using S-parameters

Linking ICM to IBIS

[Node Declarations]
|Die pads or pin names
A1, A2, A3, A4
pad1, pad2, pad3, pad4
[End Node Declarations]

IBIS

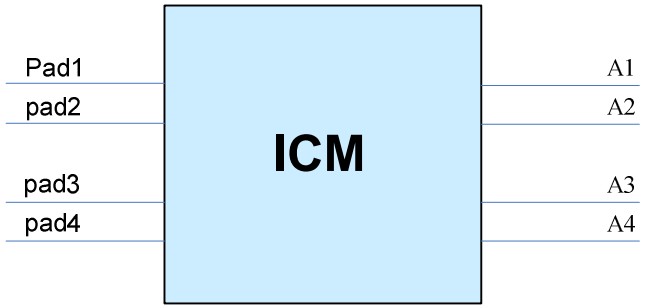
[ICM Pin Map] sample_int
Pin_order Row_ordered
Num_of_columns = 4
Num_of_rows = 1
Pin_list
|Pin Name
pad1 D1
pad2 D2
pad3 D3
pad4 D4

ICM

[ICM Pin Map] sample_ext
Pin_order Row_ordered
Num_of_columns = 4
Num_of_rows = 1
Pin_list
|Pin Name
A1 D1
A2 D2
A3 D3
A4 D3

ICM

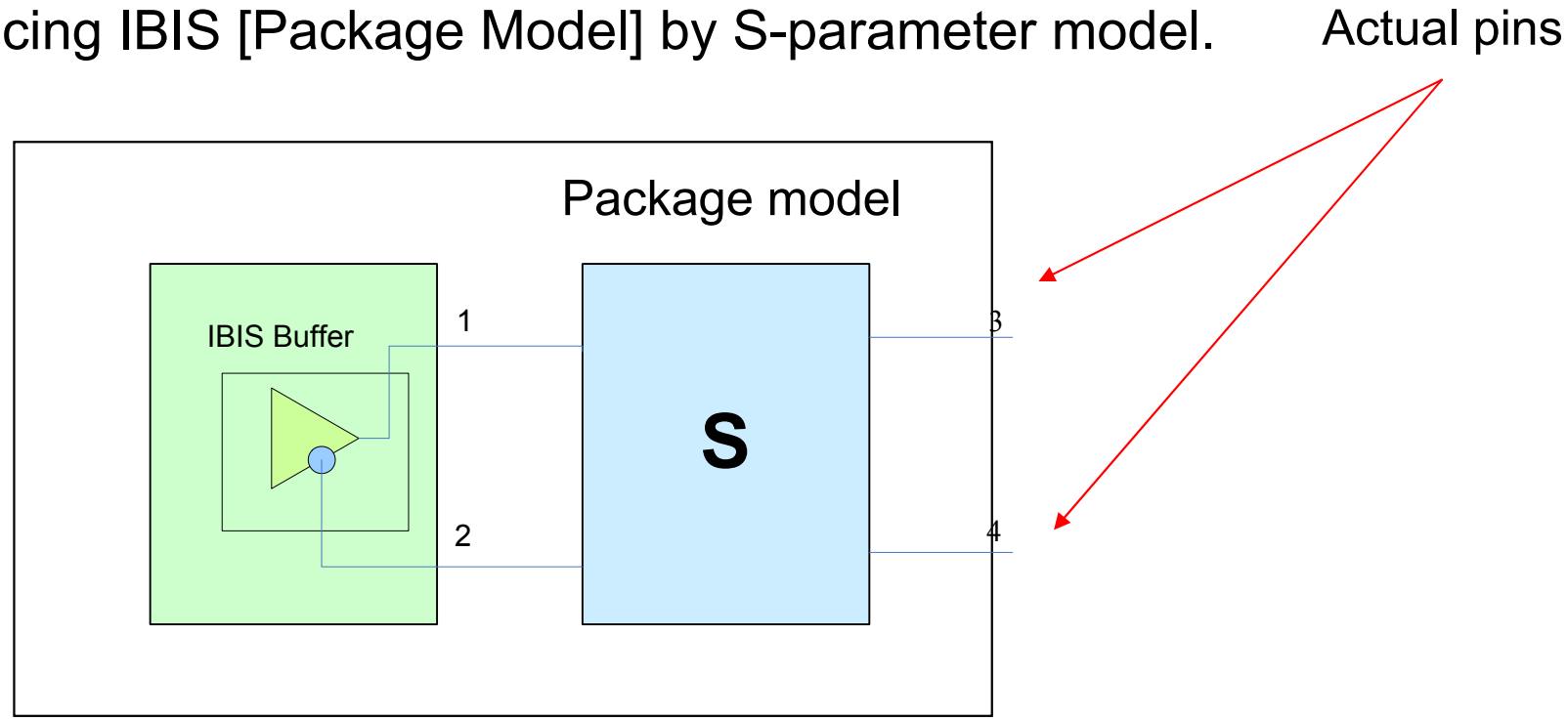
To Buffer



How do we use S-parameters for package modeling now?

Package modeling using S-parameters

- Many EDA tools support S-parameter simulation.
- Using subcircuits to describe S-parameter model.
- Replacing IBIS [Package Model] by S-parameter model.



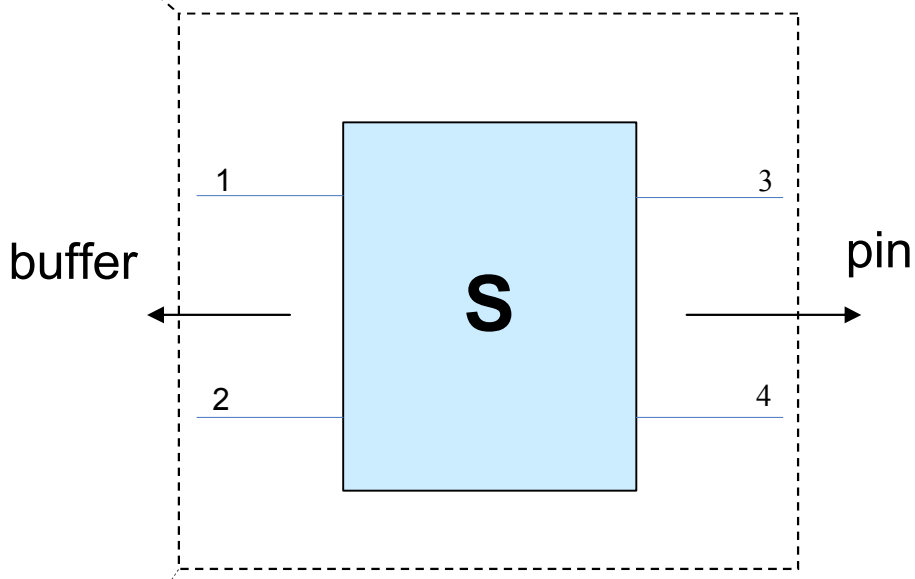
A solution for package modeling using S-parameters

```
("../../../Pkg_models/s_para_pkg.dml"
 (PackagedDevice
  (s_para_pkg
   (ESpice ".subckt s_para_pkg 1 2 3 4
Xs_para_pkg_4Port 1 3 2 4

.subckt s_para_pkg_4Port_Data 1 2 3 4
S1 1 2 3 4 algorithm=default
DATAPOINTS SPARAM
R=50.000000
DATAUNIT=HZ
FREQUENCY=0.000000e+000
.
. END SPARAM
.ends s_para_pkg_4Port_Data

.ends s_para_pkg_4Port" )
   (PinConnections
.
      (NumberOfPorts 4 )
   (SubType SPARAM ) ) )
 (LibraryVersion 136.2 ) )
```

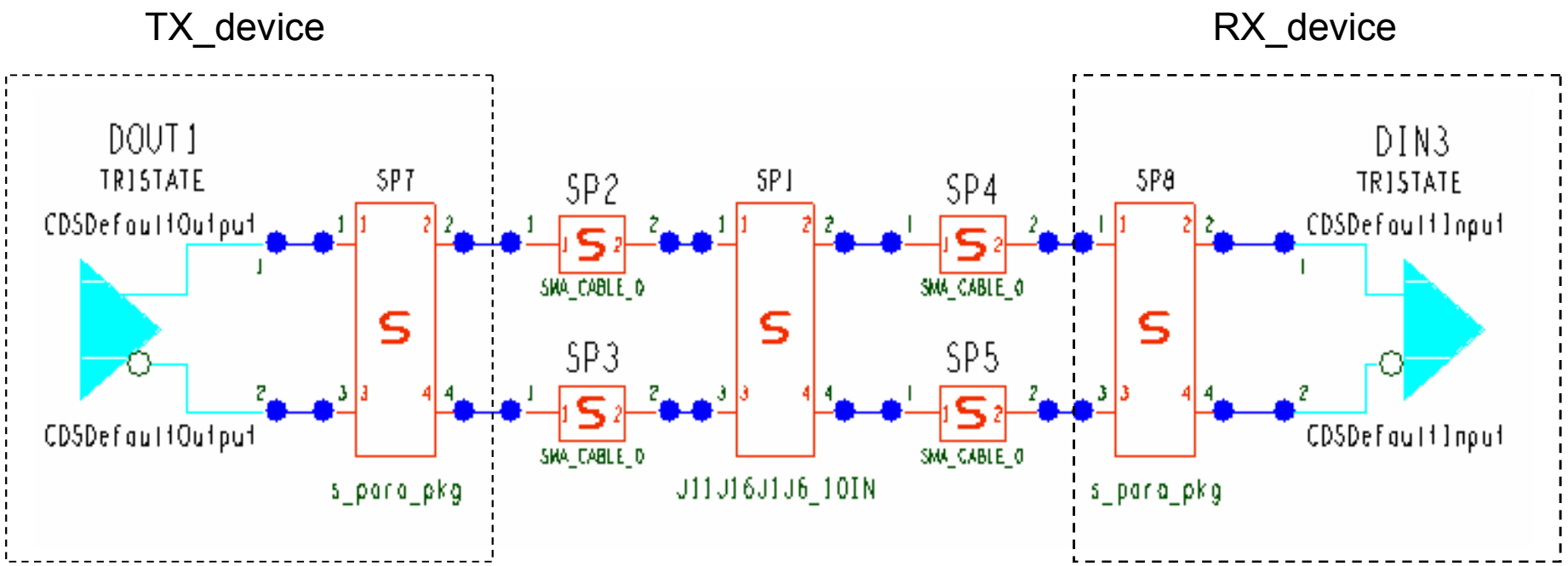
Package modeling using DML model



S-parameters can be added to Cadence DML file.

A solution for package modeling using S-parameters

- IBIS IO buffer modeling
- S-parameter package models of transceiver
- Connecting buffer models to package models in topology.



Summary

- S parameter features:
  - Behavioral modeling method compatible with IBIS style.
  - Much shorter simulation time compared with RLC connector models..
- Benefit IBIS ICM with S parameter:
  - “One model, one platform, one simulator” for both active and passive components.
  - Pave the way for behavioral, yet accurate enough IBIS simulation for very high speed circuit well beyond gigahertz.

References

- Michael Mirmak,”IBIS & ICM Interfacing: A New Proposal”.
- IBIS Interconnect Modeling Specification (ICM) Version 1.0 (Sept. 12, 2003)
- I/O Buffer Information Specification (IBIS) Version 4.2 (June 2, 2006)

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Thank You

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