Using S-Parameters for High Performance Simulation

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What’s S-Parameter

- S-parameter-- Scattering parameter

**S Parameters**

\[
S_{11} = \frac{b_1}{a_1} \quad a_2 = 0
\]

\[
S_{22} = \frac{b_2}{a_2} \quad a_1 = 0
\]

\[
S_{21} = \frac{b_2}{a_1} \quad a_2 = 0
\]

\[
S_{12} = \frac{b_1}{a_2} \quad a_1 = 0
\]
**Insertion Loss & Return Loss**

**REFLECTION**

\[
\frac{\text{Reflected}}{\text{Incident}} = \frac{A}{R}
\]

Return Loss

**TRANSMISSION**

\[
\frac{\text{Transmitted}}{\text{Incident}} = \frac{B}{R}
\]

Insertion Loss
How to get S-Parameter

- Simulation: Full Wave EM Simulation
  - Including complex 3D construction and non-idea return path

- Measurement
  - Vector Network Analyzer
  - Test fixture de-embedding
What’s S-Parameter tell you

- Accurately describe the electrical characteristics of passive structures over a very wide bandwidth
  - Insertion loss and return loss of non-idea T-Line
  - Isolation of separate plane
- Multi-coupling of signals and power nets
S-Parameter of Non-idea plane
S-Parameter of idea plane
Transient analysis results

- 100ps Tr/Tf, 1GHz pulse
Cross gap analysis

SI Investigation ---Signal Net IOA8 Cross Split Power Plane: Reference Changed

Power Plane Split Here
Cross gap analysis

Signal Trace Transmission / Reflection\((S_{21}/S_{11})\)
Cross gap analysis

Signal Trace Transmission / Reflection ($S_{21} / S_{11}$)

After 26 Capacitors Added
Isolation of split plane
Isolation analysis

port 1

port 2

12 in.

10 in.
Result
Isolation analysis

port 1

port 2

12 in.

10 in.

Separate
Isolation analysis

port 1

port 2

10 in.

12 in.

One point connect
Result

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S-Parameter Magnitude Plot
split

18 Mar 2007

Freq [GHz]
0.00 0.50 1.00 1.50 2.00

S Parameter in dB
0.00 -25.00 -50.00 -75.00 -100.00 -125.00

High-Performance EDA
Isolation analysis

port 1

port 2

Change layer

port 2

port 1
Result

16 Mar 2007

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S-Parameter Magnitude Plot
Isolation

10:45:47

S Parameter in dB

Frequency [GHz]

0.00 0.50 1.00 1.50 2.00

-250.00 -200.00 -150.00 -100.00 -50.00 0.00

db(S(port1,port1))
Isolation

db(S(port2,port1))
Isolation

db(S(port2,port2))
Isolation

High-Performance EDA

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Isolation analysis

Add Capacitor
Result

S-Parameter Magnitude Plot
isolation

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11:25:57
Isolation analysis

Add Xgap Capacitor
Result
SSO analysis using N-port S-Parameter
Problem in using S-Parameter for Transient analysis

- Non-convergence
  - Most Timing domain simulator using IFFT to solve the S-parameter (because it’s Frequency domain)
  - Mostly happen in multi-port S-parameter(>10) or long delay
  - S-parameter Convolution
    - Do not Consider causality/passivity problems

- Non-Causal or Non-Passive
  - State-space with rational functions or Enforce Passivity option
Ensuring accuracy across simulation domains

- **State Space**
  - Pole-residue fit to frequency-domain data
  - Only stable poles used: causal
  - Very efficient transient simulation
    - Simple first-order differential equation
  - Passivity not guaranteed
    - But can be enforced for moderate-sized problems
Transient analysis results using State Space

18 IBIS Drivers
57 Port S-parameter model

Transient simulation time: 366s
Reuse of state-space model

- Run simulation for the 1st time
- State-space fitting
- Generation of a .sss file with the state space model details
- Used in subsequent runs with unchanging S-parameter data

Save simulation time! No need to regenerate the state space model
Conclusion

- S-Parameter Model for High Speed Interconnection
  - Wideband, Accuracy
  - Full Wave Simulation or Measurement
- Time Domain Simulation for S-Parameter Model
  - Convergence, Causal and Passive
  - State Space and Convolution