An Introduction:
Or
What is this talk really about?
Two pictures...
Measurement, Modeling and Simulation Techniques for High Speed Systems (Transmission Line Systems)
Assumptions

• High speed  $\Rightarrow$  $\frac{T_d}{C} > T_r$
  – $T_r$ = rise-time,
  – $C$ = velocity of propagation in the system and
  – $T_d$ is the propagation time from one end to the other

• Low loss in package and bond

• $\sim$ 0-6dB loss in transmission system at $F_s/2$

• The goal is to understand the systems
Assumptions

• Build up all models from pieces
  – They are more portable
  – The user/builder can understand them
  – Easier to tease out interactions

• Switch to the Hspice W element, or equivalent, after everything is well understood – not covered in this talk-
Case studies

• Non-ideal terminated receiver
• Package and bond wires
• Plating stubs
RX test circuit
Cable model
Transmission line model
Cable loss model
Cable loss characteristic
Connector model

Diagram:
- p1
- n1
- com
- p2
- n2
- line
- I0
  - Ro = 140
  - len = 0.006
  - w = 20g
- I1
  - Ro = 70
  - len = 0.003
  - w = 20g
- I2
  - Ro = 70
  - len = 0.003
  - w = 20g
Board model

I3  Ro=55  len=0.1  w=20g
     p1            p2
     n1            n2

I6  Ro=1k  len=0.05  w=20g
     p1            p2
     n1            n2

I5  Ro=1k  len=0.1  w=20g
     p1            p2
     n1            n2

I4  Ro=55  len=0.1  w=20g
     p1            p2
     n1            n2

com

This line models the fast made in air at the board surface.

Line to line

Line to return

Line to return
Package and bond model
Directional coupler model
Return loss at connector
At the cable end
After the connector
After 5cm of board
On the chip at the terminator
System frequency response
TDR sim test bench
TDR sim result
Package and bond wires

• Single lumped models:
  – Watch out above 100-200MHz
  – Break into more lumps based on extracted data
    • Can extract a small group of pins by hand
    • Use a solver
Lumped model test bench
2 lumps and 8 lumps
Lumped results
Lumped models
Cross-talk

• Interconnected transmission lines generally do the trick.

• Hspice W element is really good but try getting one quickly.
Obligatory cross-talk slide
X-talk zoom
Plating stubs

- EPBGA Package Shown
- Bond-site is to the left, Package connection is the dot and the “back-stub” extends to the right
- The long ones are about 3-4 mm long
- Back-stubs required in manufacture of PBGA and EPBGA packages
Plating stub models

Top level test bench
Plating stub models
Plating stubs

- At 5GHz >1mm stubs can cause signal integrity problems
- Only trace that meets the XFI Return Loss spec. is the lowest one
Comments

• RLG C models o.k. for narrow BW
• Better models are needed for > 1:5 frequency range typical of serial PHYs
• The Hspice W element is very complete and will work with multi-octave bandwidths
• Simpler models are also useful
Where to start?

- Estimate physical parameters from geometry, easier than L,C directly
- Set impedances to match TDR/network analyser data
- Try SQRT(L/C) from lumped after correcting for K factor
- Use a good EM solver
Parting shots...

If you see a system signal specification that is not measured at the termination point of a transmission line into a matched load you should:

A. Run
B. Tell them “We’ll get back to you on that.”
C. Offer to sell the authors the Brooklyn Bridge
D. All of the above