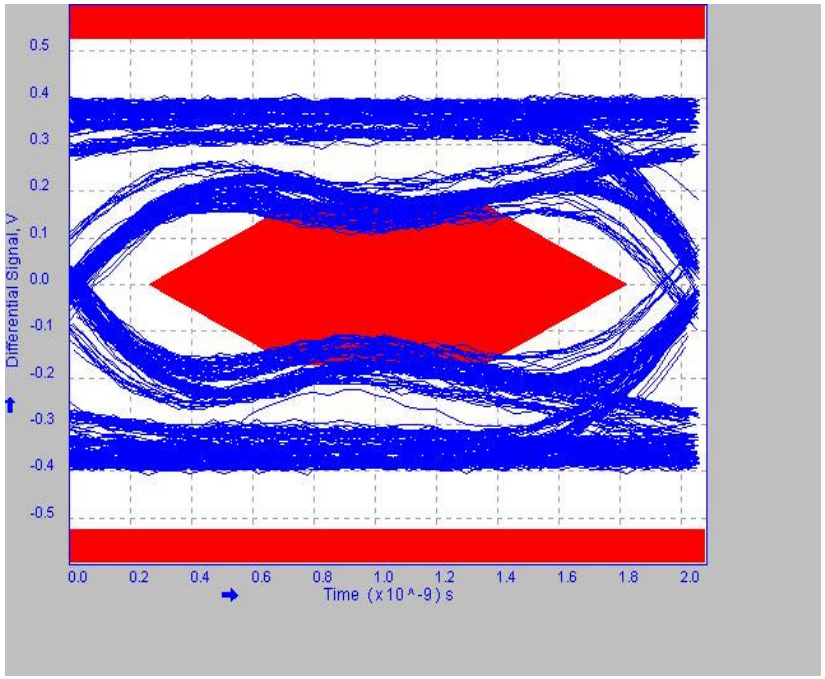
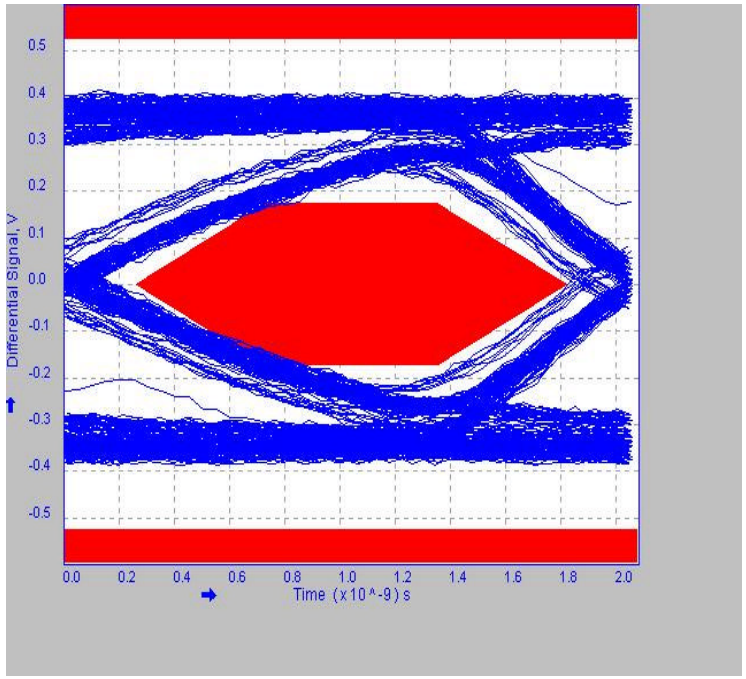
An Introduction:
Or
What is this talk really about?

Two pictures…





Measurement, Modeling and Simulation Techniques for High Speed Systems (Transmission Line Systems)

Assumptions

- High speed => Td/C > Tr
  - Tr = rise-time,
  - C = velocity of propagation in the system and
  - Td is the propagation time from one end to the other
- Low loss in package and bond
- ~ 0-6dB loss in transmission system at Fs/2
- The goal is to understand the systems

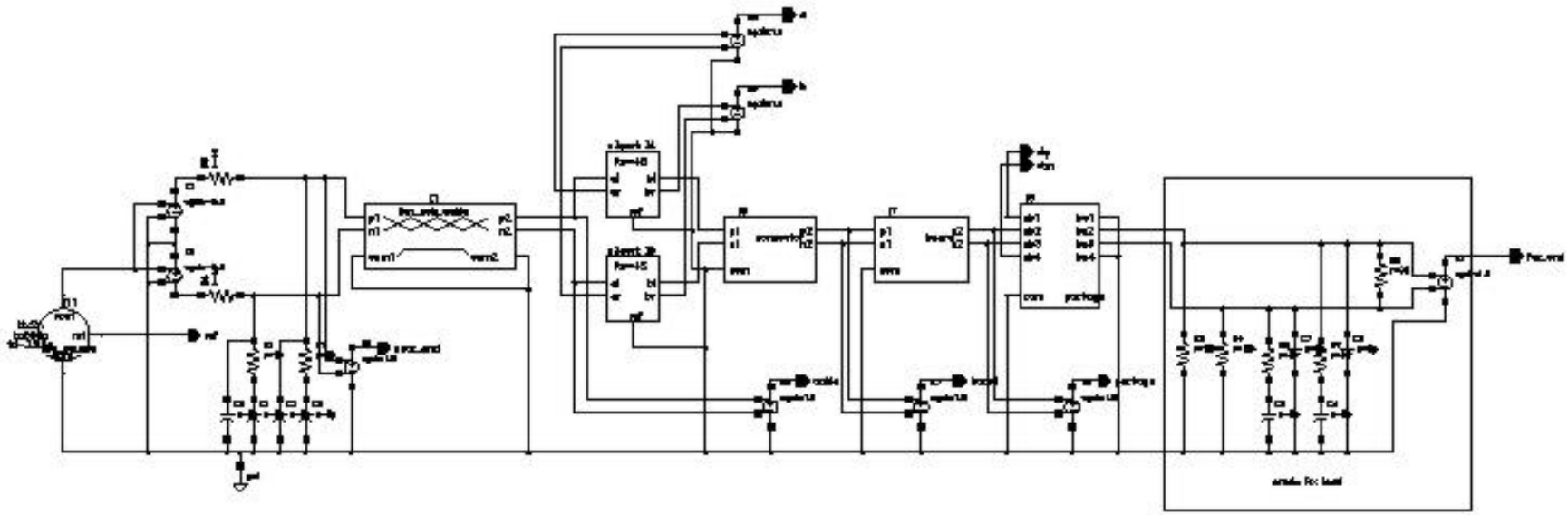
Assumptions

- 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-

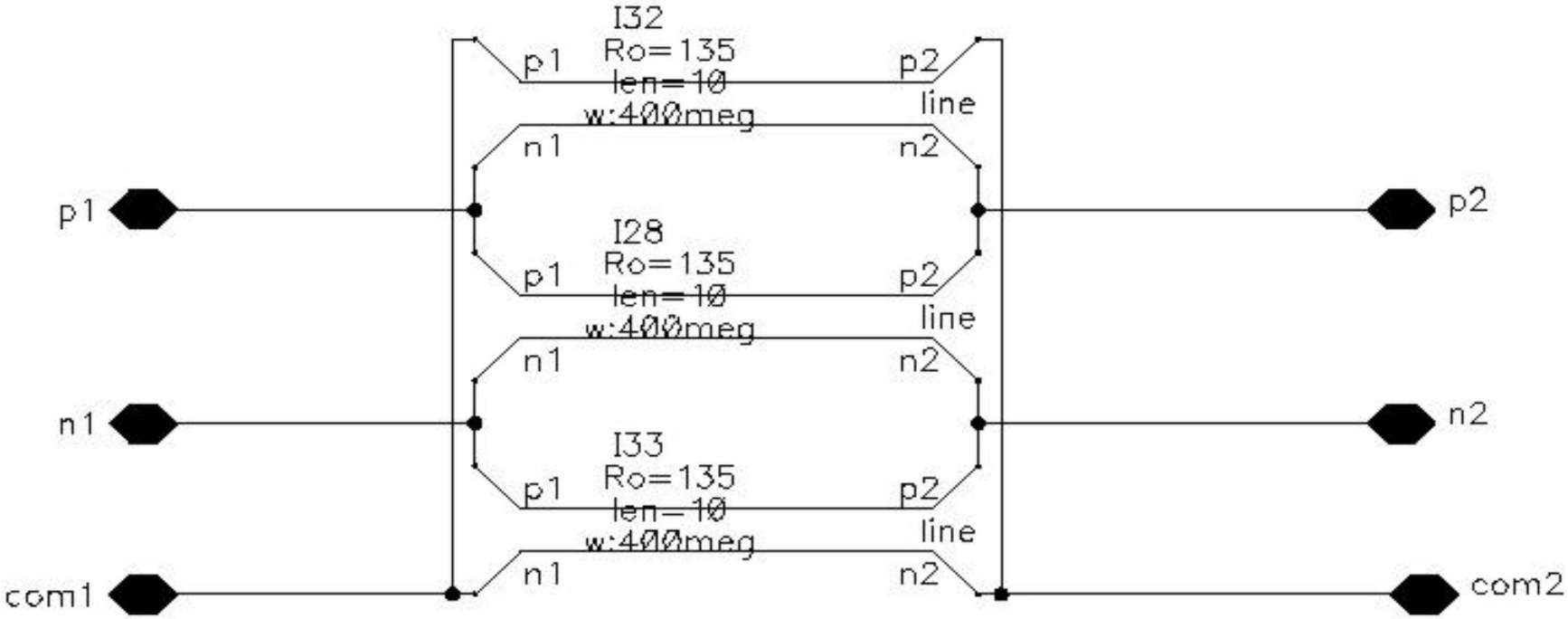
Case studies

- Non-ideal terminated receiver
- Package and bond wires
- Plating stubs

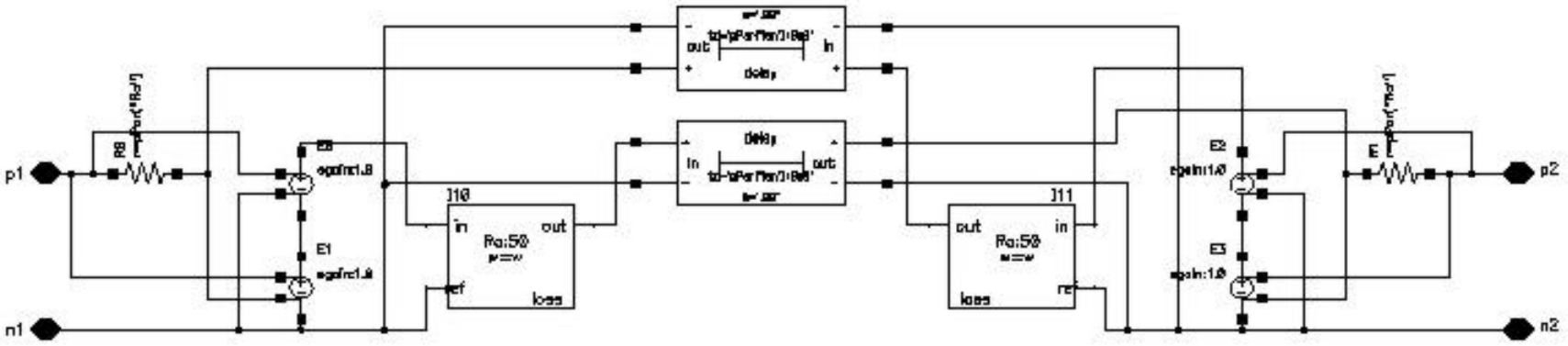
RX test circuit



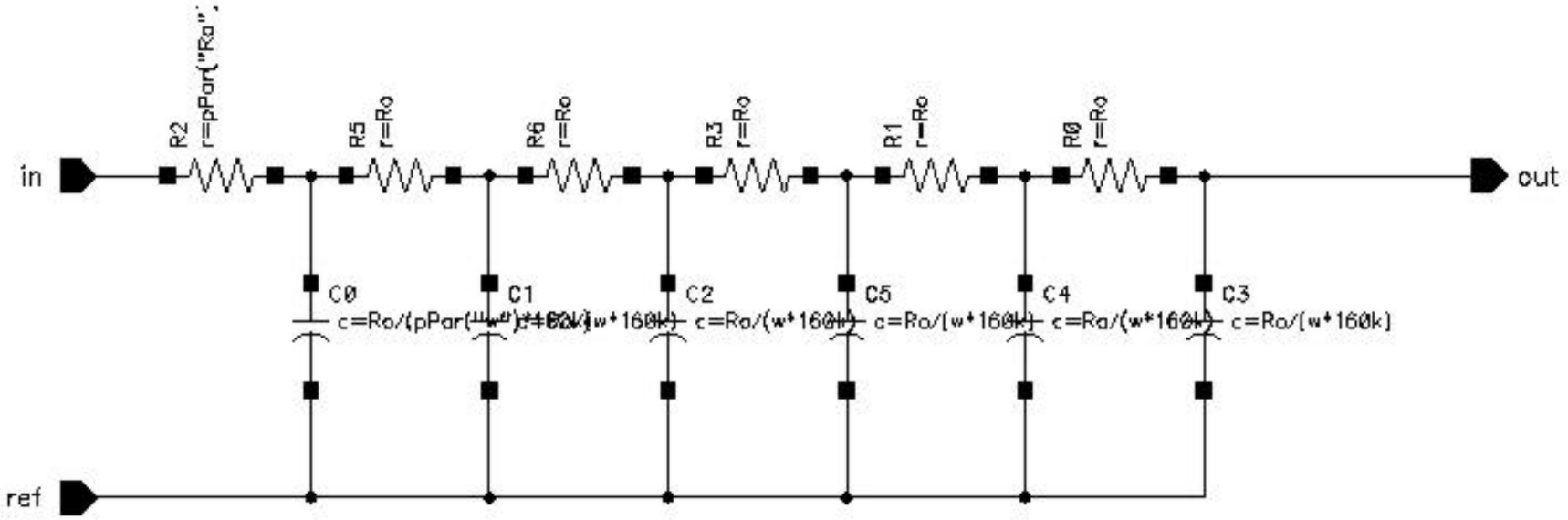
Cable model


I32
Ro=135
len=10
w:400meg
p1
p2
line
n1
n2
I28
Ro=135
len=10
w:400meg
p1
p2
line
n1
n2
I33
Ro=135
len=10
w:400meg
p1
p2
line
n1
n2
p1
n1
com1
p2
n2
com2

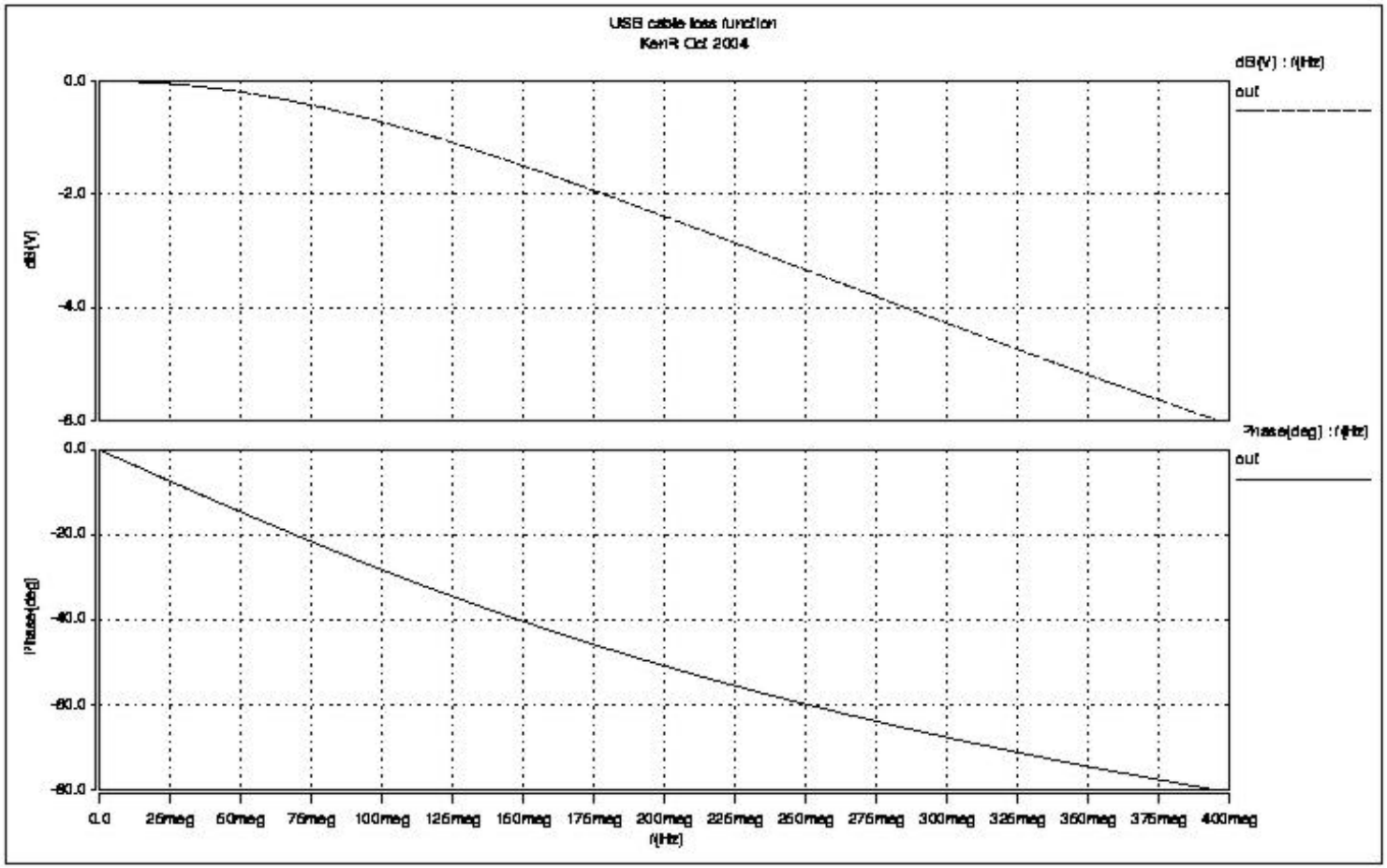
Transmission line model



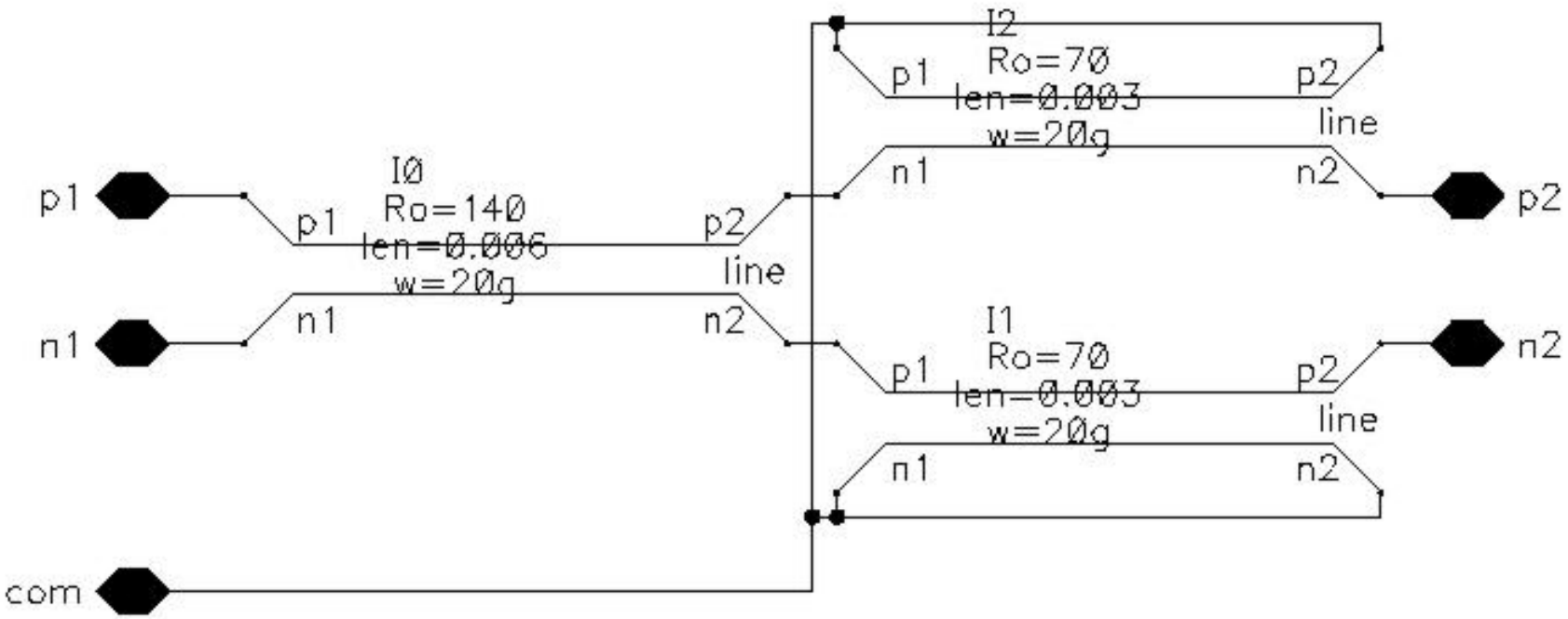
Cable loss model



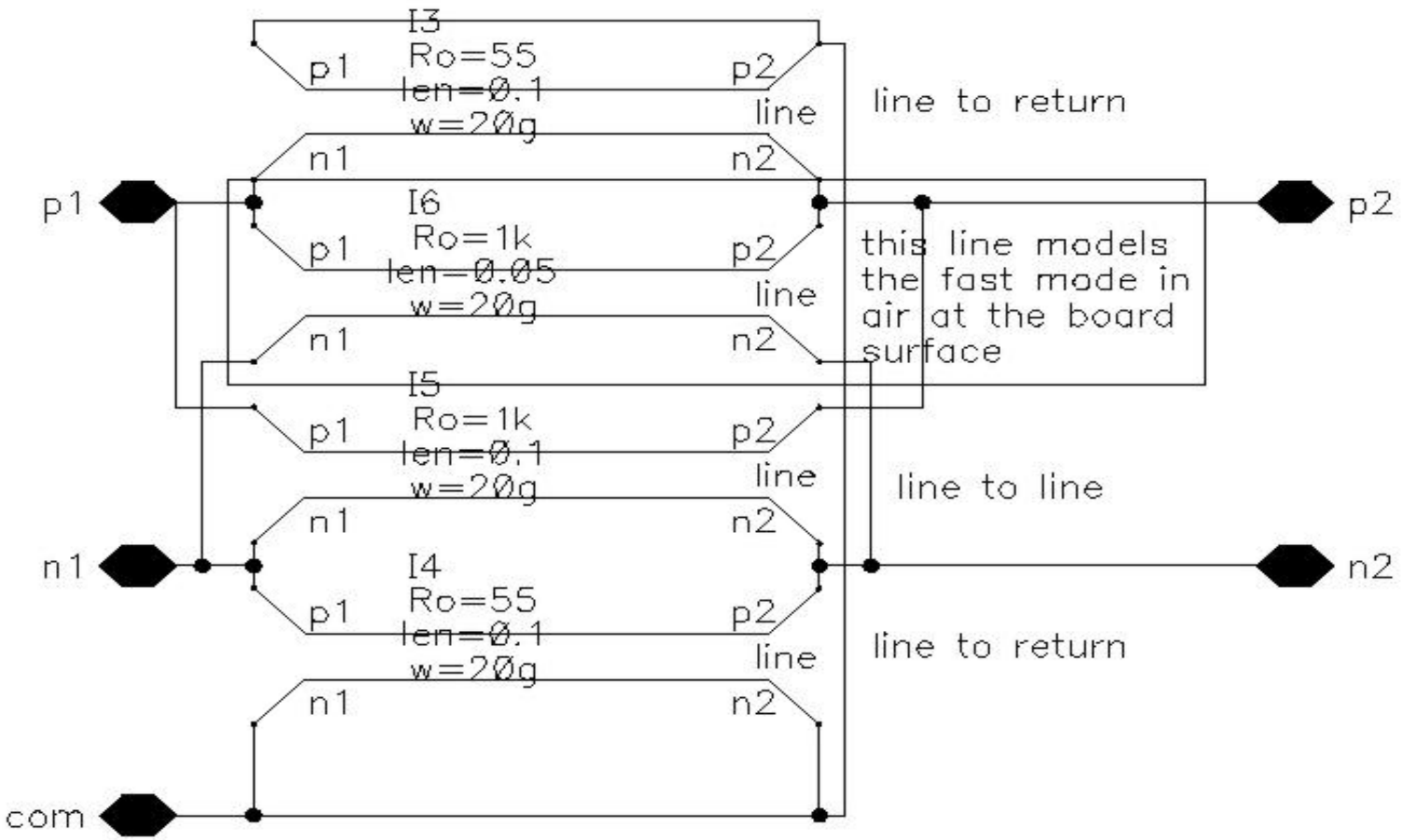
Cable loss characteristic



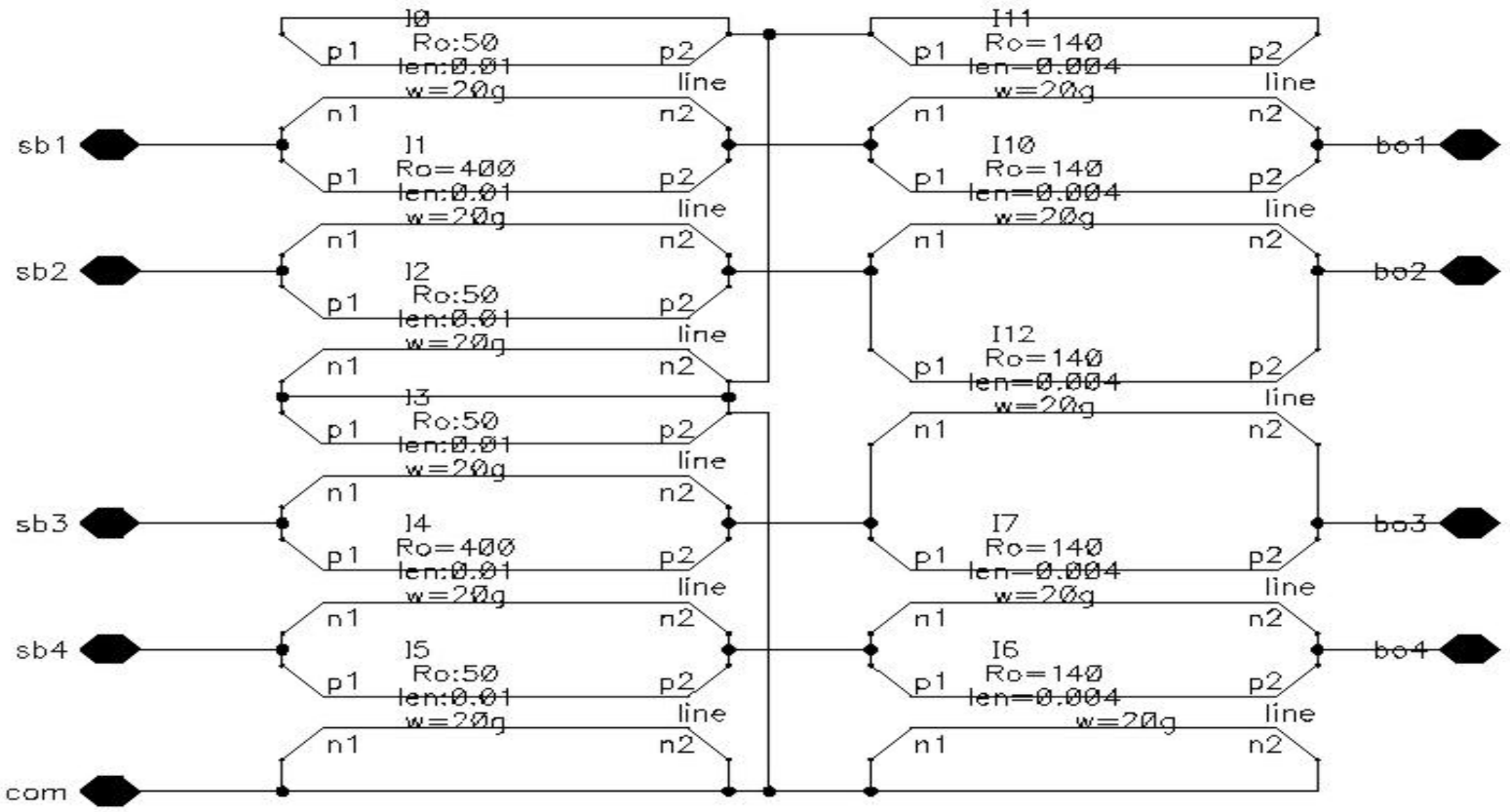
Connector model



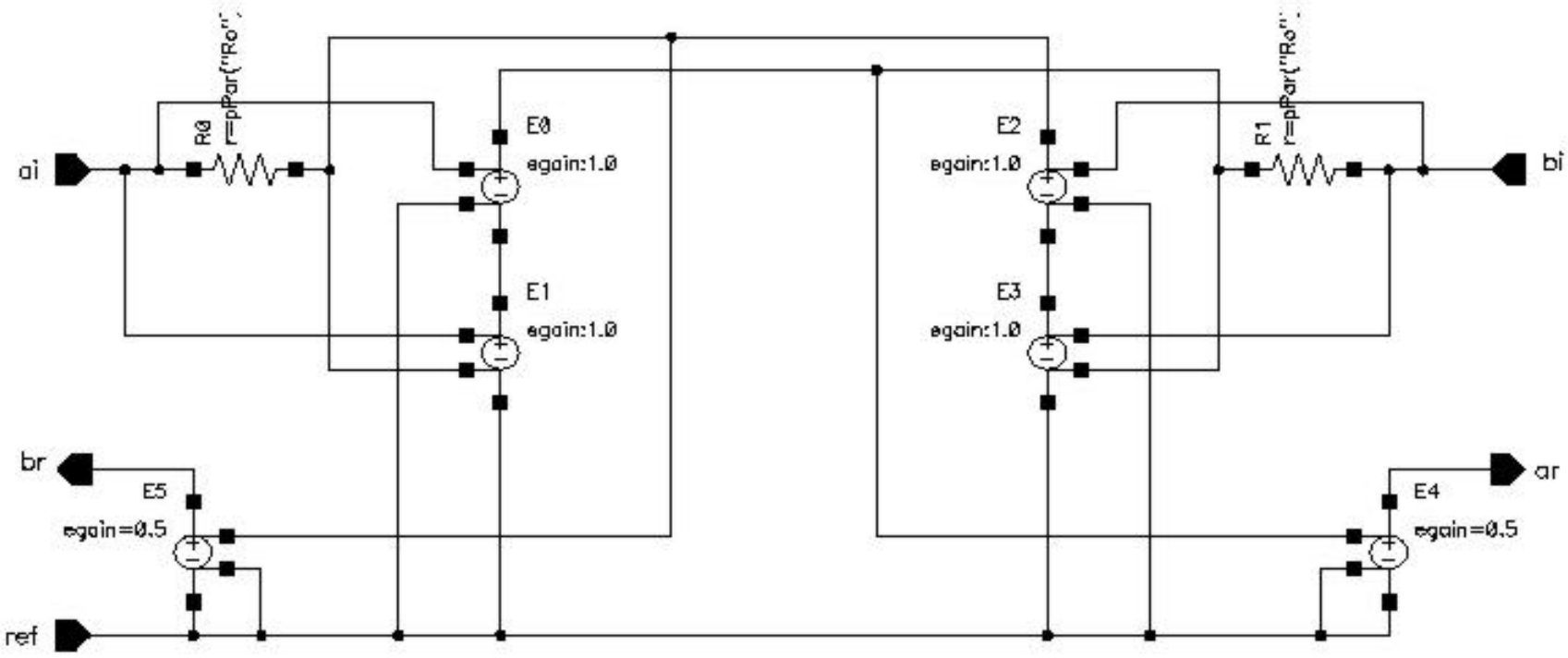
Board model


I3
Ro=55
len=0.1
w=20g
p1
p2
line
n1
n2
line to return
p1
I6
Ro=1k
len=0.05
w=20g
p1
p2
line
n1
n2
this line models the fast mode in air at the board surface
p2
I5
Ro=1k
len=0.1
w=20g
p1
p2
line
n1
n2
line to line
n1
I4
Ro=55
len=0.1
w=20g
p1
p2
line
n1
n2
n2
line to return
com

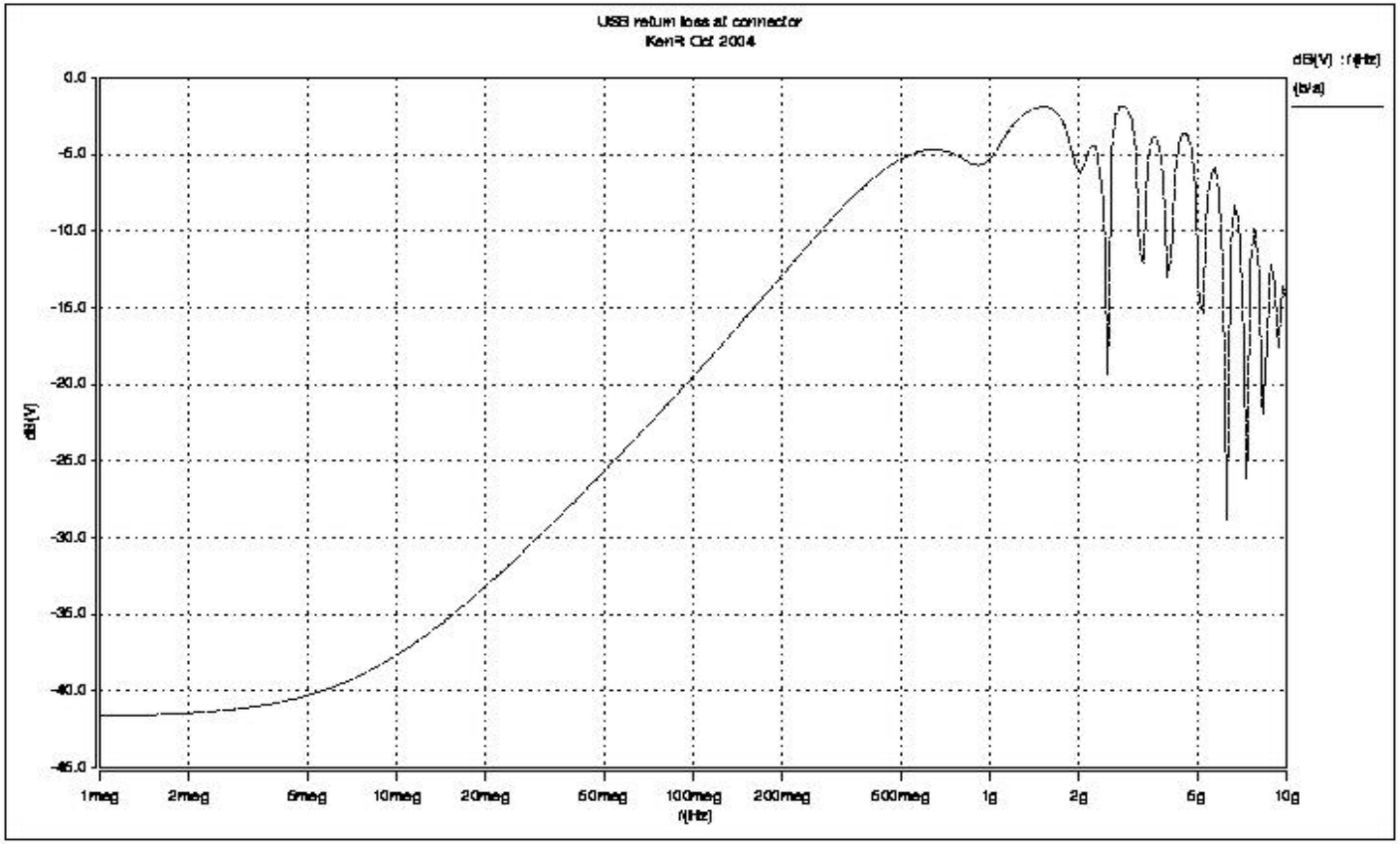
Package and bond model



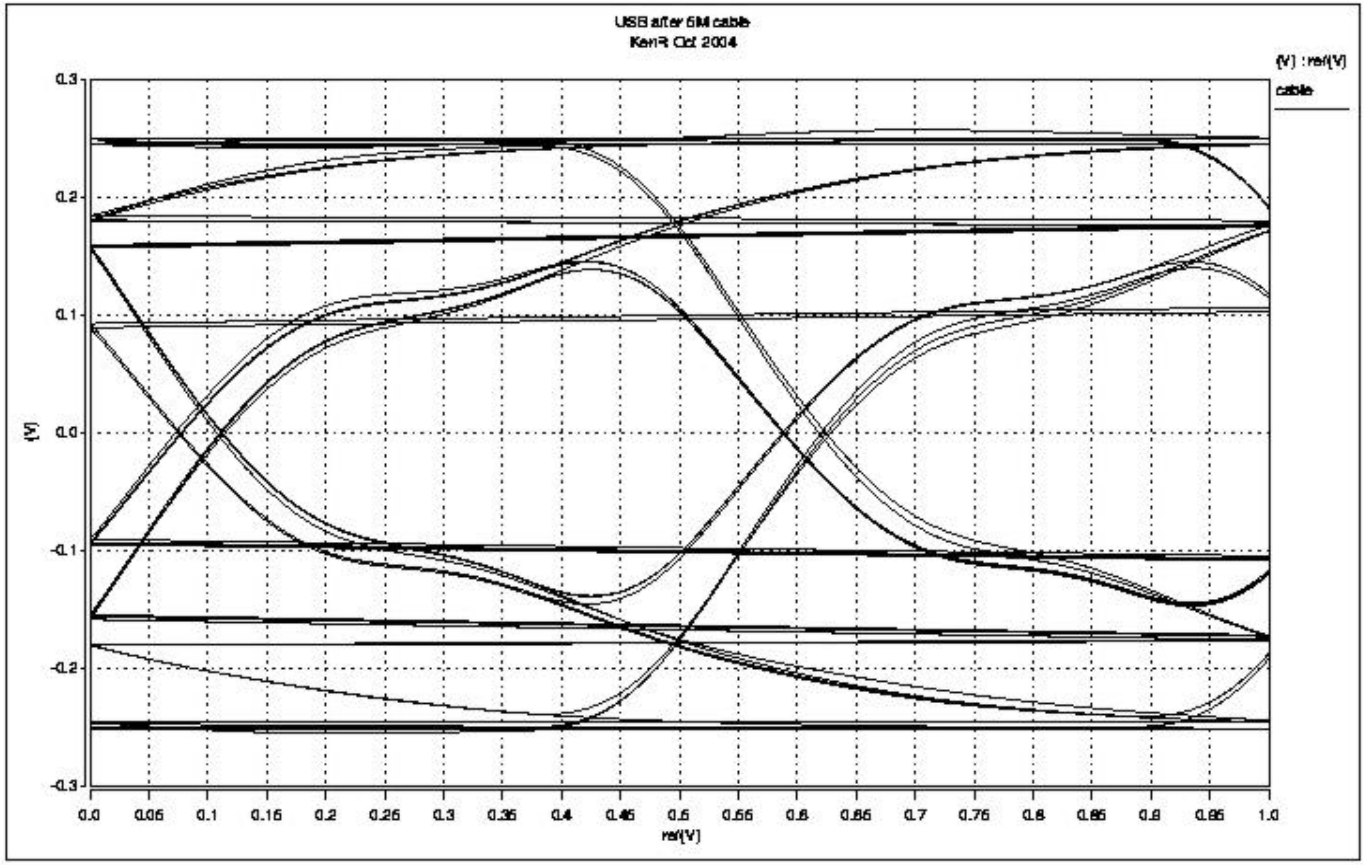
Directional coupler model



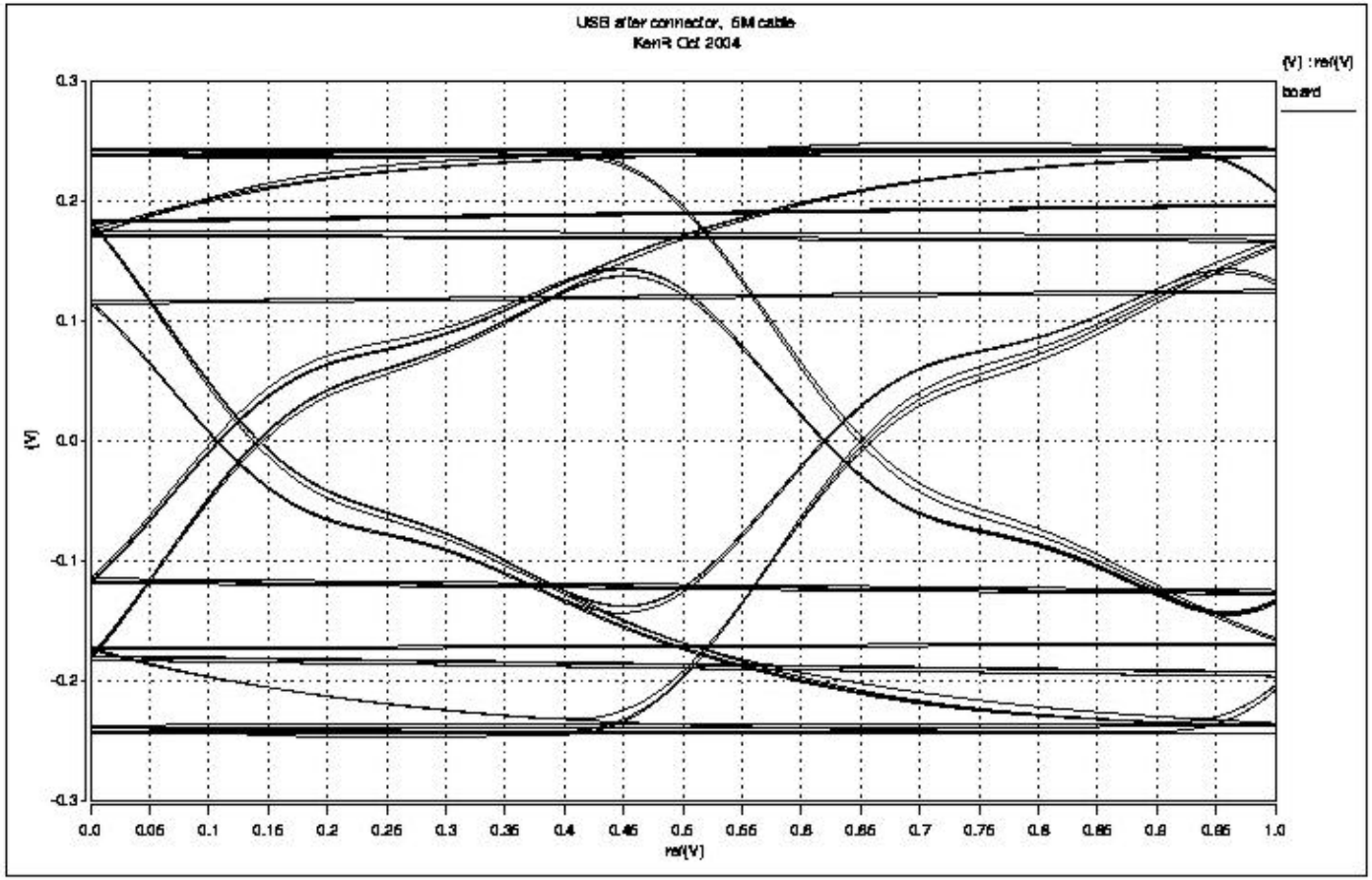
Return loss at connector



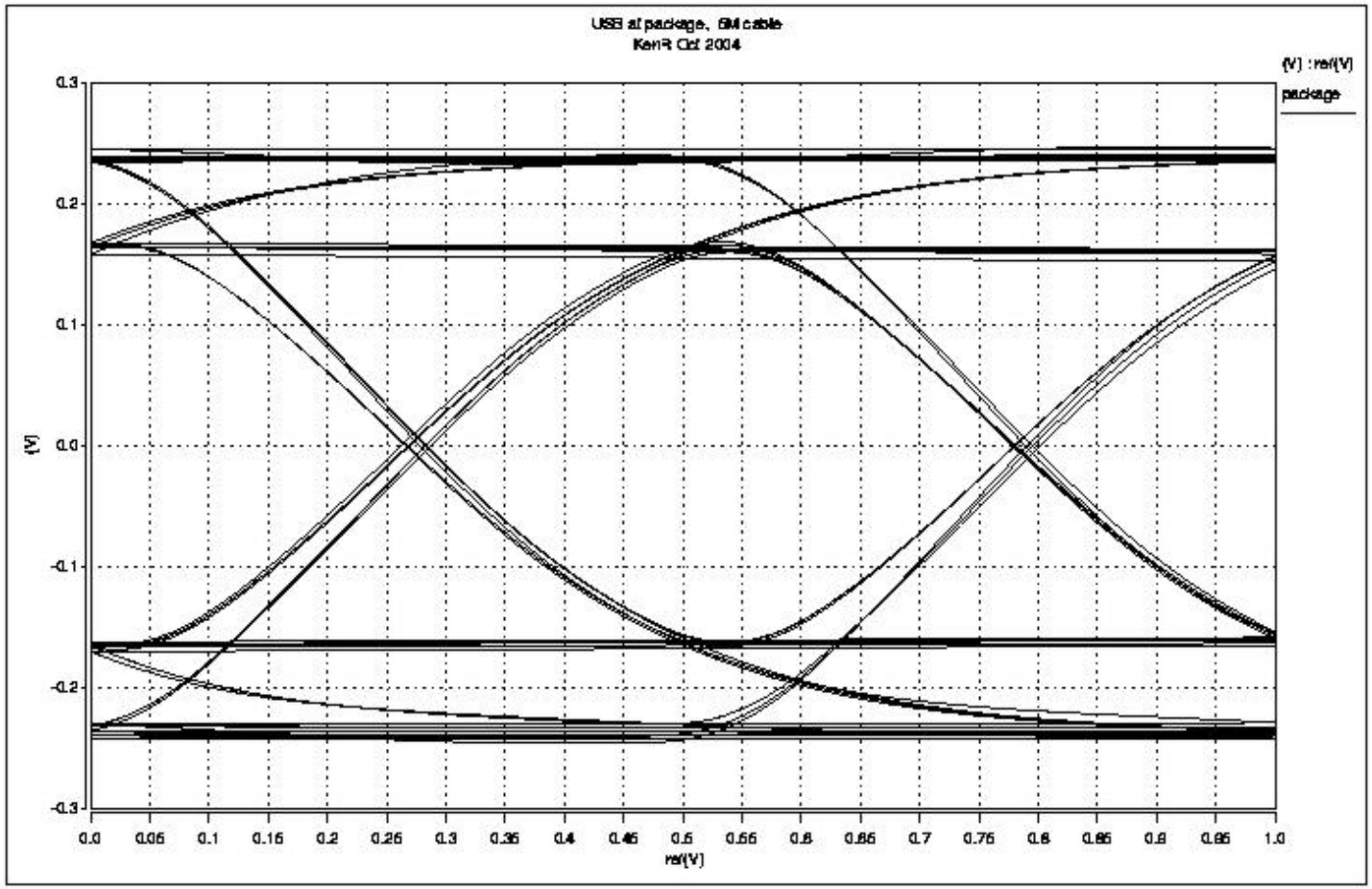
At the cable end



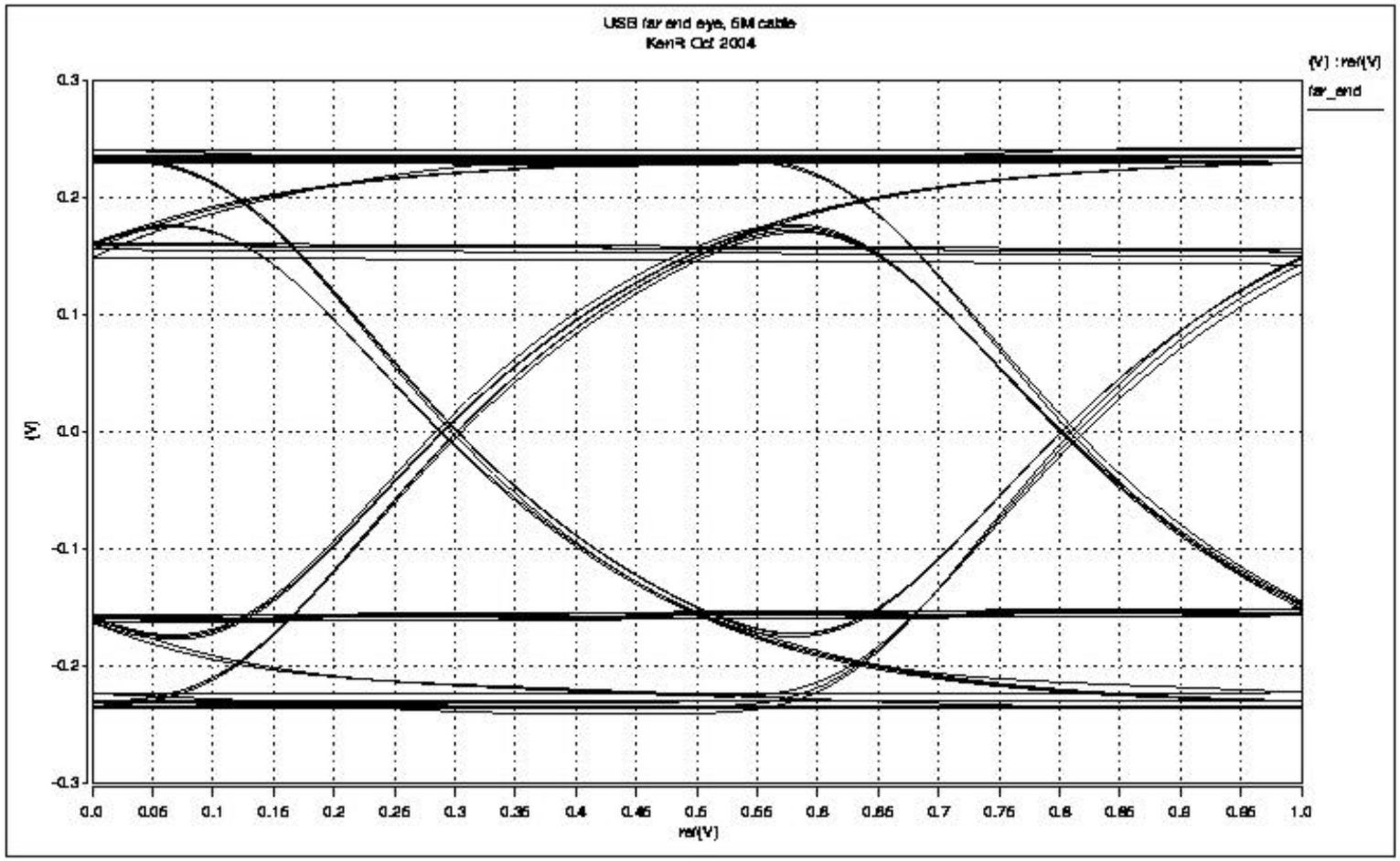
After the connector



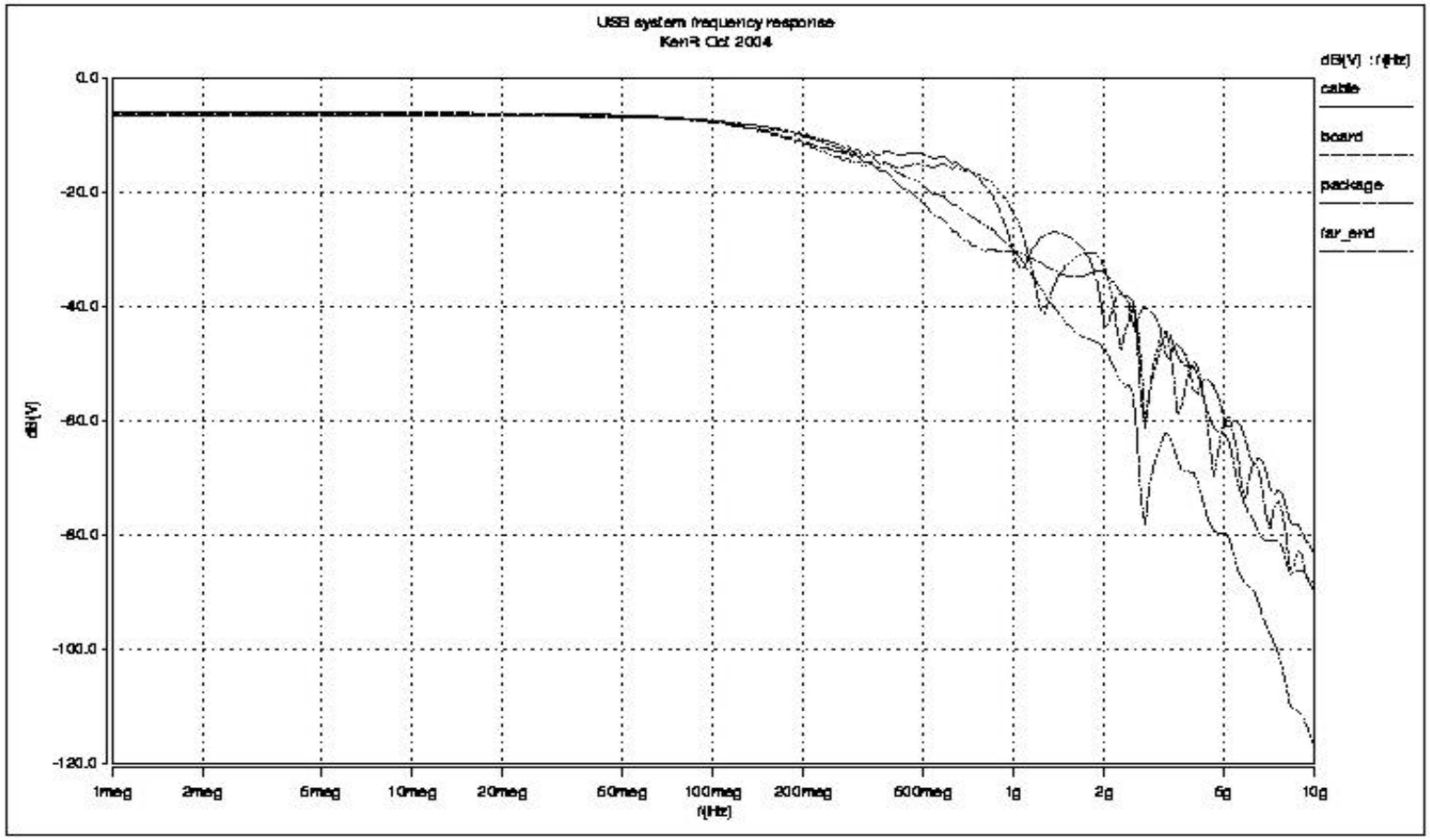
After 5cm of board



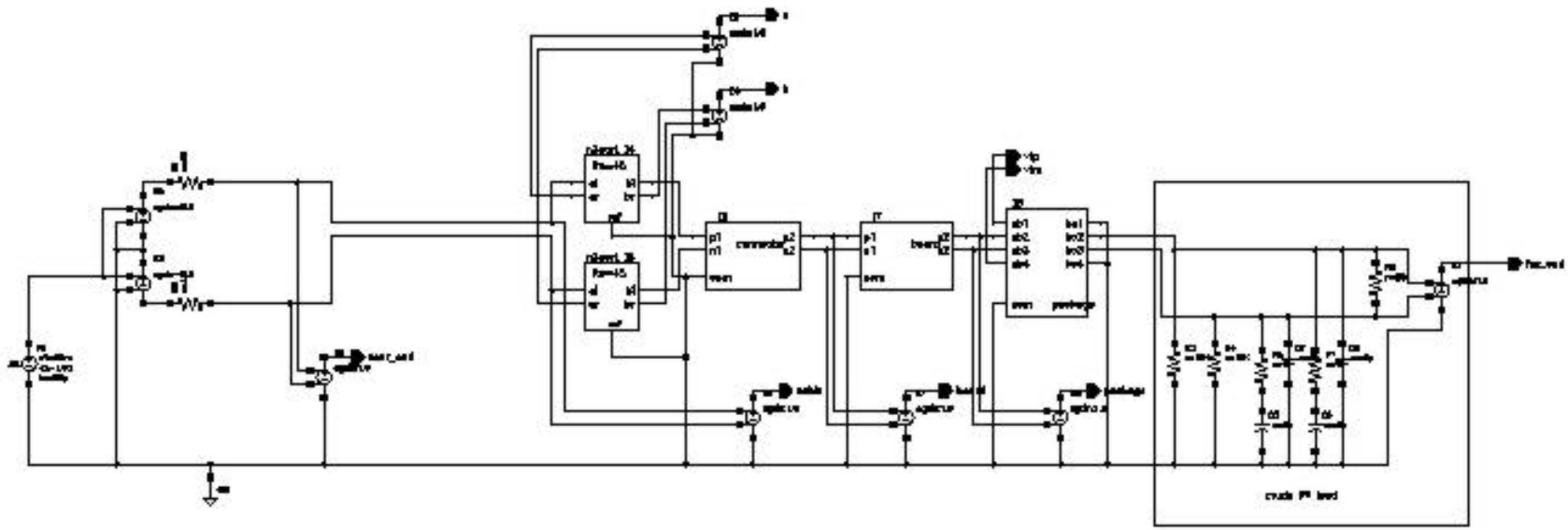
On the chip at the terminator



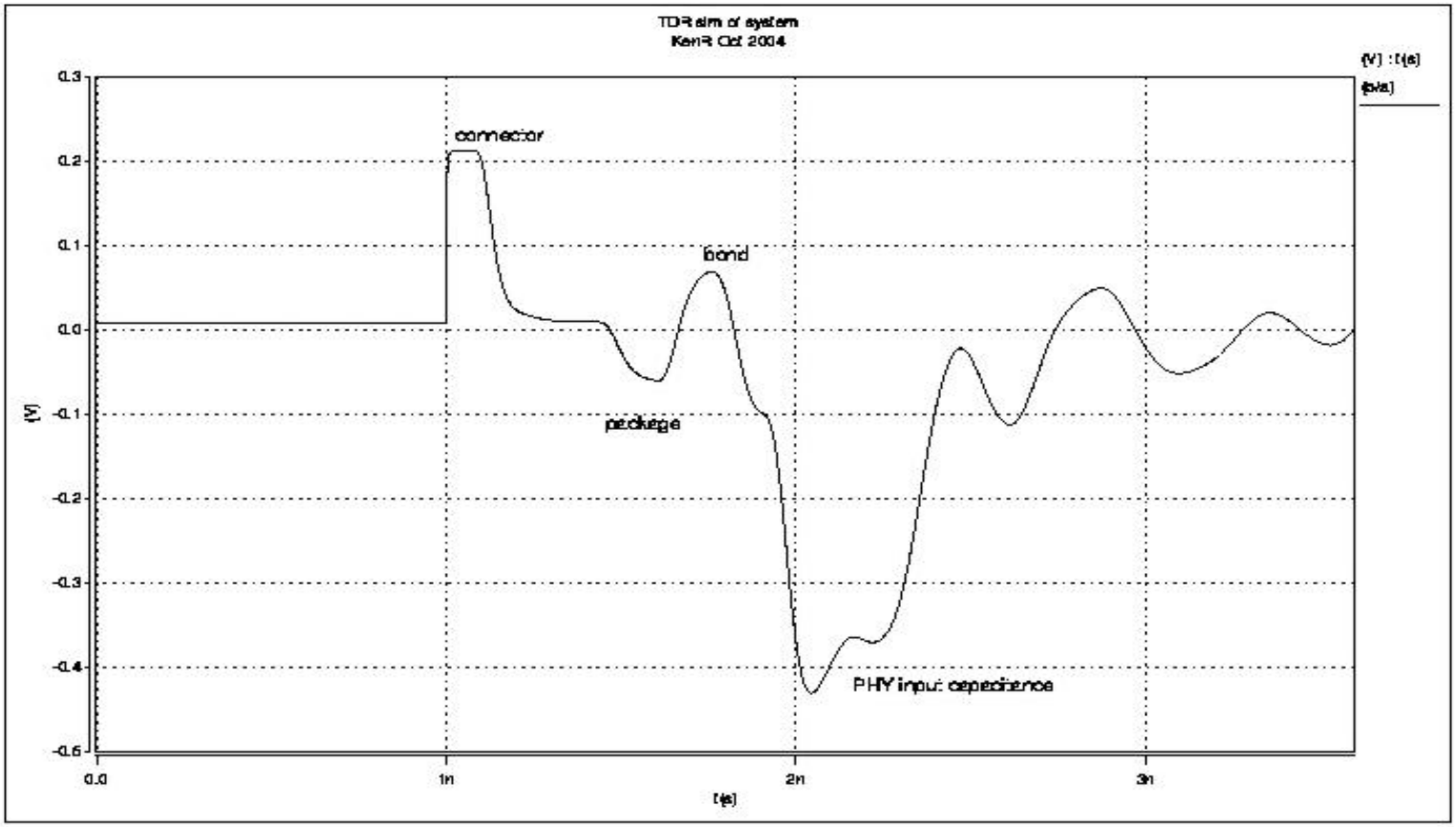
System frequency response



TDR sim test bench



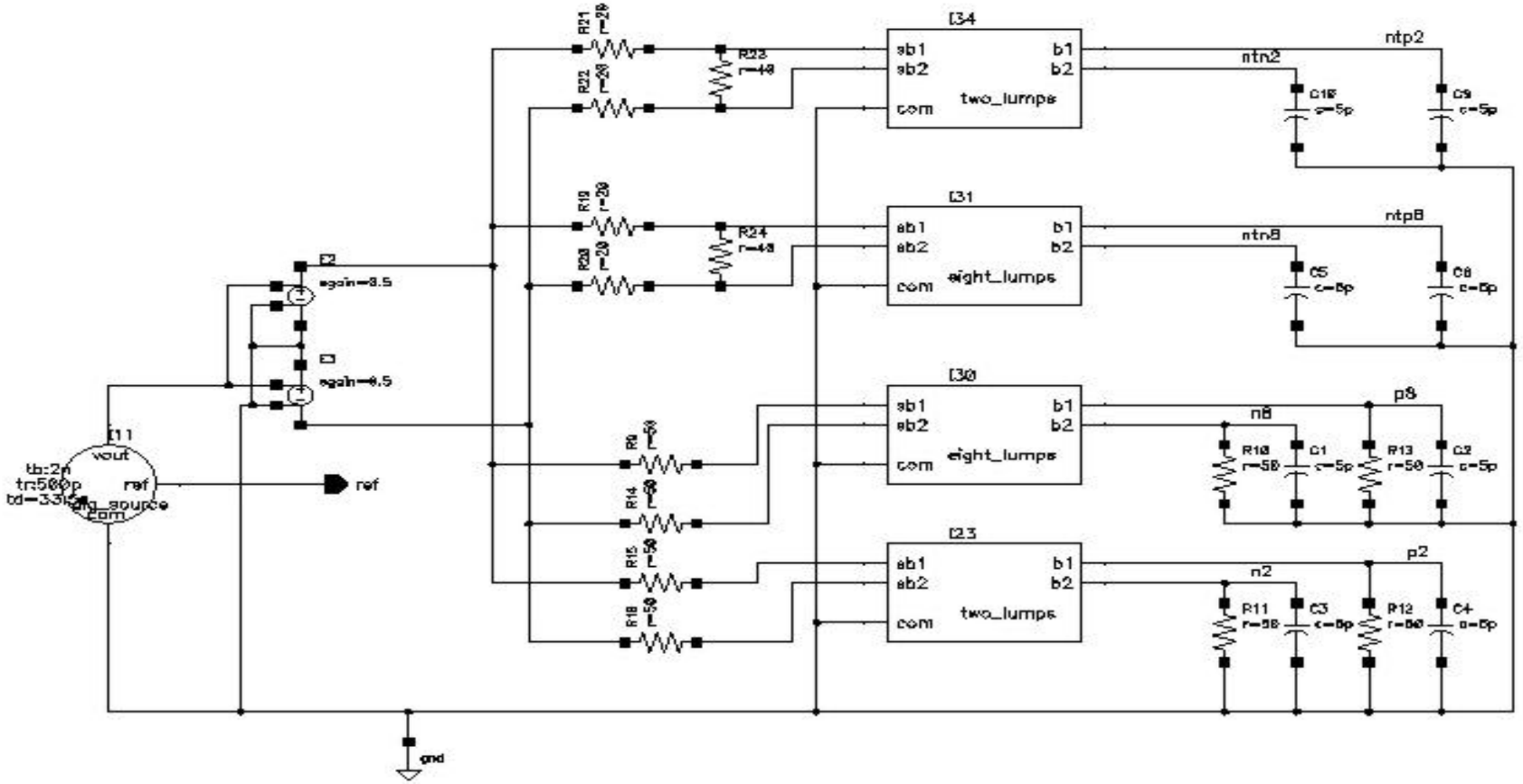
TDR sim result



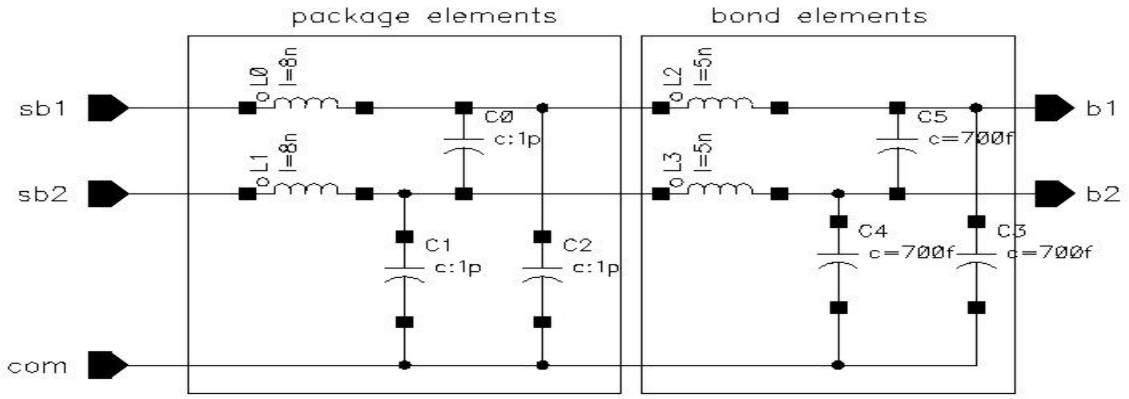
Package and bond wires

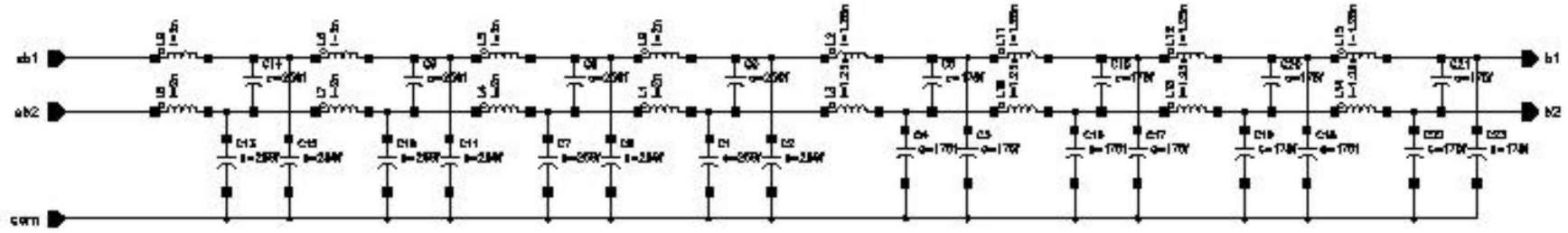
- Single lumped models:
  - Watch out above 100-200MHz
  - Break into more lumps based on extracted data
    - Can extract a small group of pins by hand
    - Use a solver

Lumped model test bench

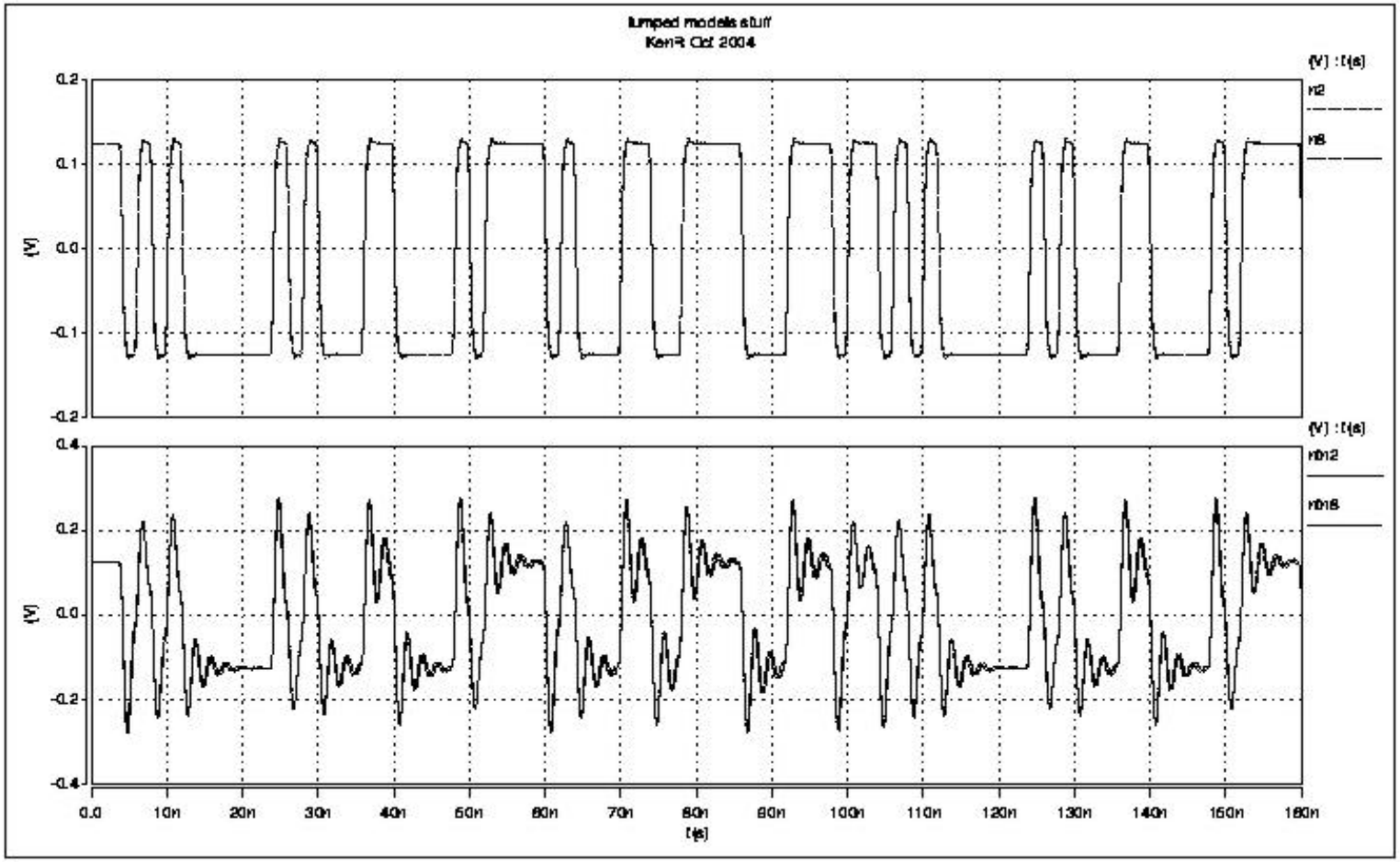


2 lumps and 8 lumps

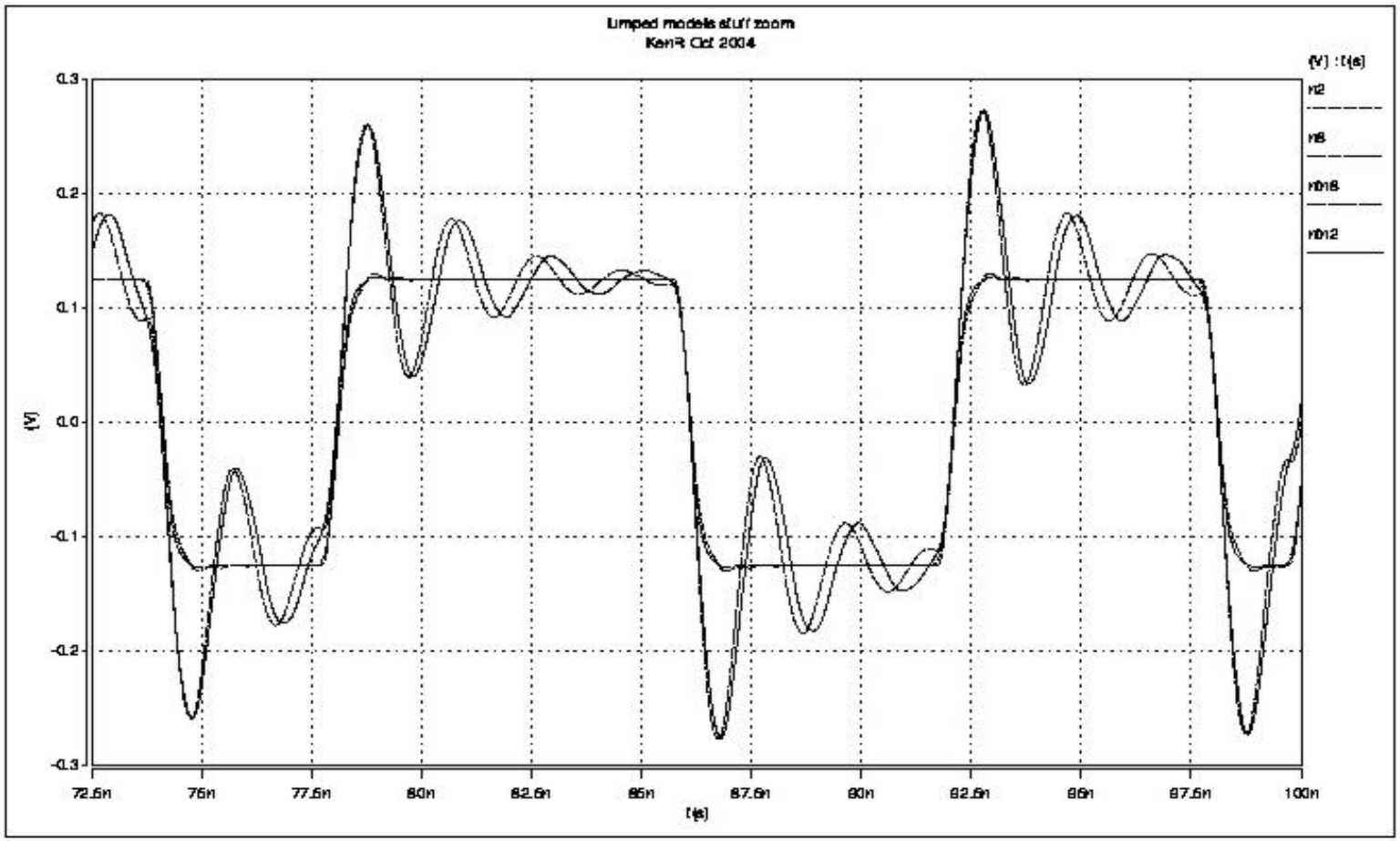




Lumped results



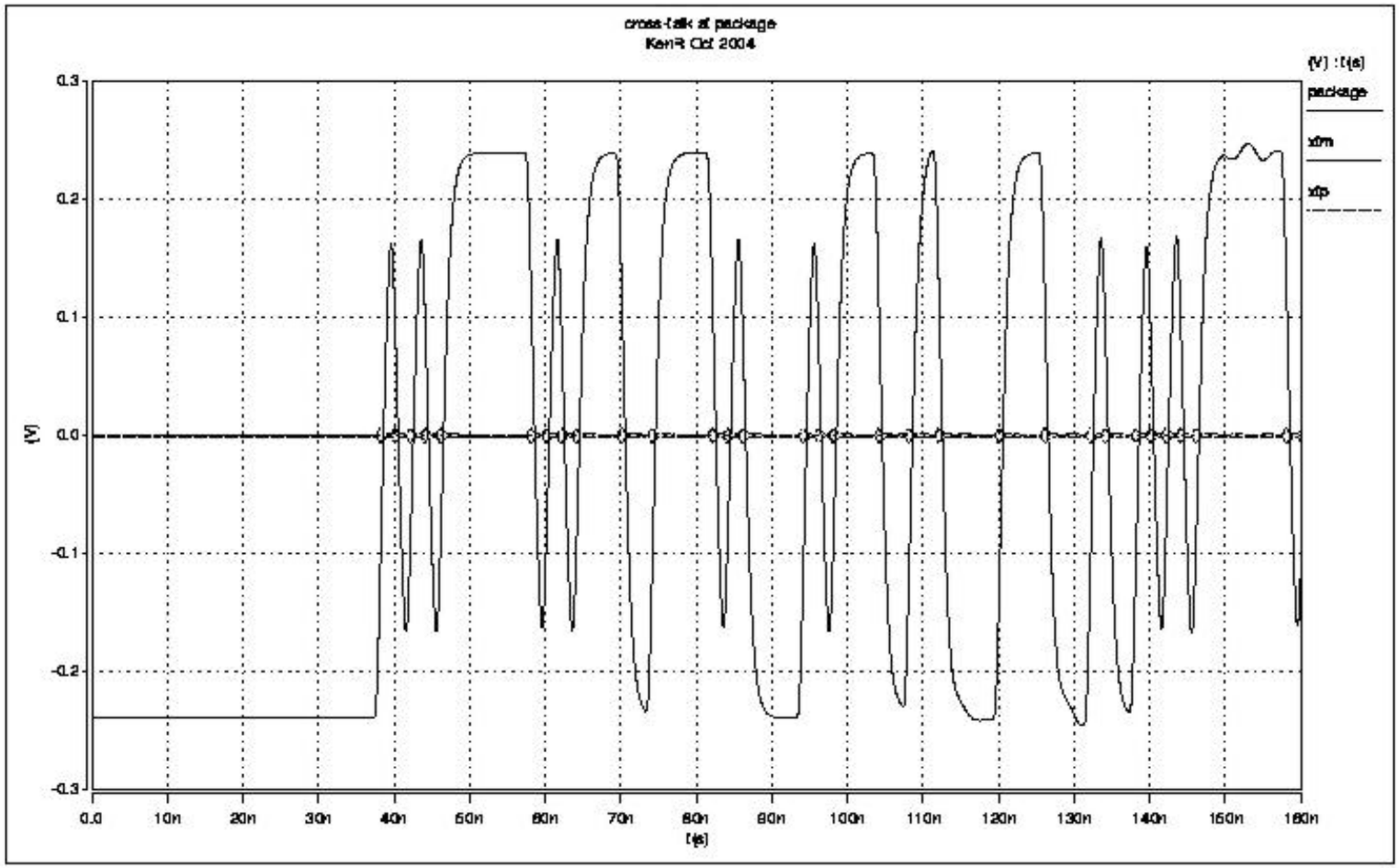
Lumped models



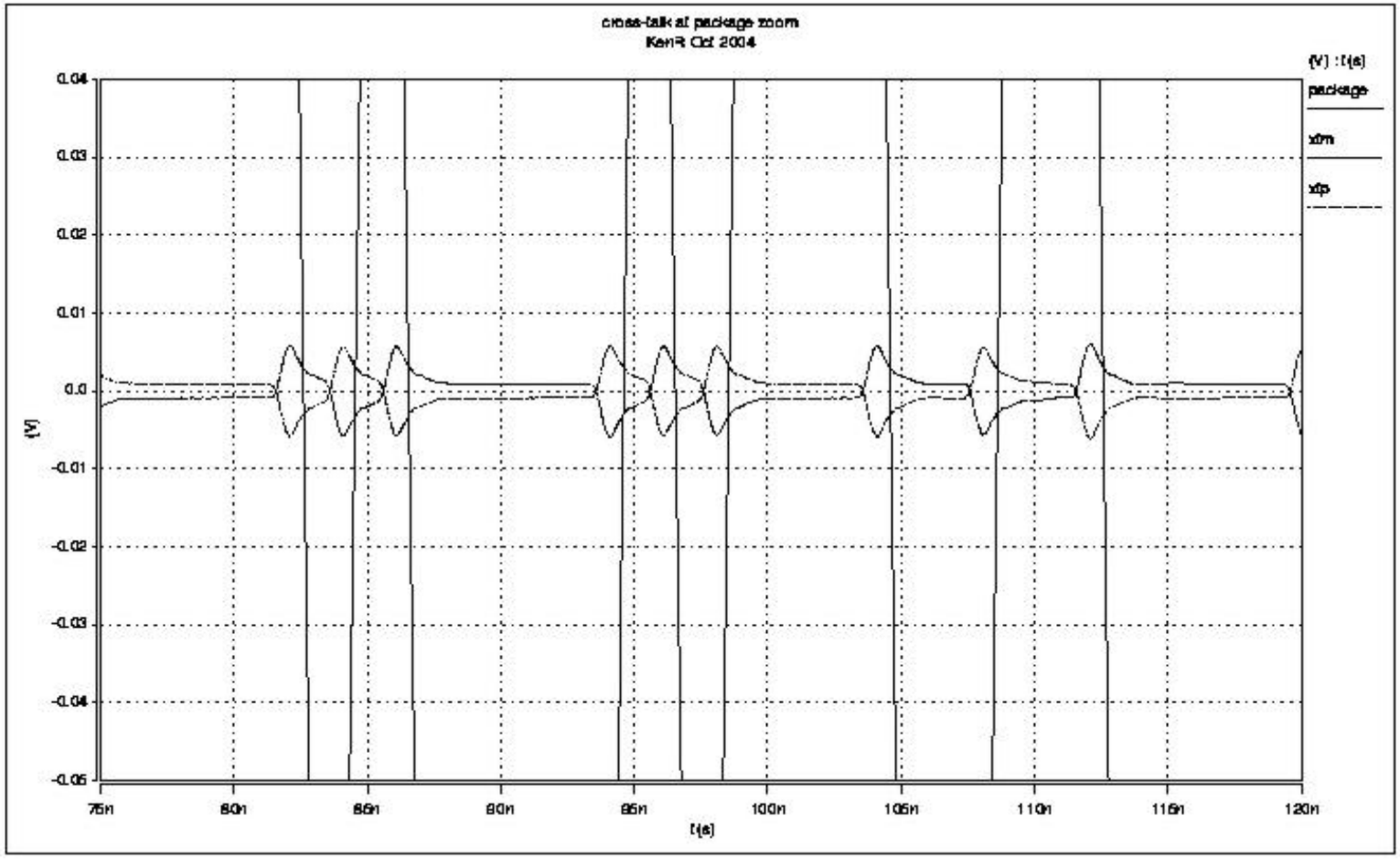
Cross-talk

- Interconnected transmission lines generally do the trick.
- Hspice W element is really good but try getting one quickly.

Obligatory cross-talk slide

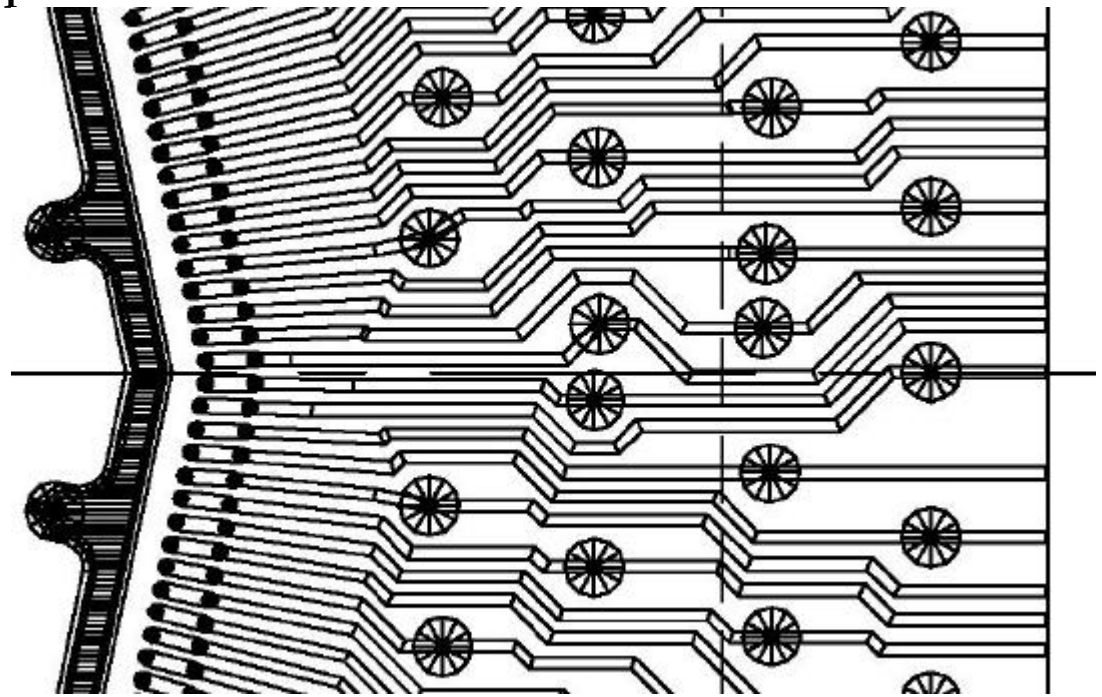


X-talk zoom


cross-talk at package zoom
KenR Oct 2004
(V) :t(s)
package
xtm
xtp
0.04
0.03
0.02
0.01
0.0
-0.01
-0.02
-0.03
-0.04
-0.05
(V)
75n
80n
85n
90n
95n
100n
105n
110n
115n
120n
t(s)

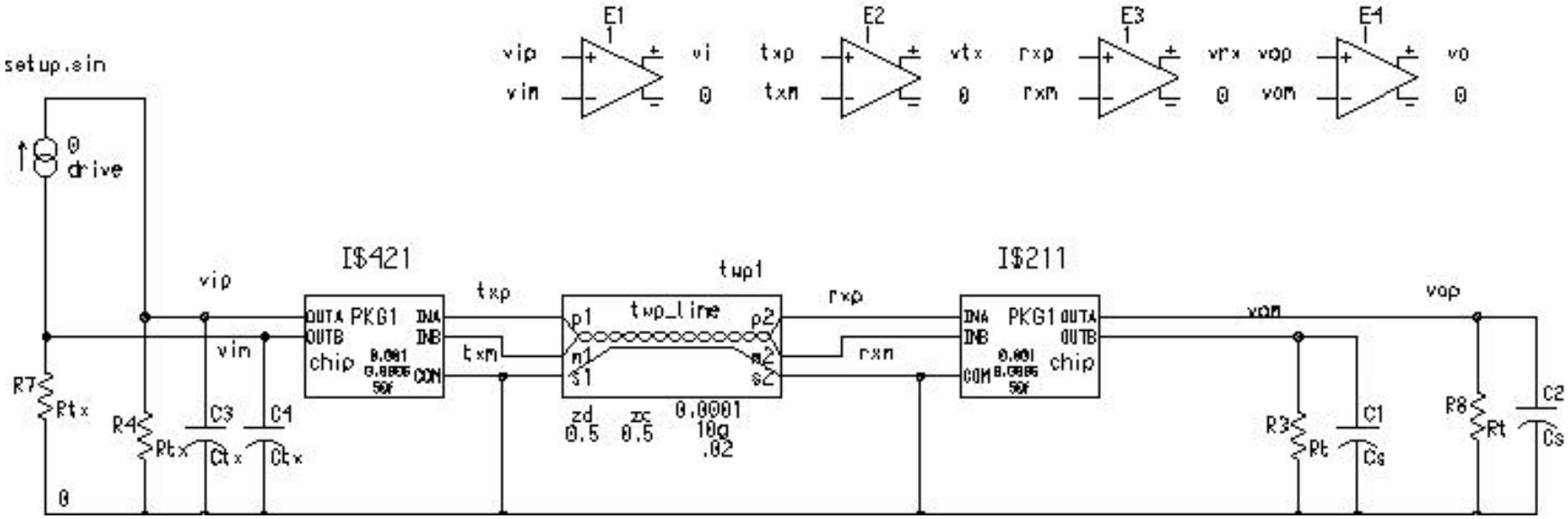
Plating stubs

- 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

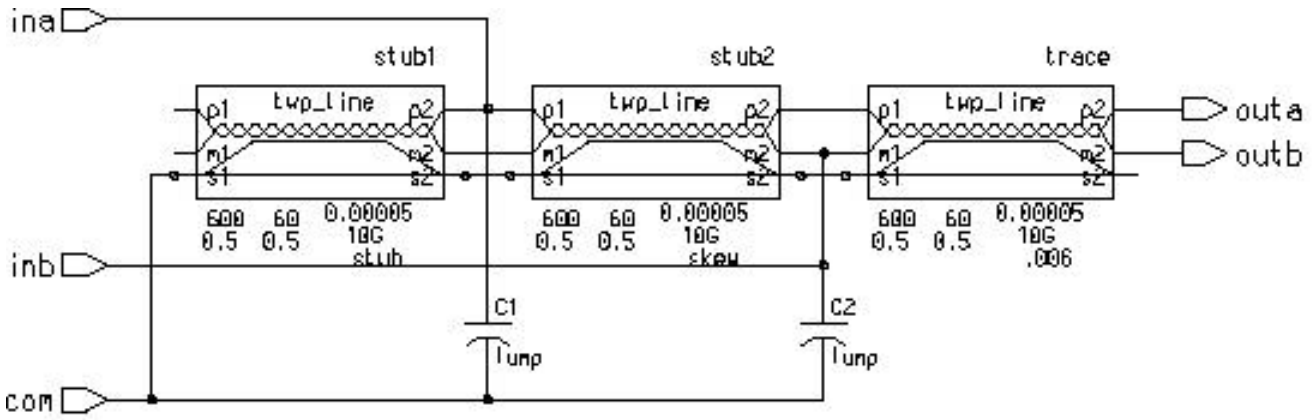


Plating stub models

Top level test bench

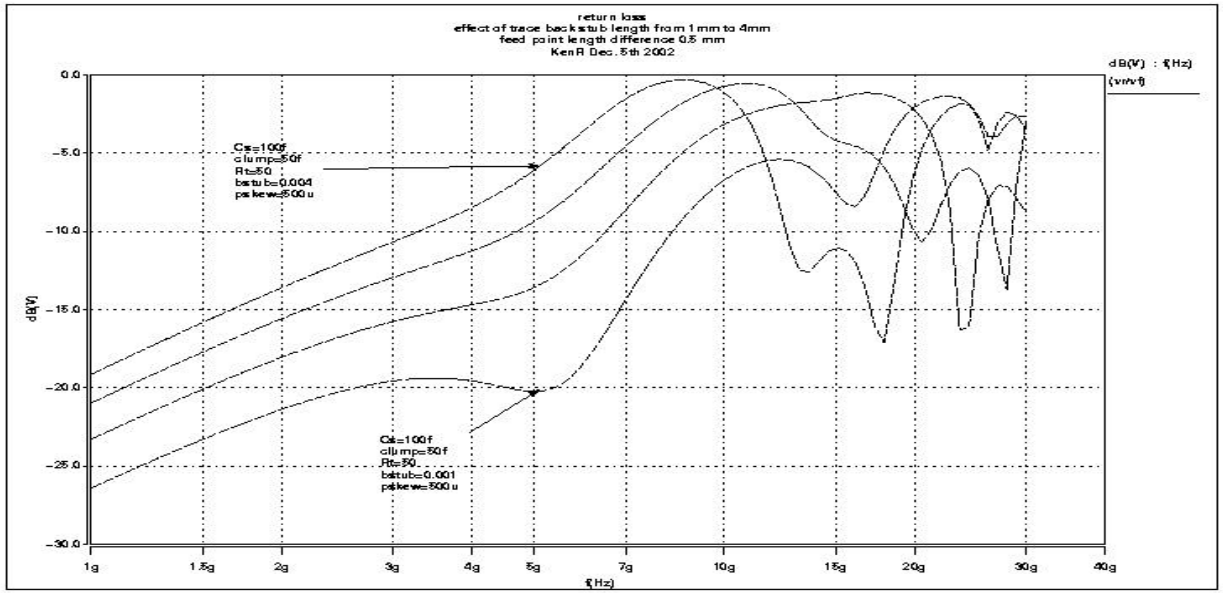


Plating stub models



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

- RLGC 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