Accuracy Considerations of Power-Ground Plane Models

I. Novak

October 1999

Sun microsystems

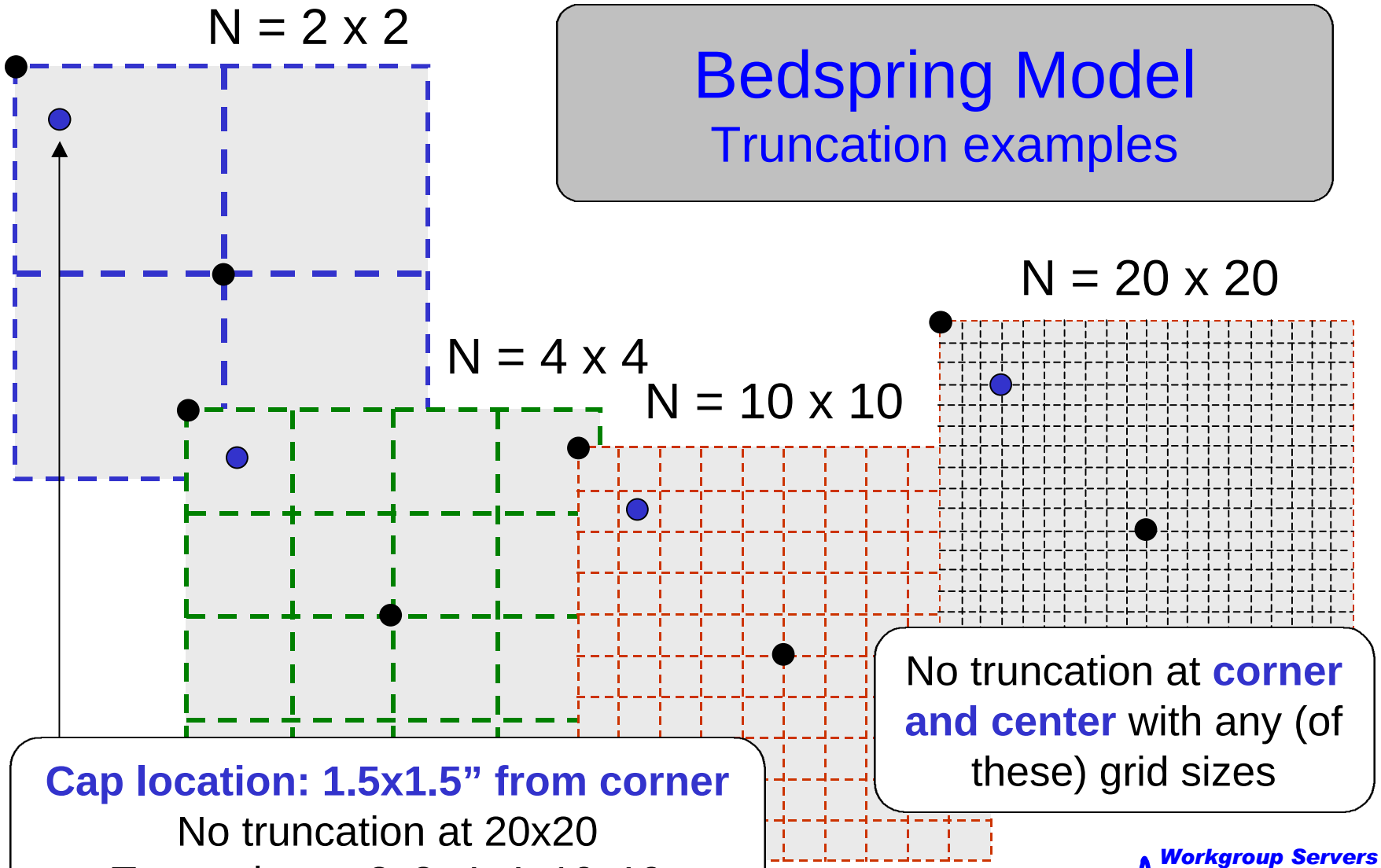
Workgroup Servers

Board Design Technology

Outline

- Bedspring model truncation limitations
- Analytical model summation-limits
- Measured-simulated plane-bandwidth correlation
- Conclusions

Bedspring Model
Truncation examples



Cap location: 1.5x1.5” from corner
No truncation at 20x20
Truncation at 2x2, 4x4, 10x10

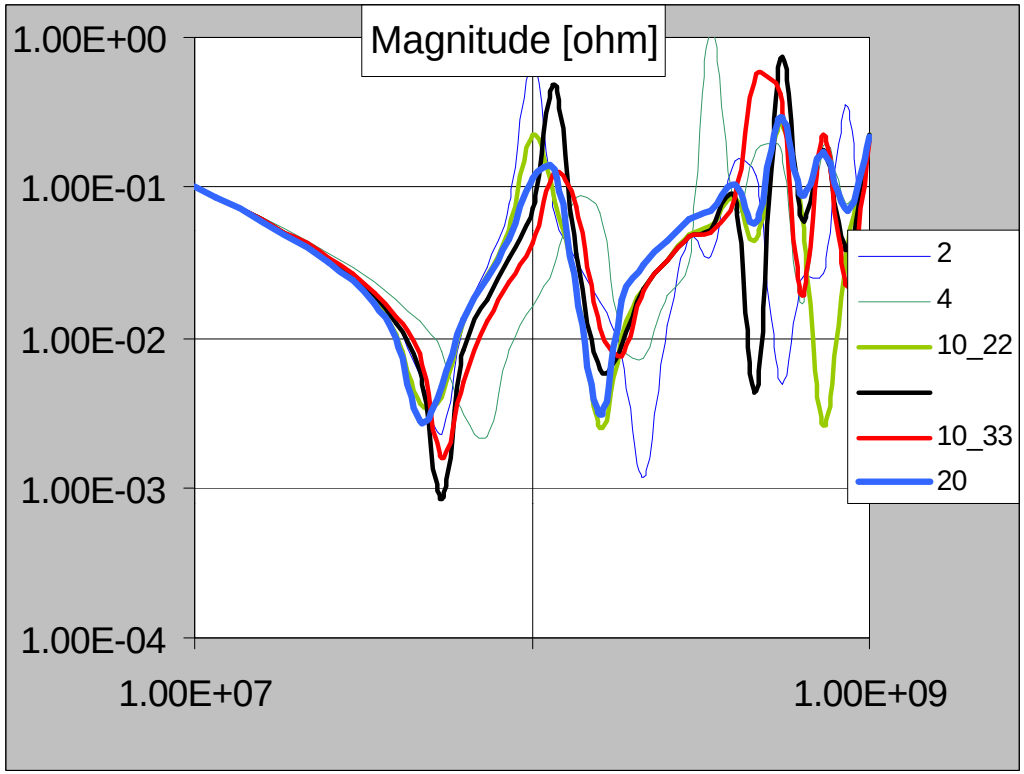
No truncation at **corner and center** with any (of these) grid sizes

Workgroup Servers
Board Design Technology

Bedspring Model Limitations

- Finite granularity of the equivalent circuit. The accuracy of model gradually decreases at frequencies where the delay through one segment of the circuit becomes a non-negligible fraction of the period of signal.
- Truncation of component and test locations. The simple bedspring model has a uniform grid step along one or both axes. If transient sources, bypass capacitors or probe points are located off grid, their locations should be truncated/adjusted to the nearest grid point.

Self-Z at Middle, One Capacitor

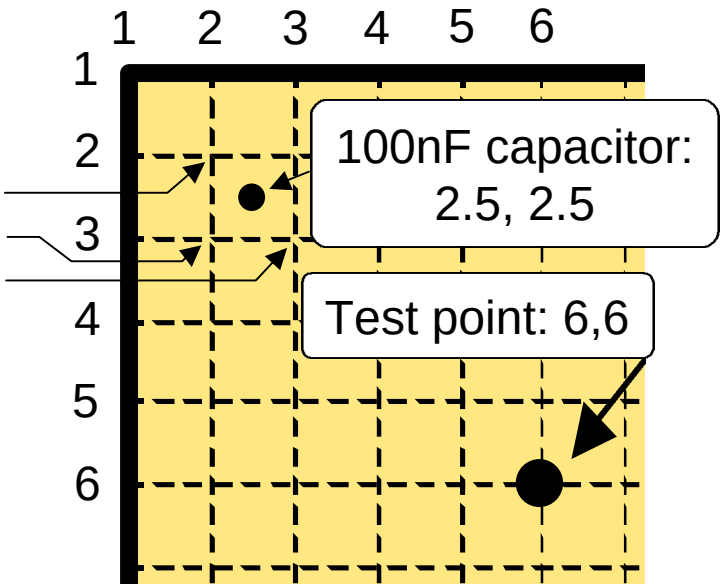


10”x10”x0.002”

One 100nF capacitor at 1.5”x1.5” from corner

No truncation at test point

Truncation for cap location



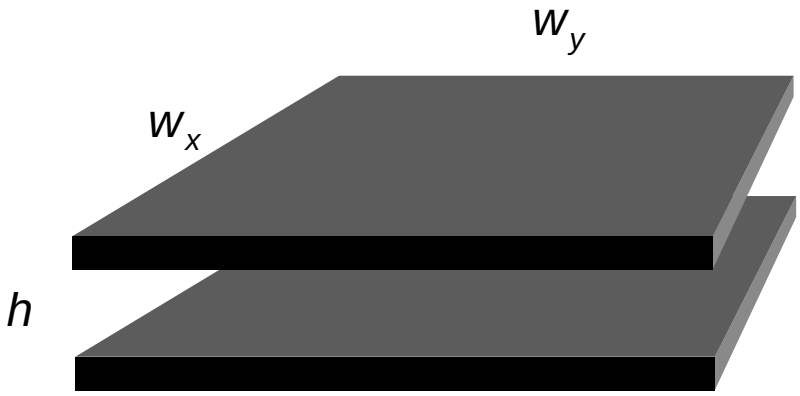
Workgroup Servers

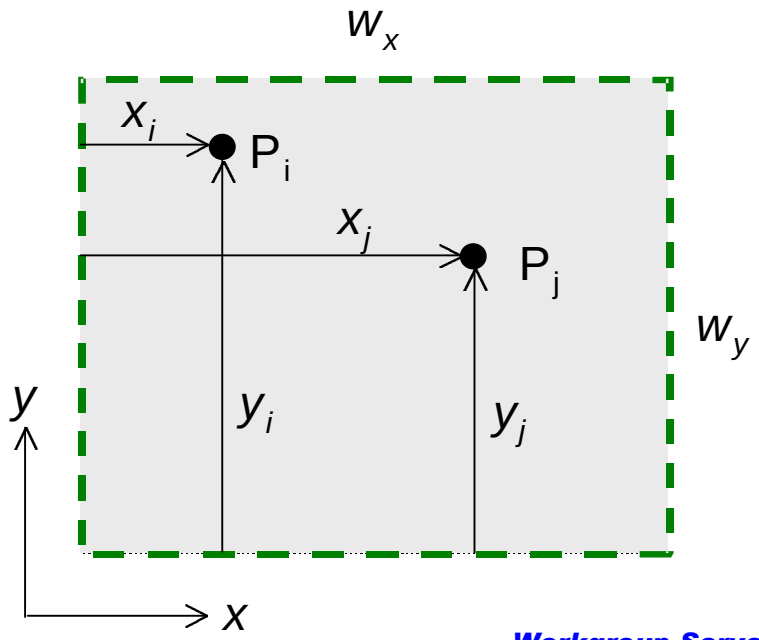
Board Design Technology

Analytical Model

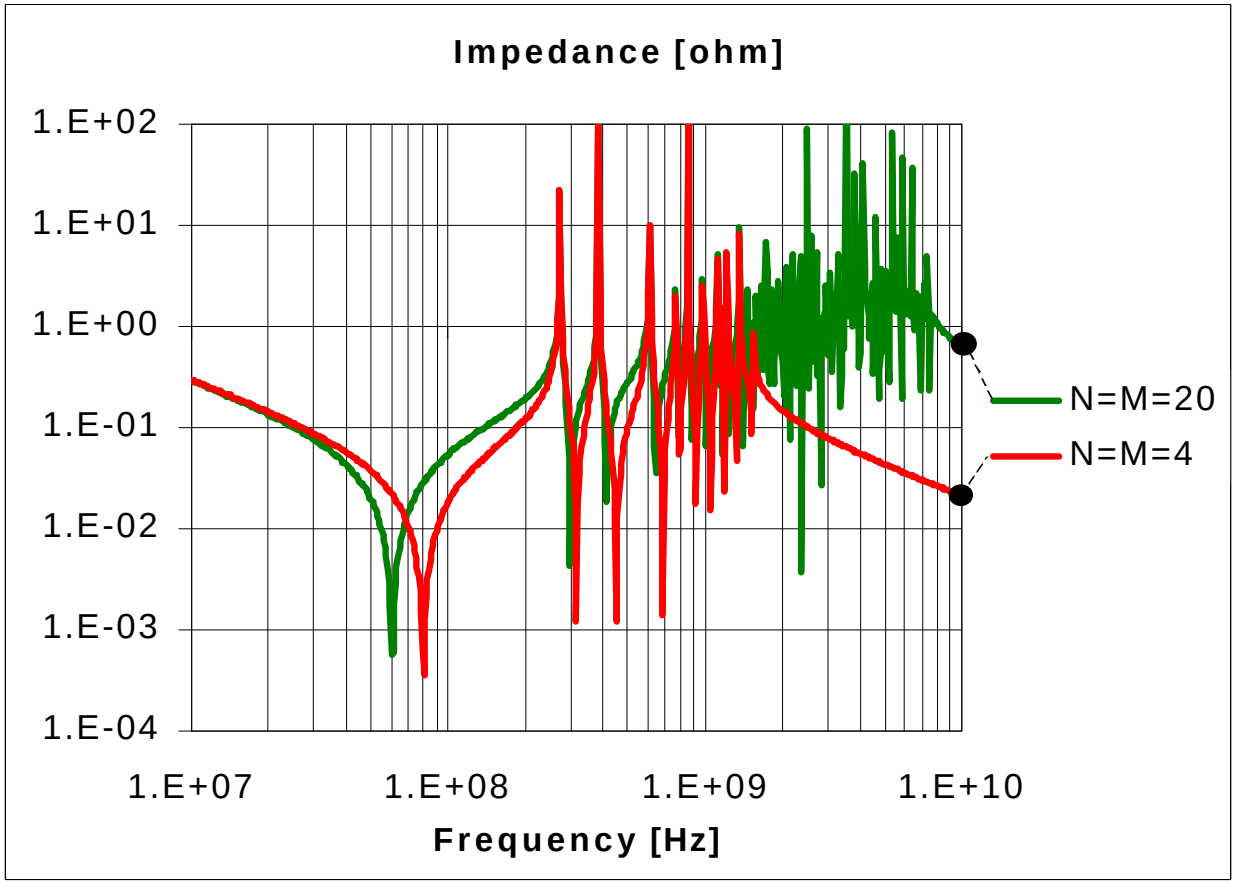
$$Z_{ij}(w) = jwm\,h \sum_{n=0}^{\infty}\sum_{m=0}^{\infty} \frac{c_{mn}^{\,2}}{w_x w_y \left(k_n^{\,2} - k^2\right)} \cos\left(\frac{2mp\ x_i}{2w_x}\right)\cos\left(\frac{2np\ y_i}{2w_y}\right)\cos\left(\frac{2mp\ x_j}{2w_x}\right)\cos\left(\frac{2np\ y_j}{2w_y}\right)$$

Double series of second-order poles



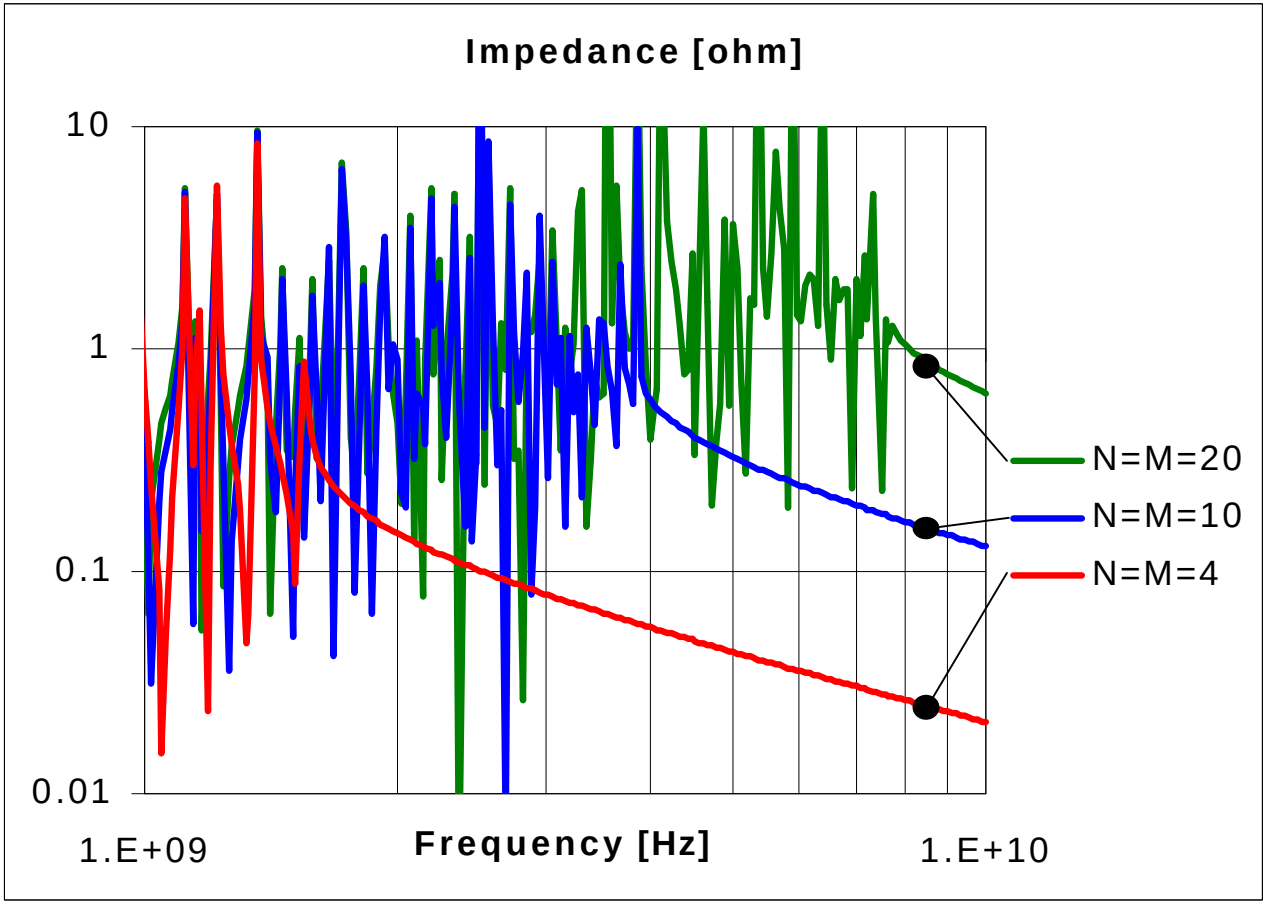


Analytical Model, Overall View



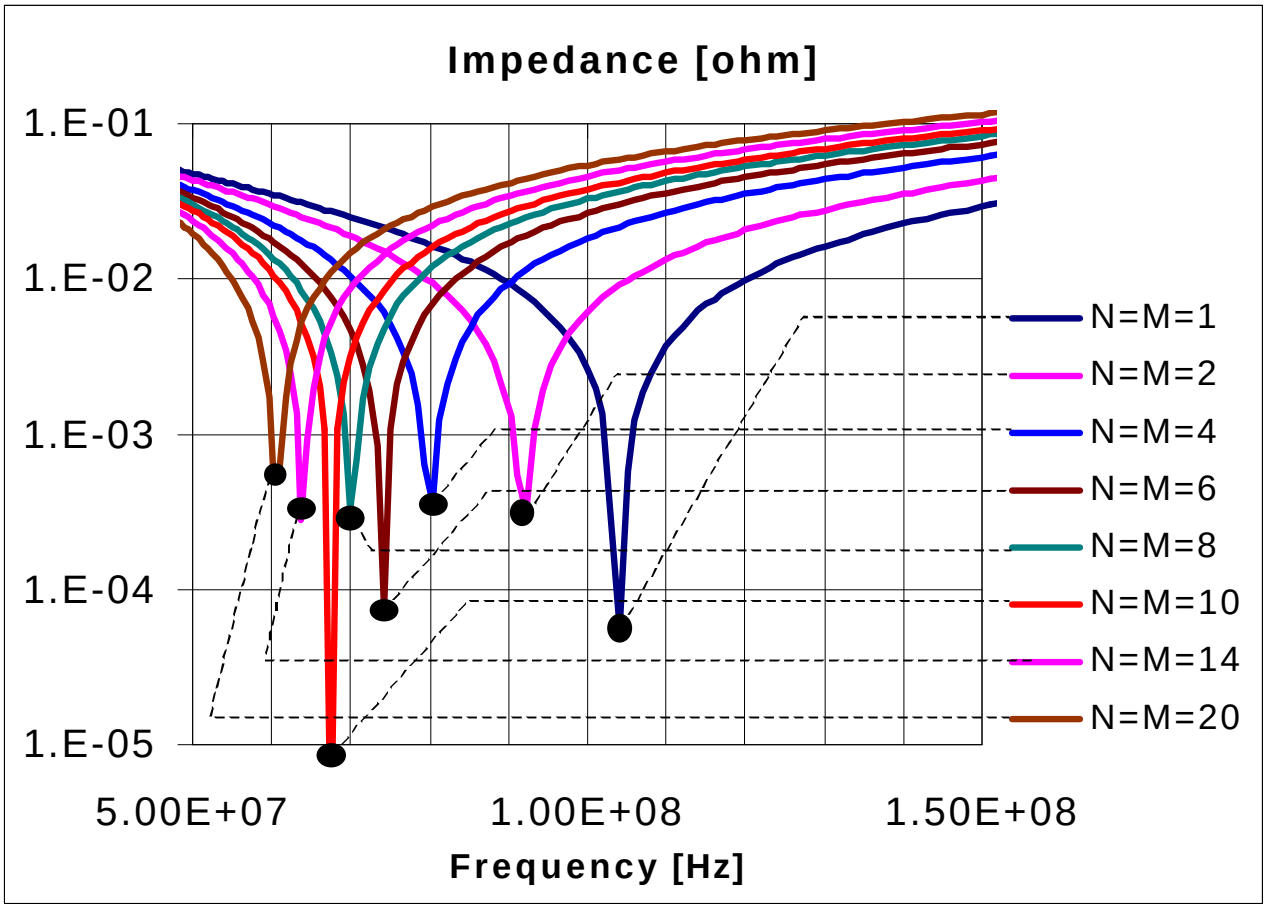
Impedance plot details depend on summation limits (10”x10”x0.002” FR4, self-Z at corner)

Analytical Model, High-Frequency



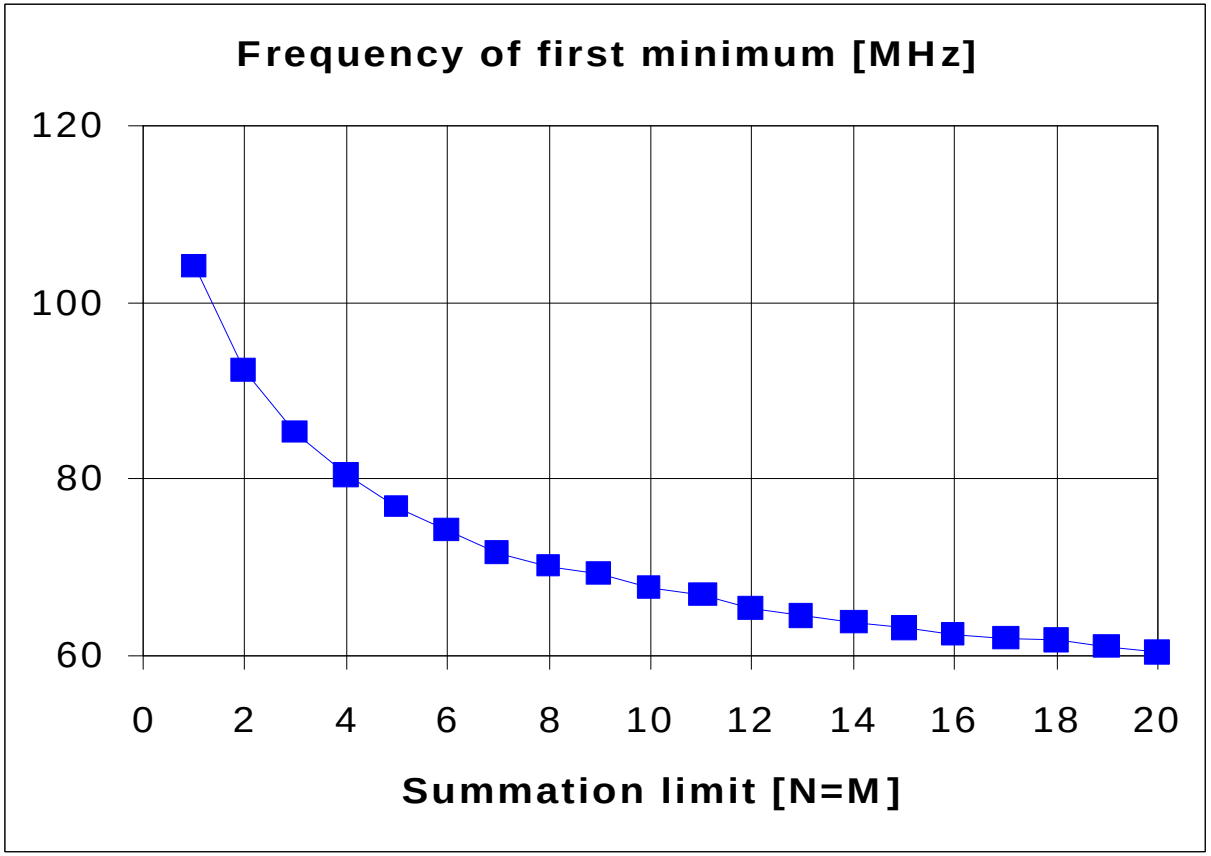
At high frequencies, Z falls beyond the last summation peak (10”x10”x0.002” FR4, self-Z at corner)

Analytical Model, Minima



At low frequencies, minima depend on summation limits (10”x10”x0.002” FR4, self-Z at corner)

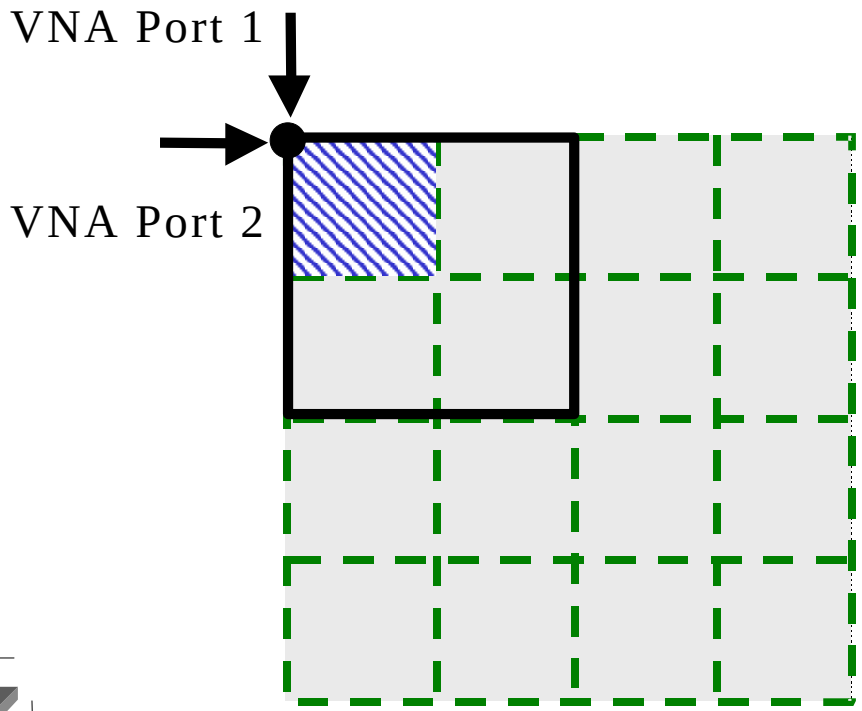
Shift of First Minimum

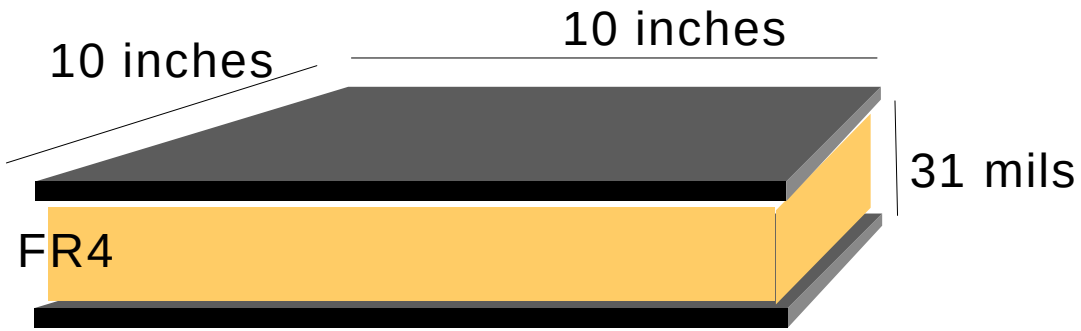


10”x10”x0.002” FR4, self-Z at corner

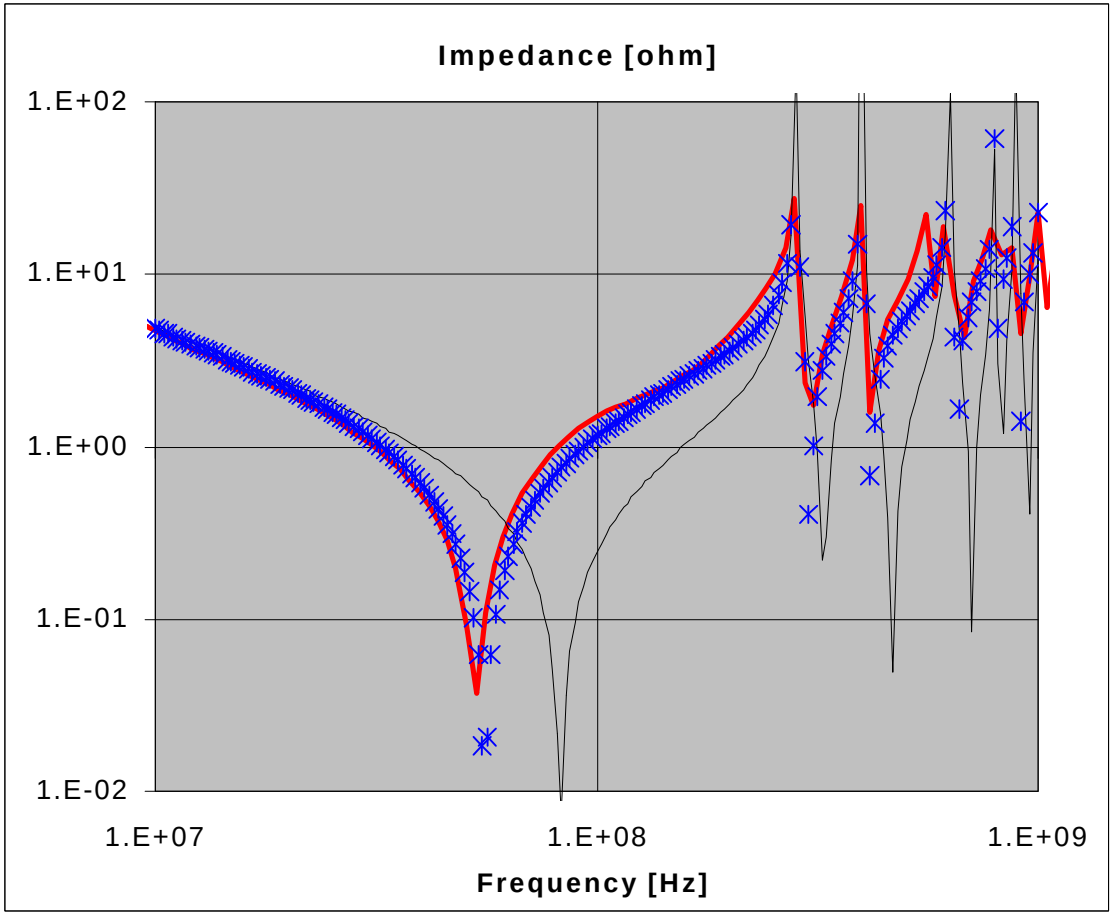
Plane Bandwidth Test Setup

- Two-port VNA impedance measurement setup
- Test point (self Z) unchanged at corner
- Plane size is cut x2, x4





Bandwidth Test, Full (10”x10”) Size



Heavy solid: measured

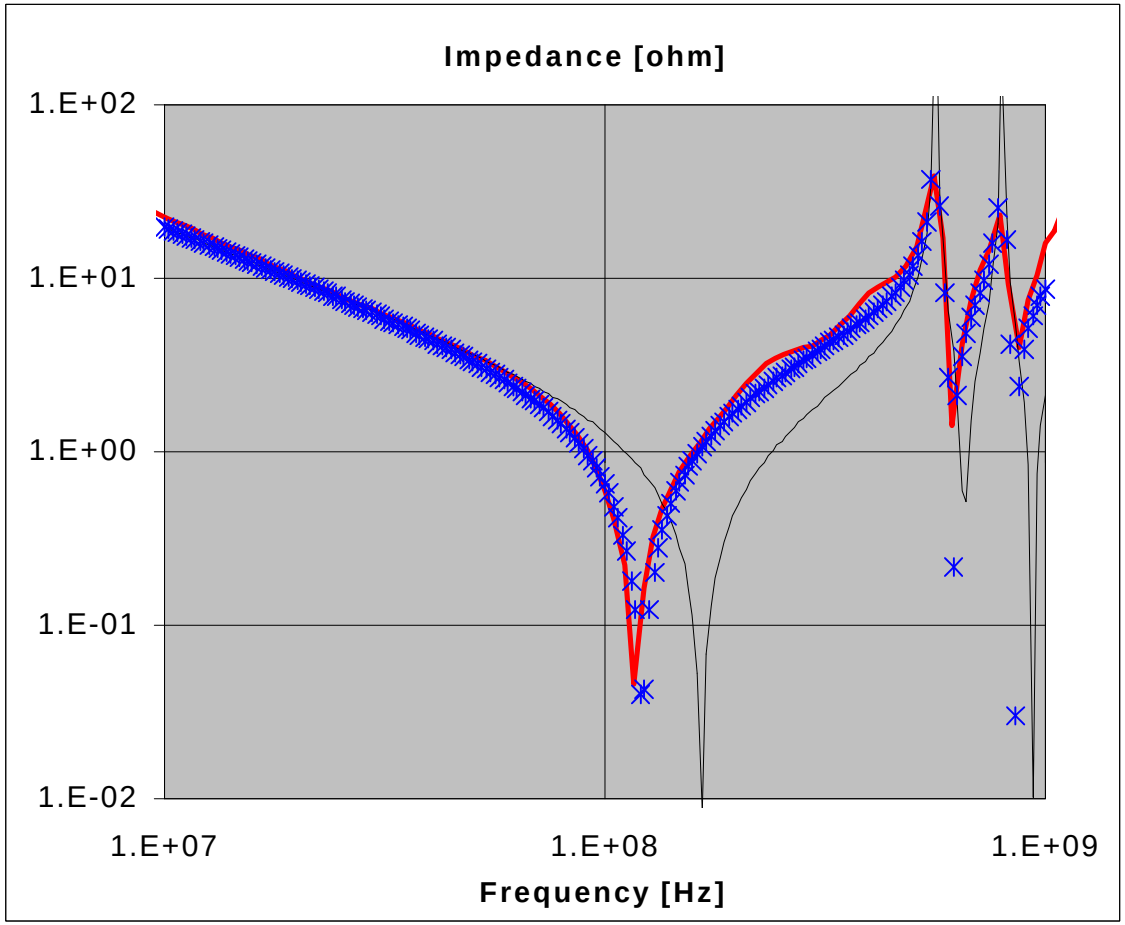
Crosses: analytical with N=M=50 (f_c~10GHz)

Thin solid: analytical with N=M=4

Workgroup Servers

Board Design Technology

Bandwidth Test, Half (5”x5”) Size



Heavy solid: measured

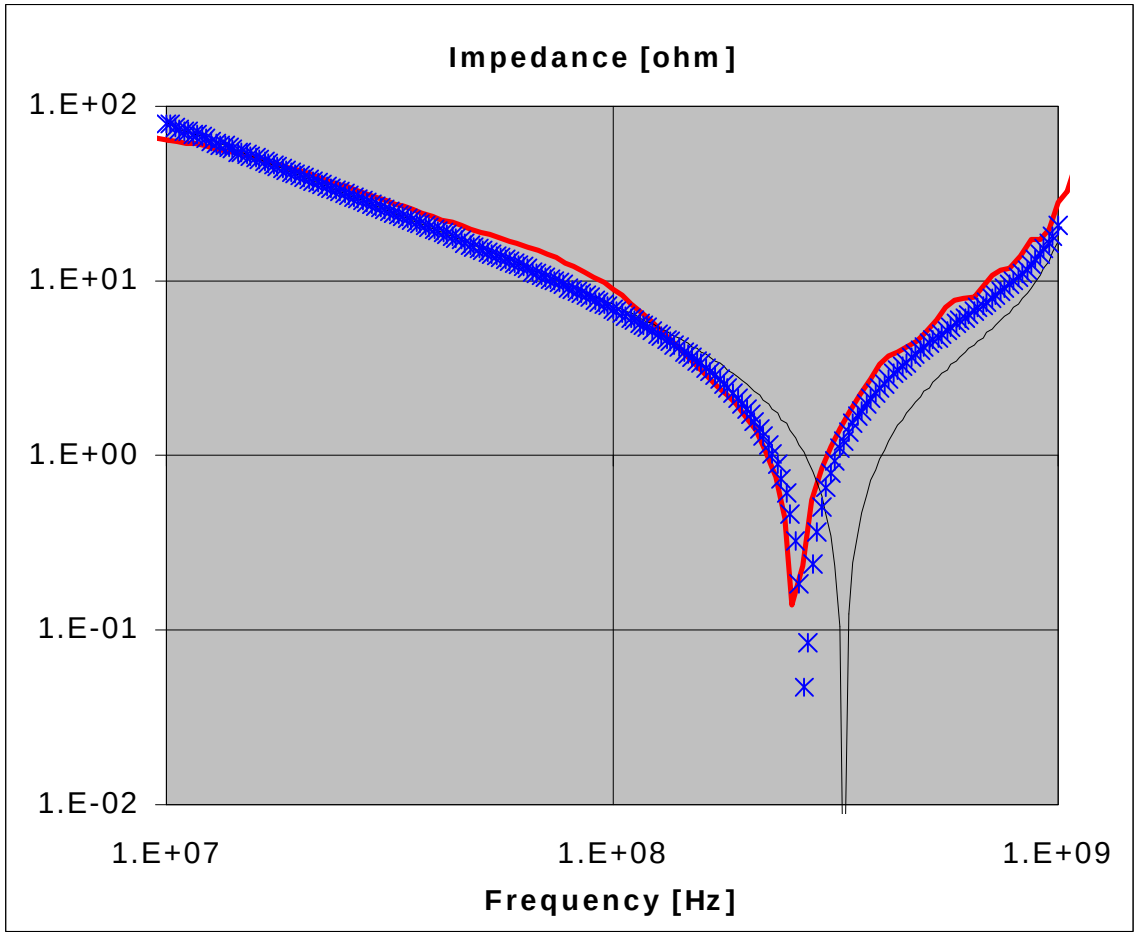
Crosses: analytical with N=M=25 (f_c~10GHz)

Thin solid: analytical with N=M=4

Workgroup Servers

Board Design Technology

Bandwidth Test, Quarter (2.5”x2.5”) Size



Heavy solid: measured

Crosses: analytical with N=M=12 (f_c~10GHz)

Thin solid: analytical with N=M=4

Workgroup Servers

Board Design Technology

Conclusions

- Bedspring plane models exhibit quantization limitations in space
- Analytical models exhibit quantization limitation in frequency domain
- Bandwidth of plane pairs:
  - Strong function of material and plane separation
  - Weak function of plane dimensions
- Analytical model summation limits should match bandwidth of planes