An Eye on Return Loss: Mathematical and Real implications of RL spec's

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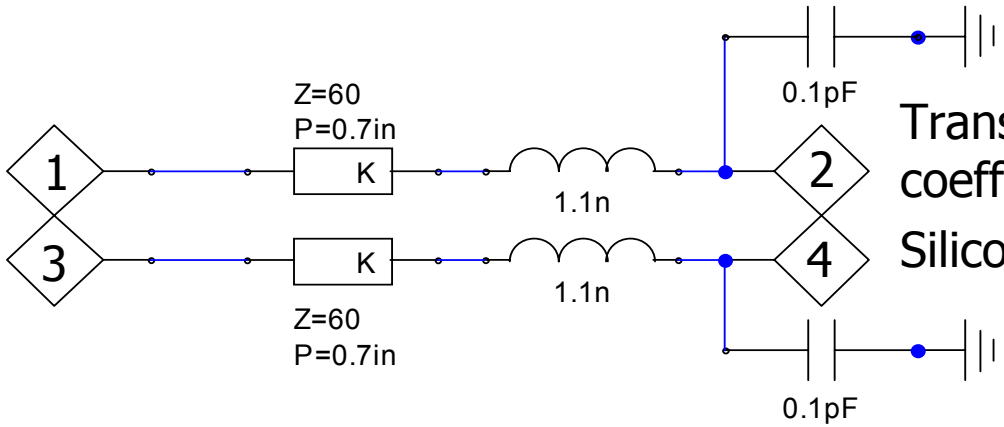
Review: PKG models -10 dB @ 5GHz

Pin side (PWB)

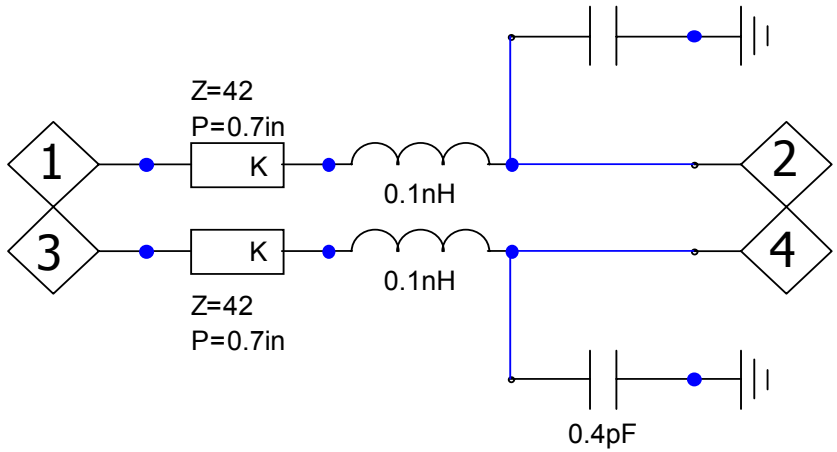


Transmission coefficient < 1

Silicon side

Ind-like pkg

Pin side (PWB)



Transmission coefficient > 1

Silicon side

Cap-like pkg

Present RL spec

72.6.1.4 Output return loss (10GBASE-KR)

For frequencies from 100 MHz to 15 GHz, the differential return loss, in dB with *f* in MHz, of the transmitter shall meet Equation 72–1 and Equation 72–2. This output impedance requirement applies to all valid output levels. The reference impedance for differential return loss measurements shall be 100 Ohms.

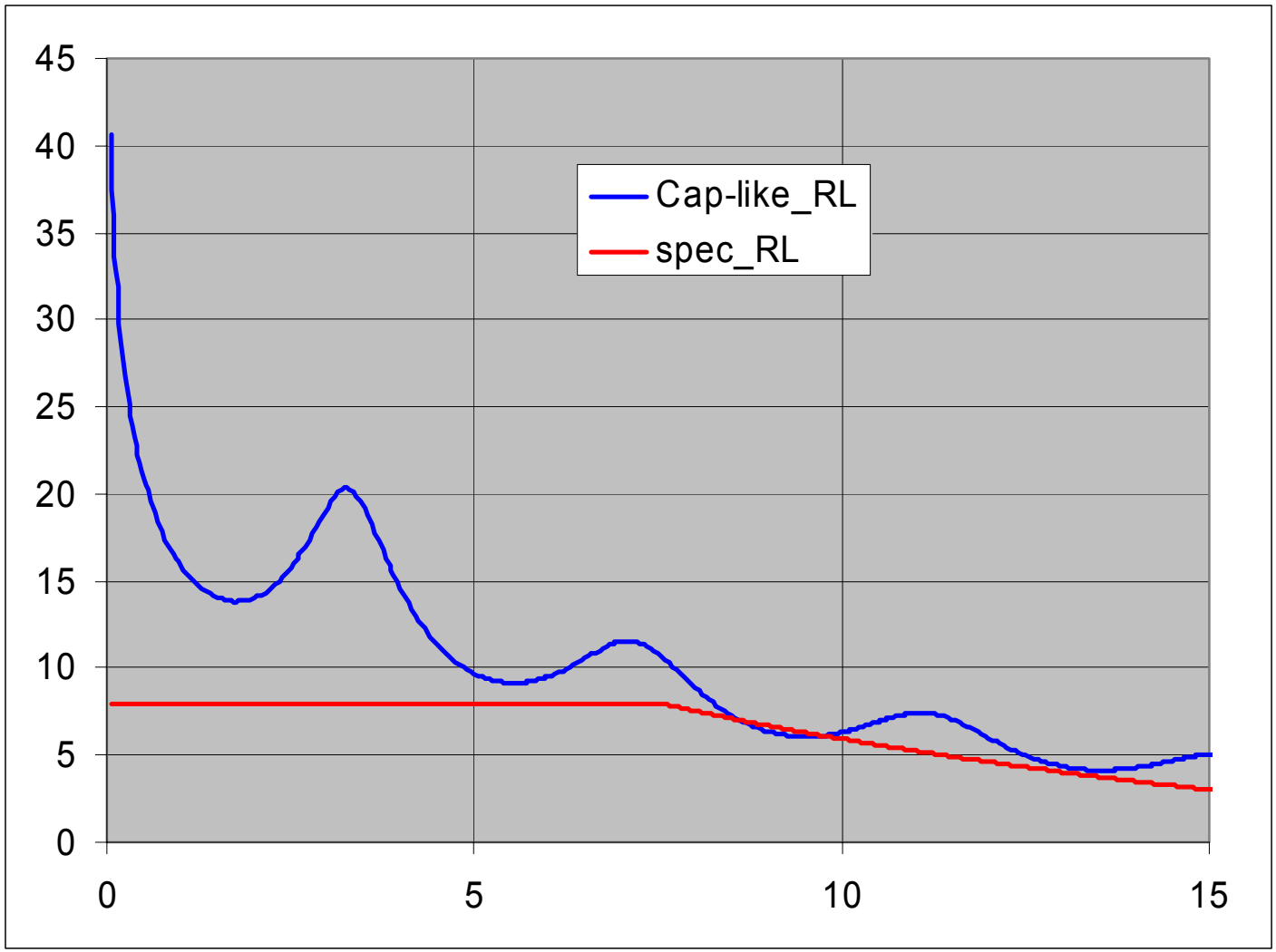
$$\mathrm{ReturnLoss}(f) \geq 8 \qquad (72\text{–}1)$$

for 100 MHz <= f < 7.5 GHz and

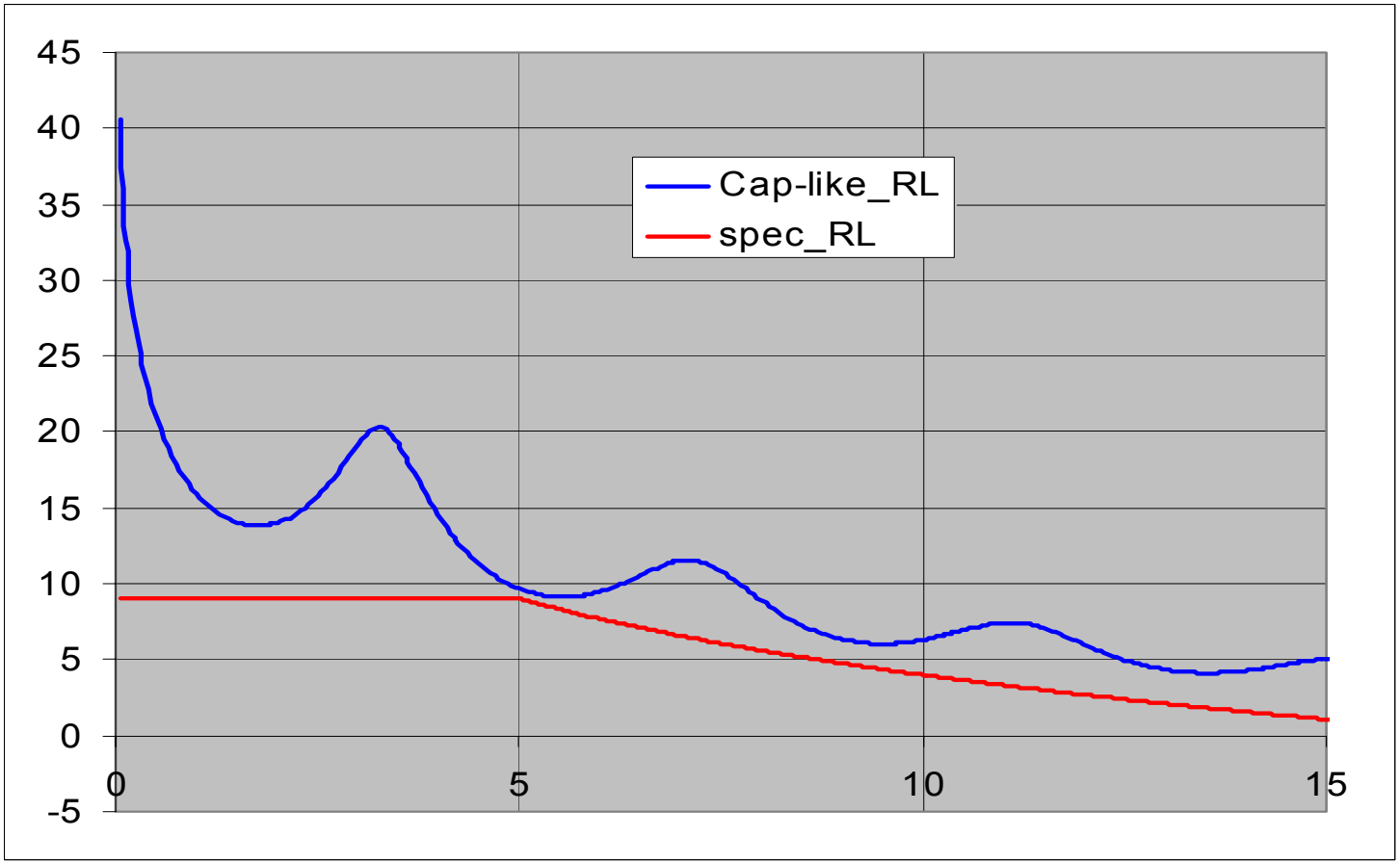
$$\mathrm{ReturnLoss}(f) \geq 8 - 16.6 \times \log\left(\frac{f}{7.5\,GHz}\right) \qquad (72\text{–}2)$$

for 7.5 GHz <= f <= 15 GHz

Compare to cap-like pkg spec



This works

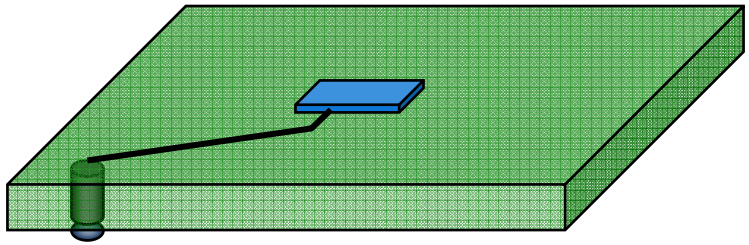


IF(B4<fbr,rl5,rl5-16.6*LOG(B4/fbr)) Fbr=5 (in GHz) rl5=9 (in dB)

Cap-like model caveats

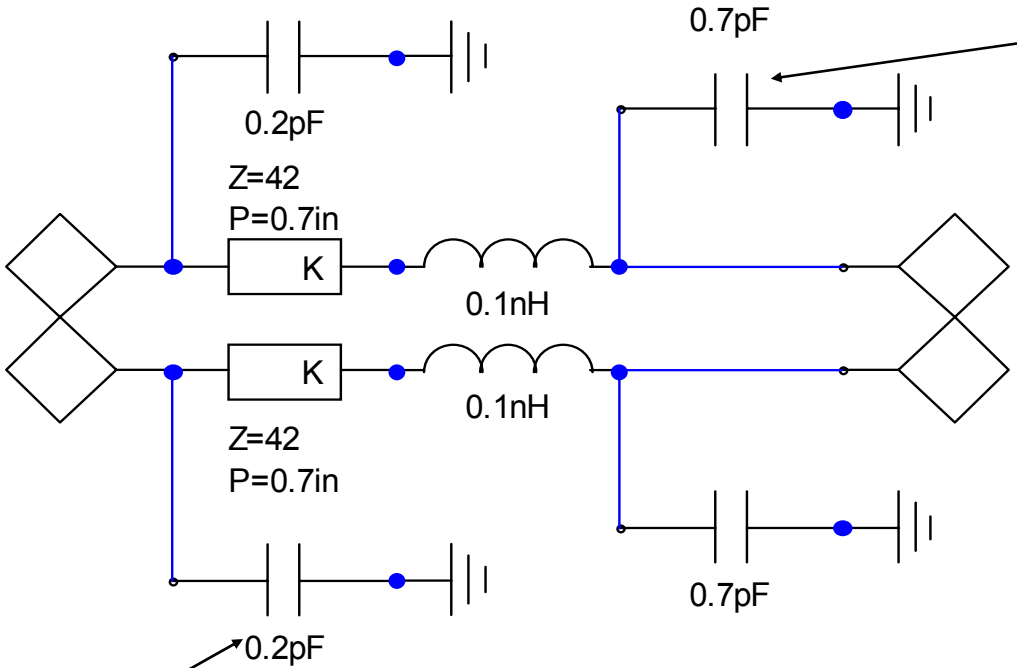
- Includes pad capacitance
- Includes ESD capacitance
- The total is only 400ff.
- Many silicon houses may see this as a real challenge.
  - Considering PVT (process, voltage, temperature) variations.
- 700 pF seems like what may be achievable with today's processes

What is in a BGA package



- Die connects to transmission line .5"-1" on package to via
- Via connects to BGA "ball"
- Typically this via can be 200 ff (+/-)
  - Could be as much as 1 pF

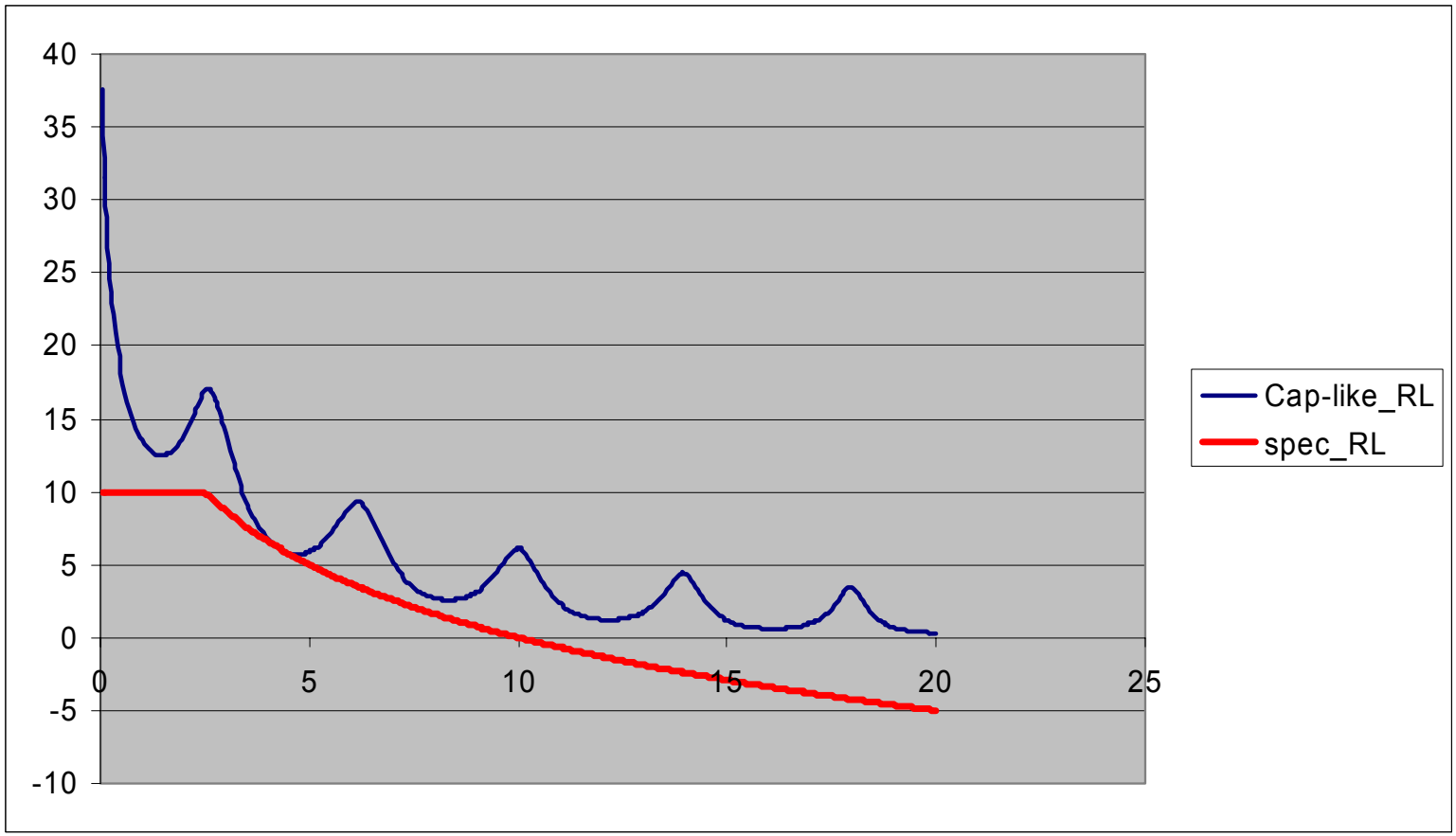
More Realistic Model of Large BGA packages



Die pad capacitance including ESD Diodes

Via capacitance

RL for more typical chip



IF(B4<fbr,rl5,rl5-16.6*LOG(B4/fbr)) Fbr=2.5 (in GHz) rl5=10 (in dB)

What does this mean?

- Assume RL (Γ) are same for Tx and Rx
- Loss ~ $(1-\Gamma s)(1+\Gamma L) = 1-\Gamma^2$ for $(\Gamma s=\Gamma L=\Gamma)$
- Loss = $1-2*\Gamma+\Gamma^2$ if $(-\Gamma s=\Gamma L=\Gamma)$
- $1-2*\Gamma+\Gamma^2 > 1-\Gamma^2$
  - For RL of 10dB, Γ^2 is .1 and $2*\Gamma$ is .63
- This means the combination of inductive-like source and capacitive-like load is the worst case combination for loss.

Key Message

- Present RL spec is likely difficult to meet
- "Capacitive-like chips" for the Tx and the Rx are not anywhere near as bad as when mixed with "inductive-like chips"
- Recommendation:
  - Use a RL spec that same as for KX4
  - Or Don't spec RL only.
    - Spec Tx eye opening into some reference WC load.