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BiTS 2015 Shanghai
Burn-in & Test Strategies Workshop

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Session 2

Frank Zhou
Session Chair

BiTS Shanghai

East Meets West

"WLP Probing Technology Opportunity and Challenge"

Clark Liu - PowerTech Technology Inc.

"Pushing the Envelope in DFM (Design for Manufacturing) for 0.2mm Pitch WLCSP Socket"

Colin Koh - Test Tooling Solutions Group

"Signal Integrity & Inpacts by Connector Structures"

Jiachun (Frank) Zhou - Smiths Connectors

"LPDDR4 Signal & Power Performance Optimization By Hardware"

Yuanjun Shi - TwinSolution Technology

BiTS Burn-in & Test Strategies Workshop 2015 Shanghai

Signal Integrity & Impacts by Connector Structures

Dr. Jiachun Zhou (Frank), Dexian Liu
Prof. Ling Sun
Smiths Connectors, Nantong University

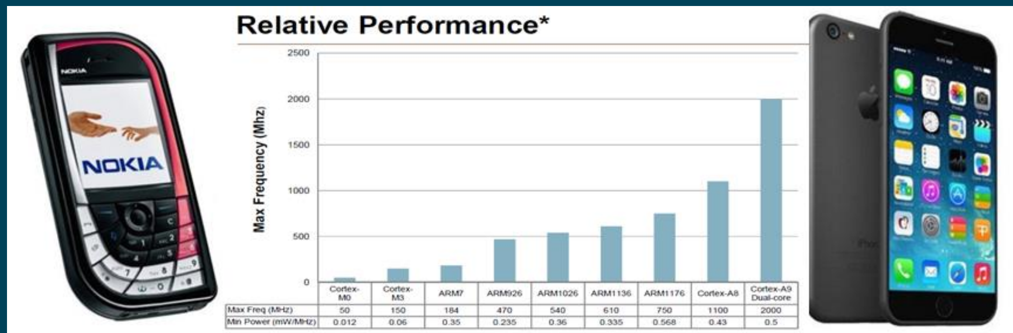
2015 BiTS Workshop
Shanghai
October 21, 2015

Contents

- Why Signal Integrity?
- Signal Integrity Basics
- Signal Integrity Characteristics
- Connector's Structures & Signal Integrity
- Summary

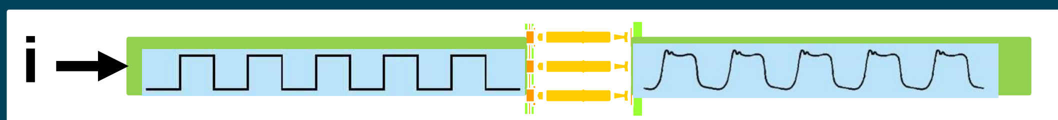
Why Signal Integrity (SI)?

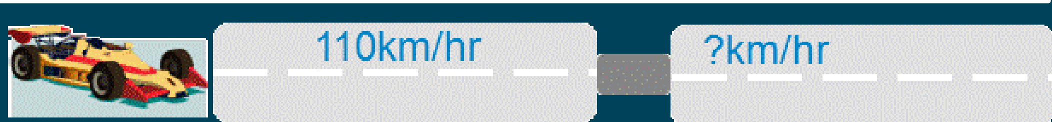
- Digital world moves to higher frequency.



	Cortex-M0	Cortex-M3	ARM7	ARM926	ARM1026	ARM1136	ARM1176	Cortex-A8	Cortex-A9 Dual-core
Max Freq (MHz)	50	150	184	470	540	610	750	1100	2000
Min Power (mW/MHz)	0.012	0.06	0.35	0.235	0.36	0.335	0.568	0.43	0.5

- Interconnect subsystems impact signal propagation significantly due to materials properties and mechanical structures.





What is Signal Integrity?

- Signal integrity refers to all the problems that arise in high-speed products due to the interconnects.
  - from Eric Bogatin in "Signal Integrity"

- Signal integrity is a set of measures to evaluate the quality of the electrical signal.
- Some of the main issues about SI are signal loss, ringing, crosstalk, ground bounce and power supply noise.

Signal Integrity Basics

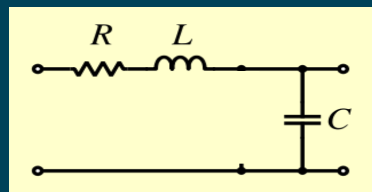
- Resistance at DC

$$R = \frac{V}{I} \qquad R = \frac{\rho l}{A}$$

ρ = material bulk resistivity
l = conductor length
A= conductor cross section area

- Impedance at AC

$$Z = \frac{V}{I}$$



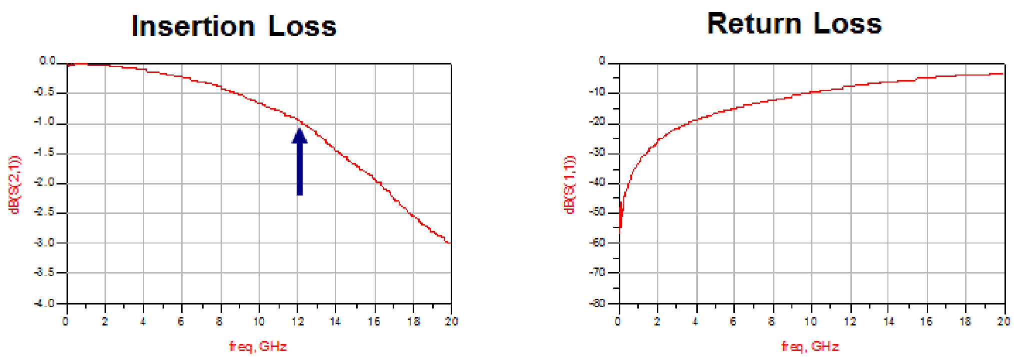
- Characteristic Impedance

$$Zo = \sqrt{\frac{L}{C}}$$

L = inductance
C = capacitance

SI Characteristics-1

- Signal has losses when going through connector
  - Insertion Loss: signal power loss resulting from the insertion of a device in a transmission line
  - Return Loss: power loss in the signal returned or reflected by a discontinuity in a transmission line
  - Bandwidth: the signal frequency transmitted without significant loss (or at allowable insertion loss)



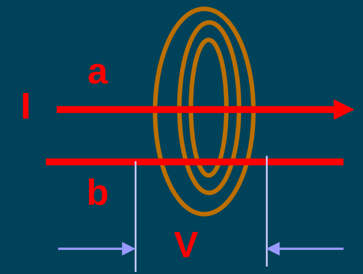
-1 dB Insertion Loss Bandwidth for 4A case is ~ 12 GHz

SI Characteristics-2

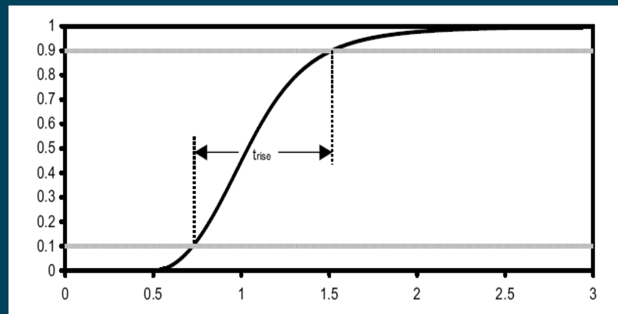
- Cross Talk
  - Induced noise to “b” line by the signal in “a”

  Vnoise = M dI/dt

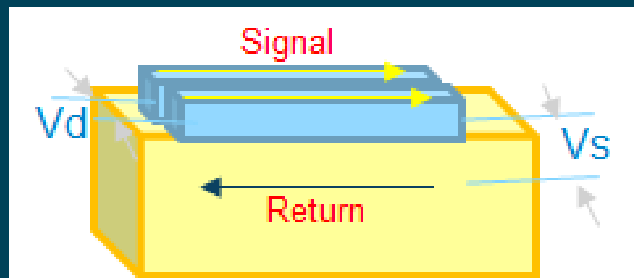
  M: Mutual inductance of 2 wires



- Rise Time
  - The time required for a pulse to rise from 10% to 90% of its steady value

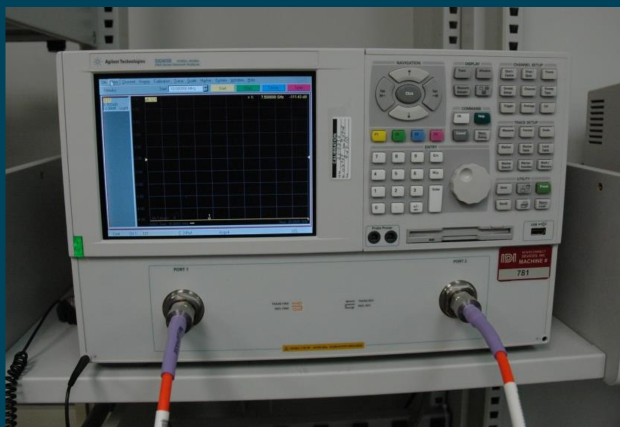


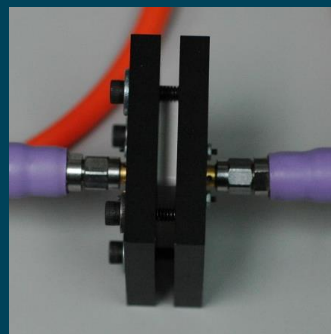
- Single ended & differentials
  - Single ended: measured between the signal ad return path
  - Differentials: measured between the two signal lines in a different pair

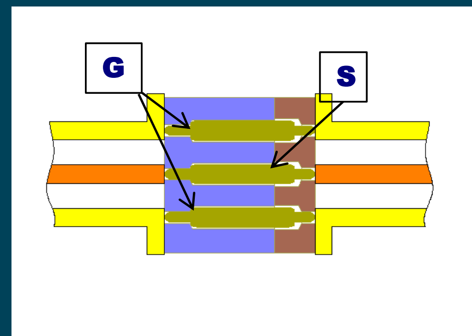


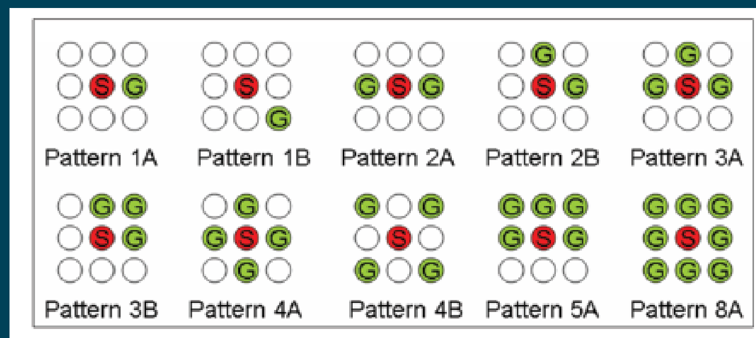
SI Measurements Set Up

- SI measurement set up includes:
  - Vector Network Analyzer
  - Connector fixture with different patterns



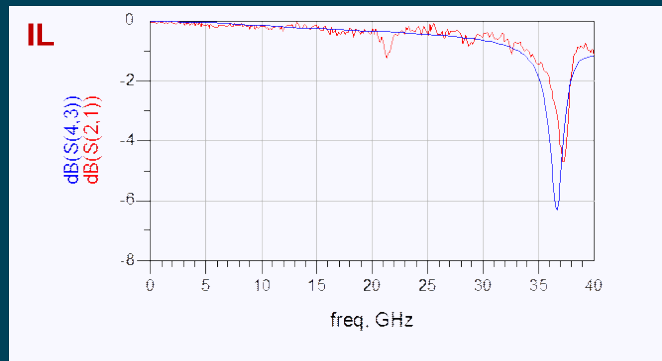


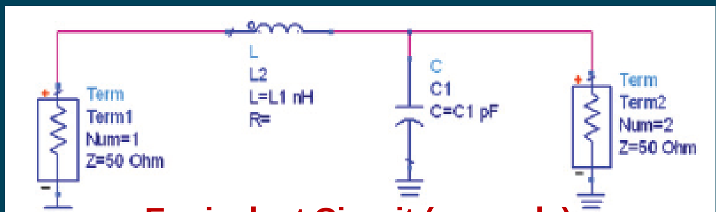




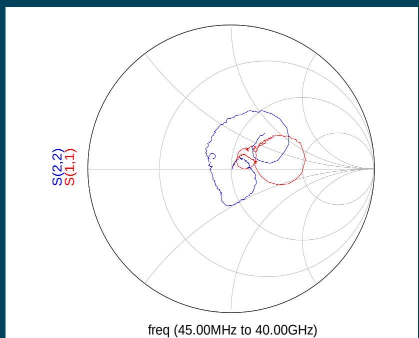
SI Measurements Method

- Measure IL, RL and Smith Chart
- Use equivalent circuit & ADS software to simulate IL, RL and calculate L, C

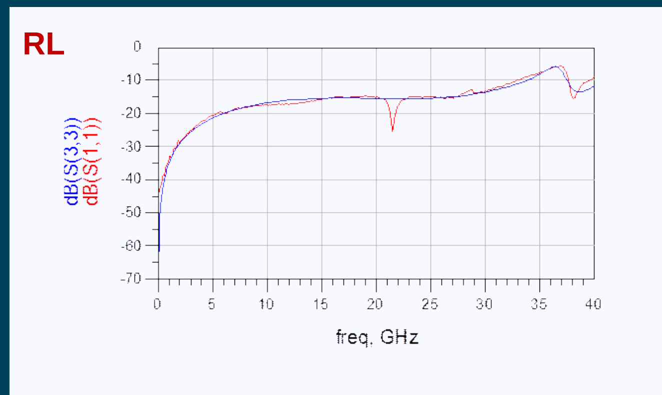




Equivalent Circuit (example)

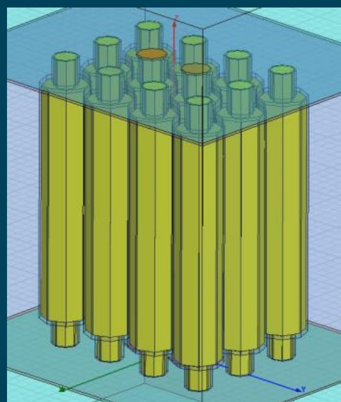


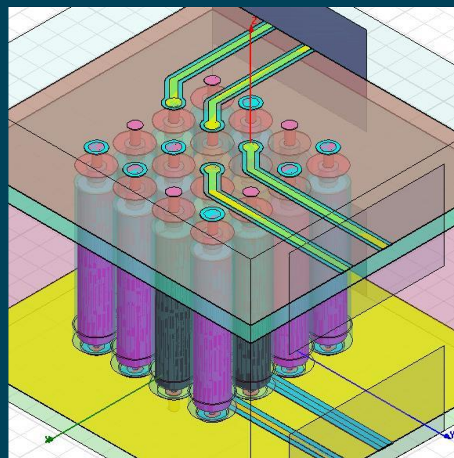
Smith Chart (example)



SI Simulation

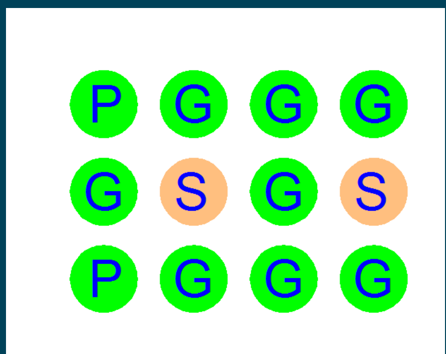
- Several software, e.g. HFSS, used in SI simulation
- Physical model following signal/ground pin pattern
- Connector geometry may be simplified by removing complex features, such as spring
- Simulation results include IL, RL, Zo, Rise time etc.

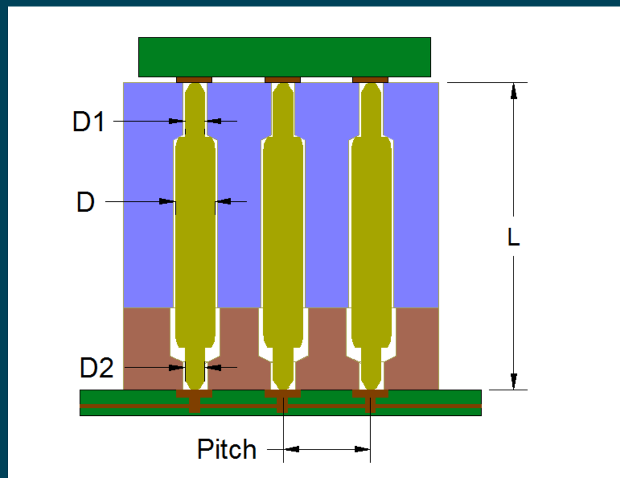




Connector Structures

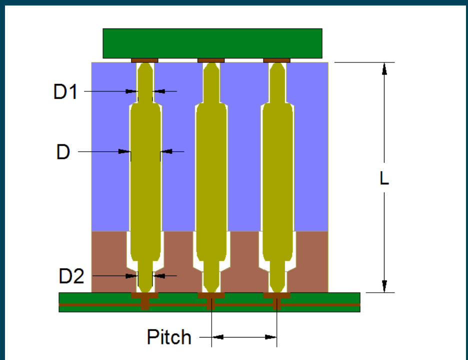
- Connect basic structures affecting SI
  - Connector length, L, from signal entrance to exit
  - Connector diameter
  - Connector housing material & structures
  - Connector layout pattern

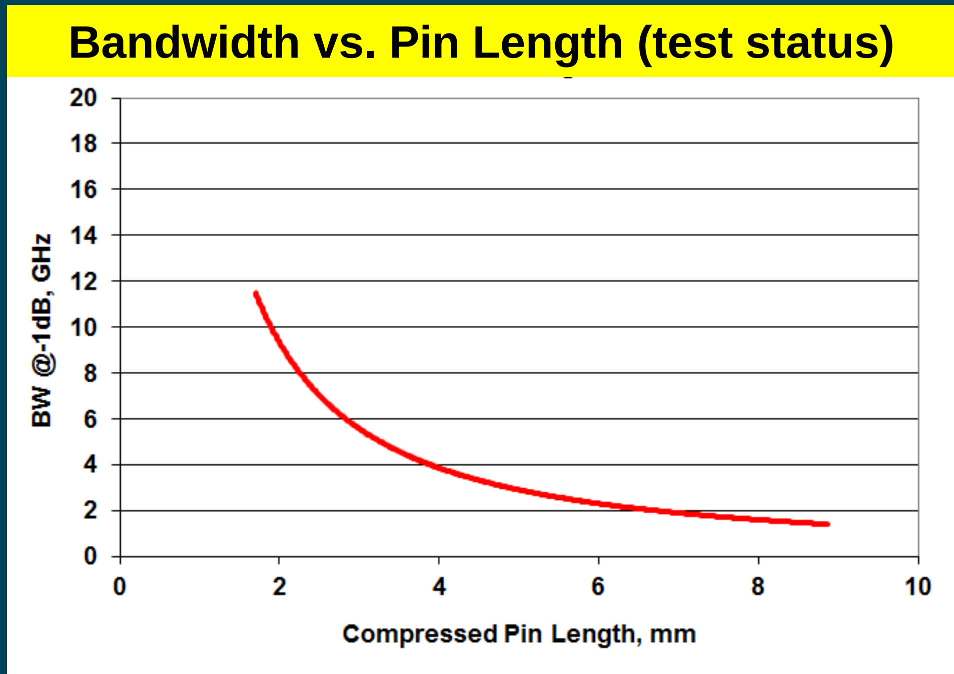




SI Performance: Pin Length

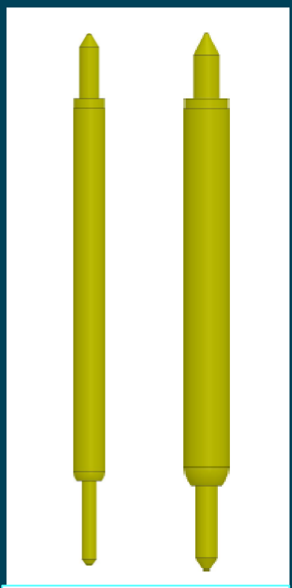
- Method: use RF measurements of over 100 different pins from various pin makers to do statistics analysis
- Results: BW @ -1dB increases after pin length < 3mm



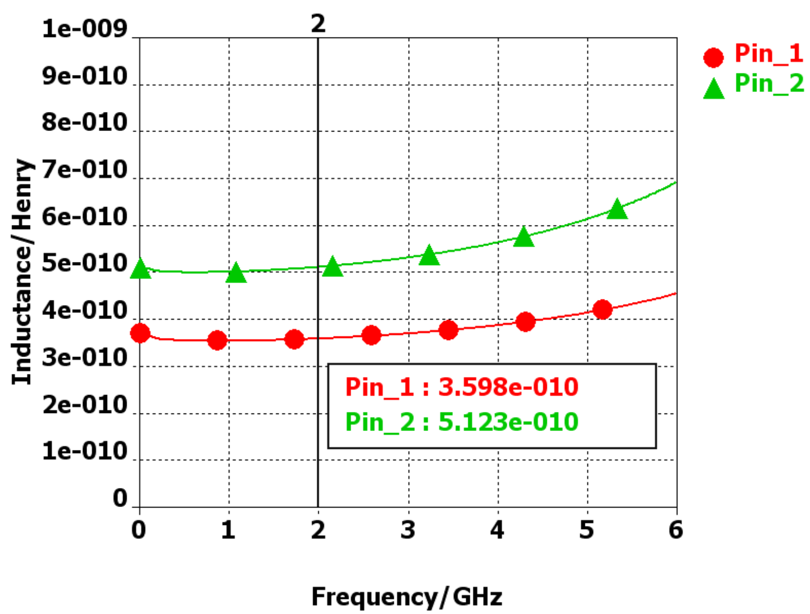


SI Performance: Pin Diameter

- Pin 1: larger diameter has less Inductance
- Pin 2: smaller diameter has higher Inductance

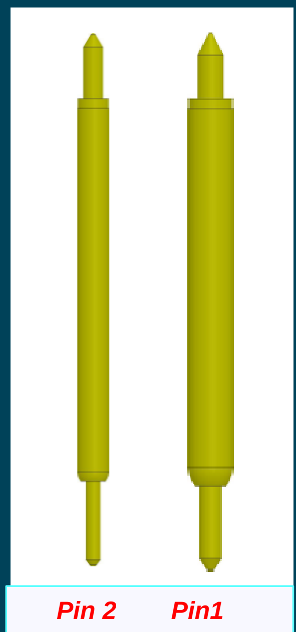


Inductance vs. Diameter vs. Frequency

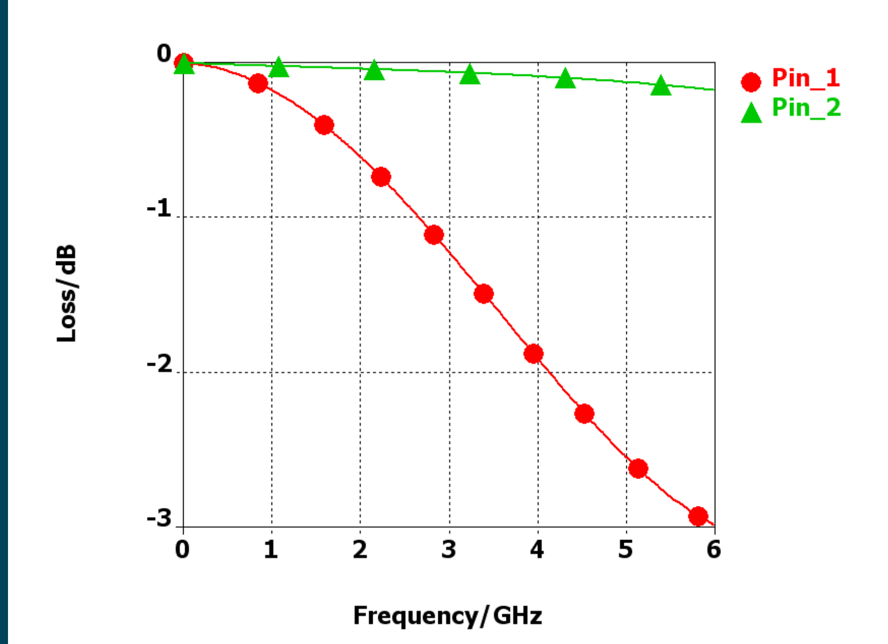


SI Performance: Pin Diameter

- Pin 1: larger diameter has low Bandwidth
- Pin 2: smaller diameter has high Bandwidth (or less signal loss)

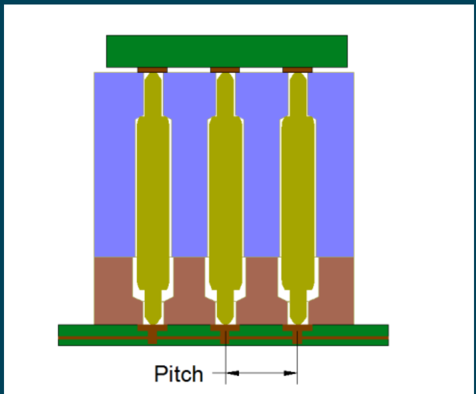


Bandwidth vs. Diameter vs. Frequency

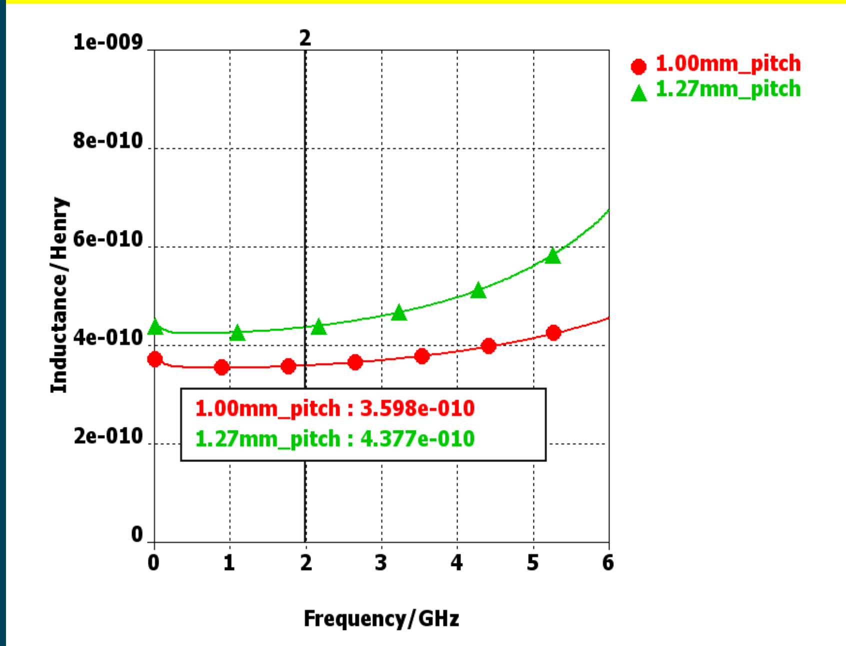


SI Performance: Pitch

- Smaller pitch (same pin): has lower Inductance
- Larger pitch (same pin): has higher Inductance

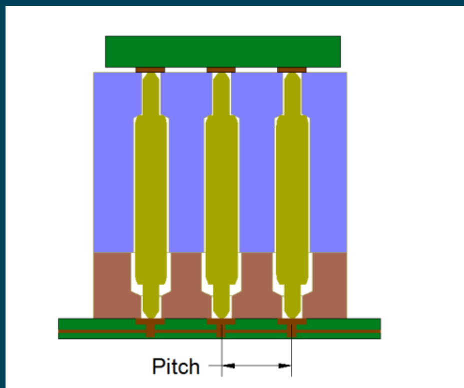


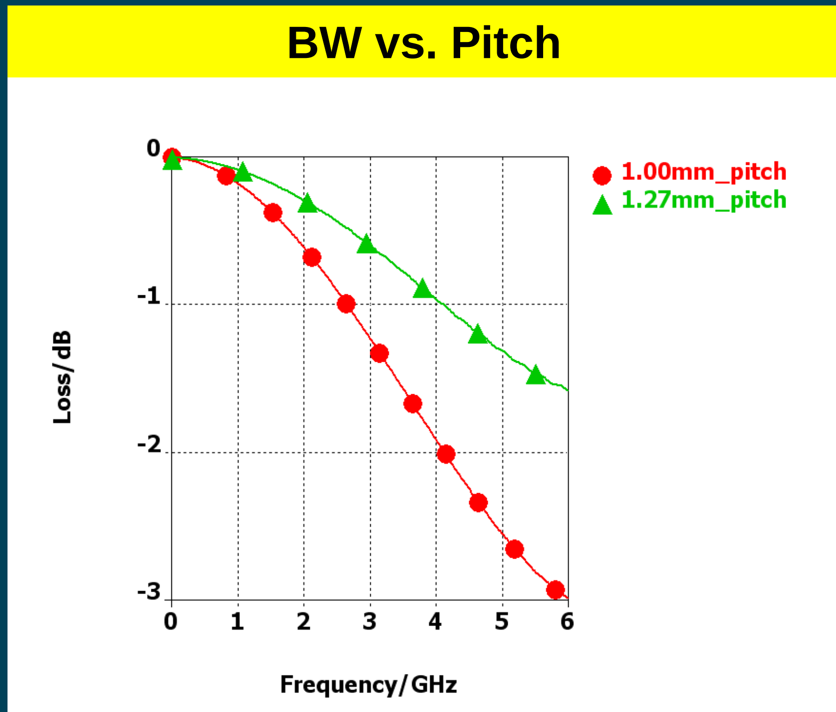
Inductance vs. Pitch vs. Frequency



SI Performance: Pitch

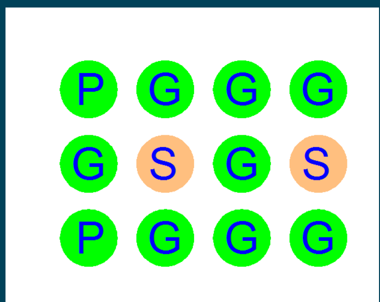
- Smaller pitch (same pin): has lower Bandwidth;
- Larger pitch (same pin): has higher Bandwidth.



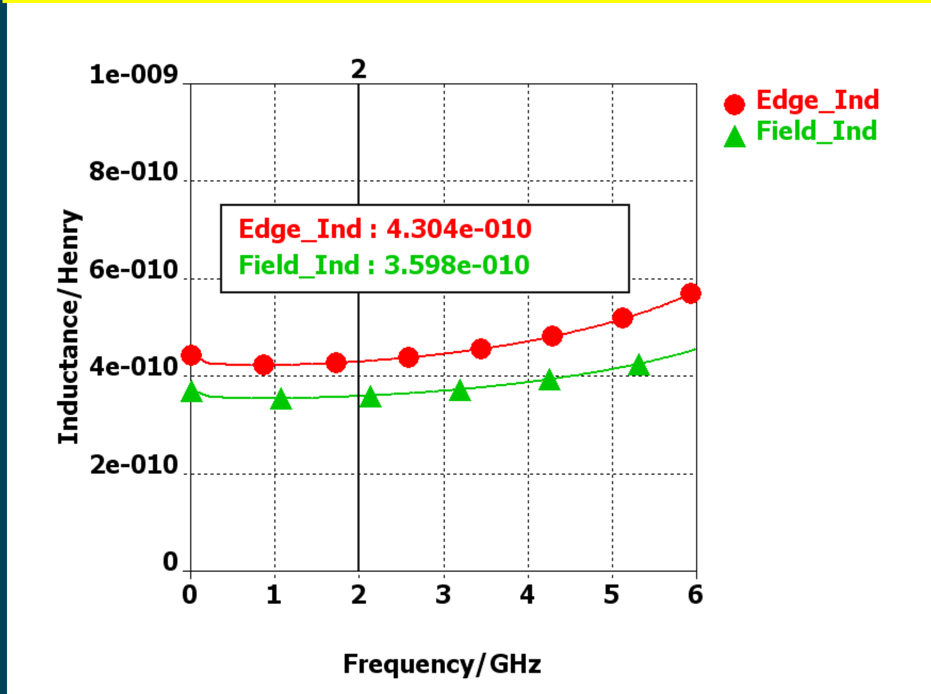


SI Performance: Edge vs. Field

- Pin at edge: has higher Inductance
- Pin at field: has lower Inductance

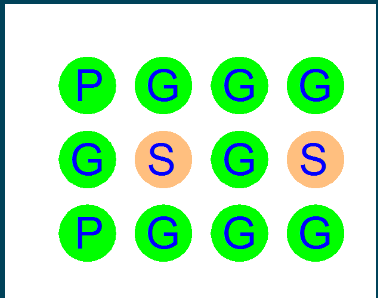


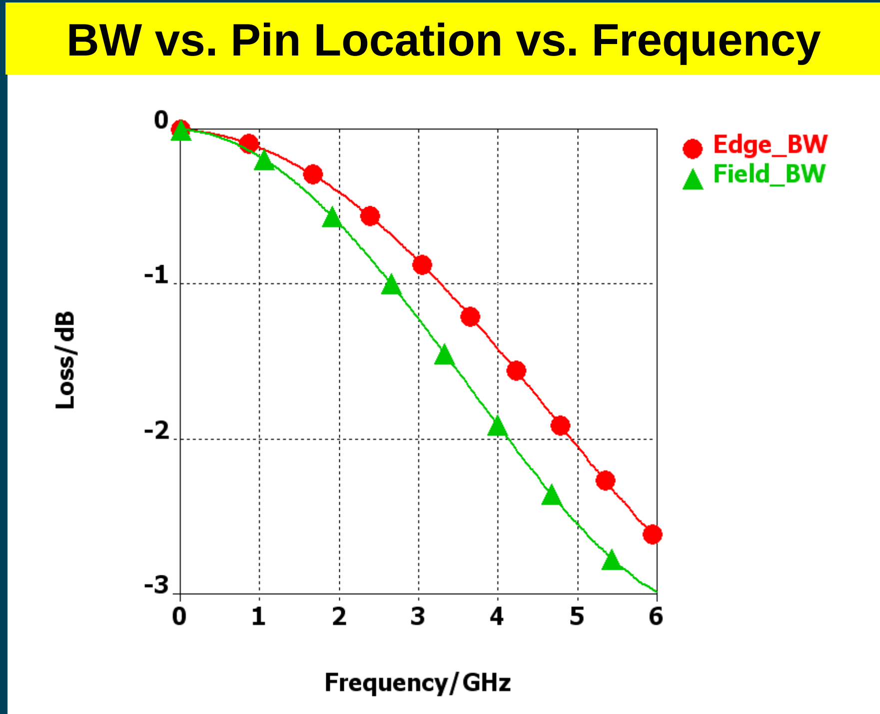
Inductance vs. Pin location vs. Frequency



SI Performance: Edge vs. Field

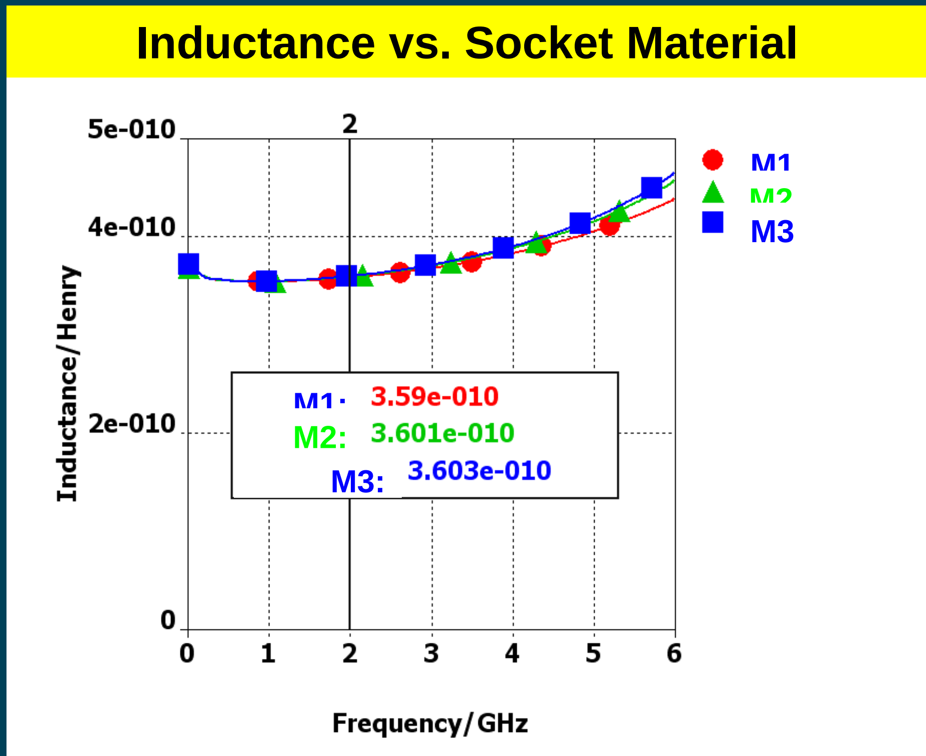
- Pin at edge: has higher Bandwidth
- Pin at field: has lower Bandwidth





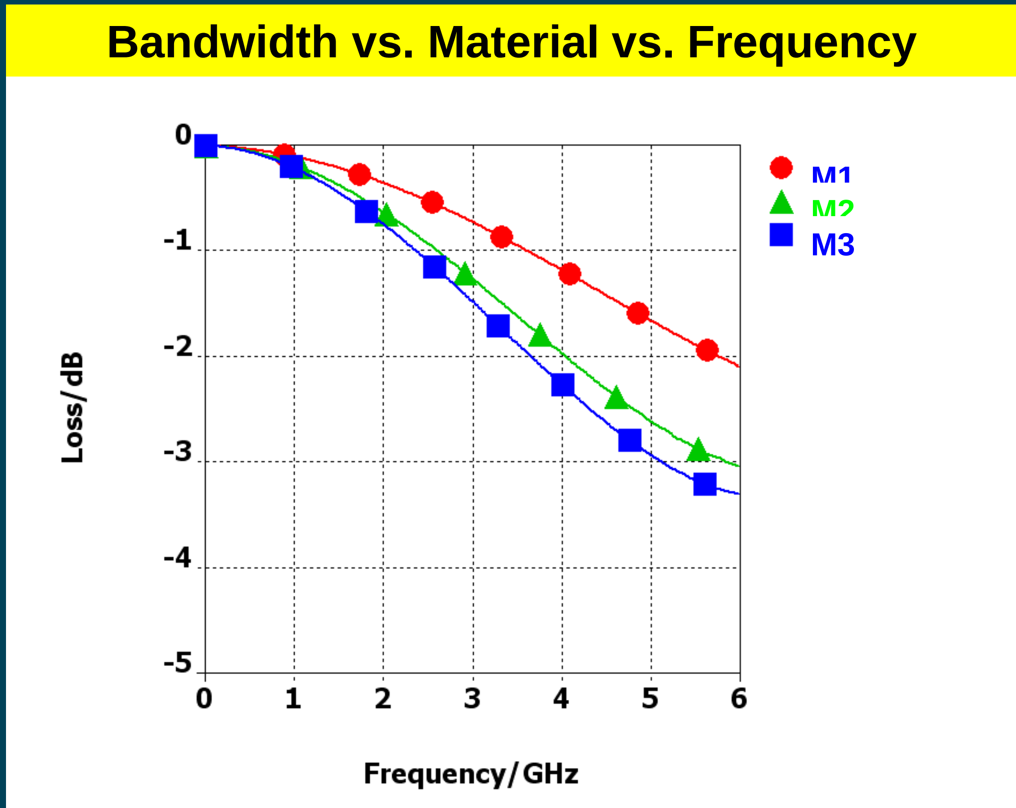
SI Performance: Socket Material

- Socket materials: has little impacts on Inductance



SI Performance: Socket Material

- Socket materials: has greater impacts on Bandwidth



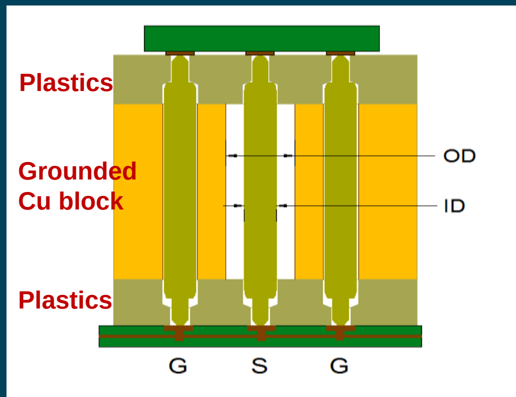
SI Performance: Coaxial Structure

- Principle: Impedance is correlated to signal pin diameter and grounded body following formula:

$$Zo = \frac{138}{\sqrt{\varepsilon_r}} \log_{10} \frac{D}{d}$$

ε_r: Relative dielectric constant of insulator in Cu & connector

- Application: impendence controlled structure to be 50Ω, bandwidth >15GHz (using optimal structure)



Summary

- Two methods to learn connector signal integrity
  - Use VNA & test fixture to measure IL, RL, BW, etc.
  - Use HFSS or other software to simulate
- Connector SI is mostly affected by its structures
  - Length, shorter pin with better SI
  - Diameter, small diameter with higher BW but larger L
  - Location, edge pin has better SI (most high frequency signal pins at edge)
  - House material, low dielectric constant has better SI
  - Coaxial structure, control the impedance for better SI
- Optimal connector design needs to consider both SI, mechanical behavior, manufacturing feasibility