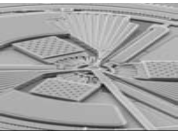
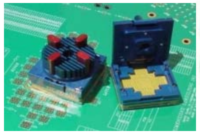
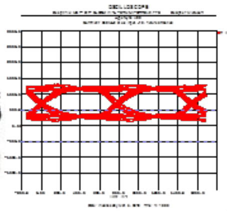
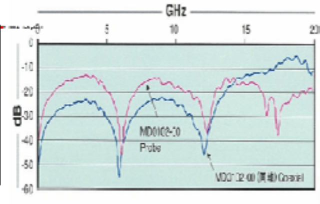


Impact of Embedded Capacitance on Test Socket and Test Board Performance

Michael Giesler, 3M, msgiesler@mmm.com
Alexander Barr, 3M
Yoshihisa Kawate, Sumitomo-3M
Yuichi Tsubaki, Sumitomo-3M

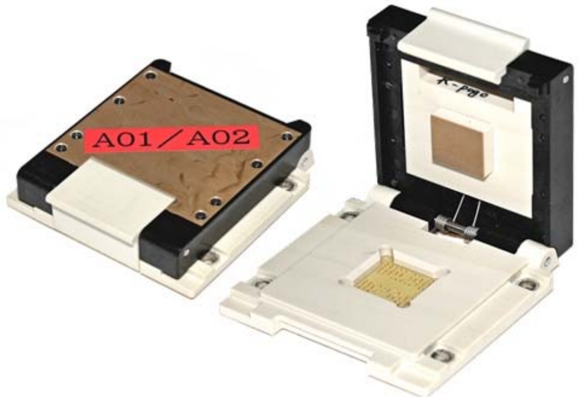
Agenda

- **Issues at High Speed Testing**
- **3M^{TM} Embedded Capacitance Material (ECM)**
- **Simulation Modeling Analysis of Socket**
  - **Power Distribution**
  - **High Speed Signal Transmission**
- **Customer Measured Results**
- **Test Board with 3M ECM**
  - **Future Work**

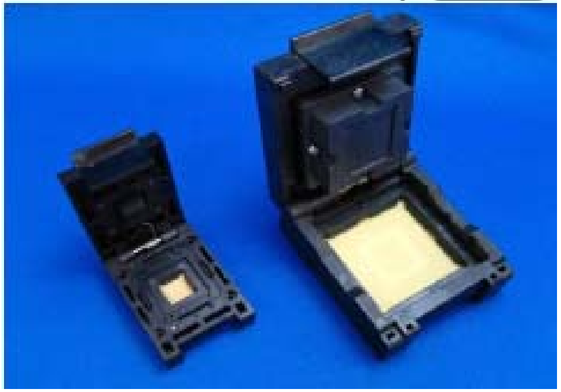
Issues for High Speed Testing

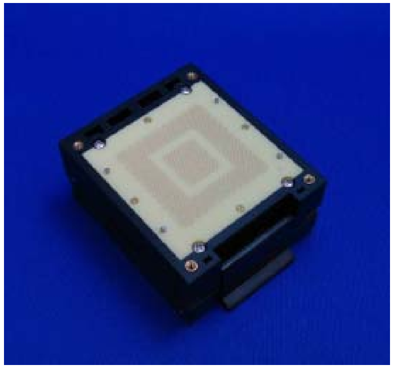
- Mechanical Performance
  - Mechanical Cycle Life
  - Low, Reliable Mating Force
- Electrical Performance
  - Power Integrity
    - Self Impedance
  - Signal Integrity
    - Insertion Loss
    - Crosstalk

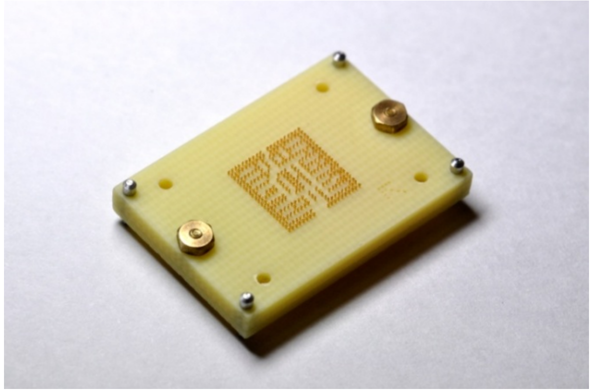
The Anatomy of the 3M™ Flexible Array Solution for Test (FAST) Socket

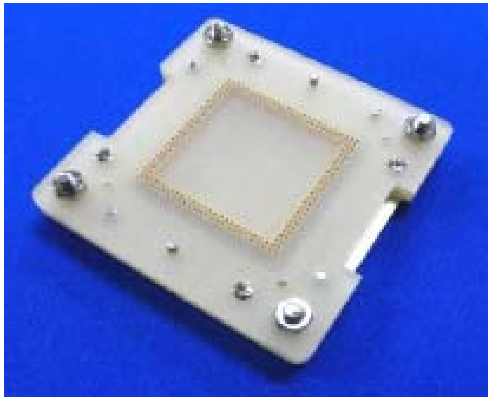


The Interposer Cartridge, its construction and its impact on performance will be the focus of this presentation.

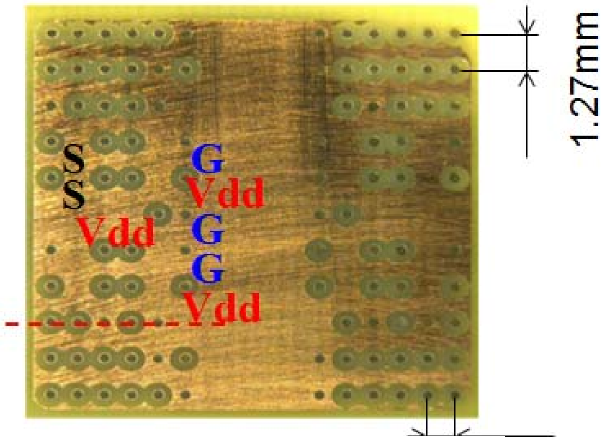






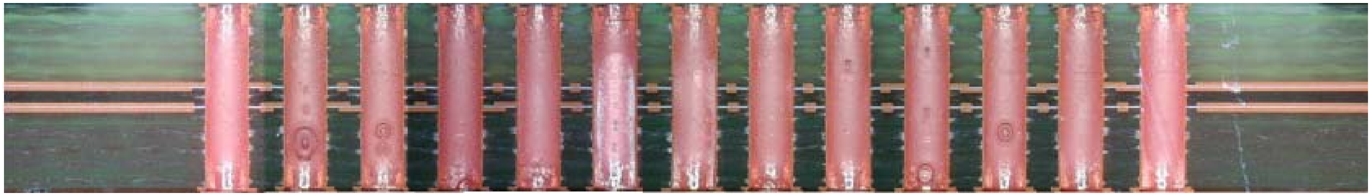


Cartridge Construction Variables

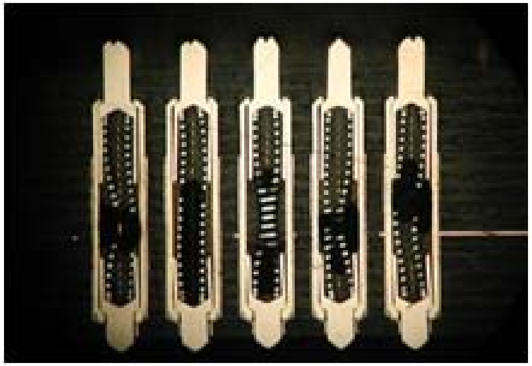


Pattern of Inner Layer

Cartridge
*** Non-PCB**
*** PCB**
- Power Planes
- Ground Planes
- ECM



Contact Pin Length



Coaxial Construct

3M™ Embedded Capacitance Material (ECM)

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(Not to scale)

Power/Ground Layer | **Discrete Capacitor**

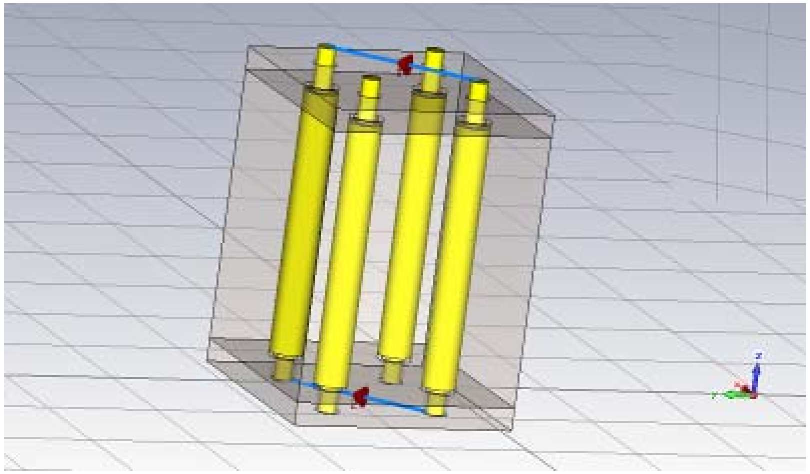
3M ECM

Copper clad laminate that can function as both a power/ground layer or a discrete capacitor.

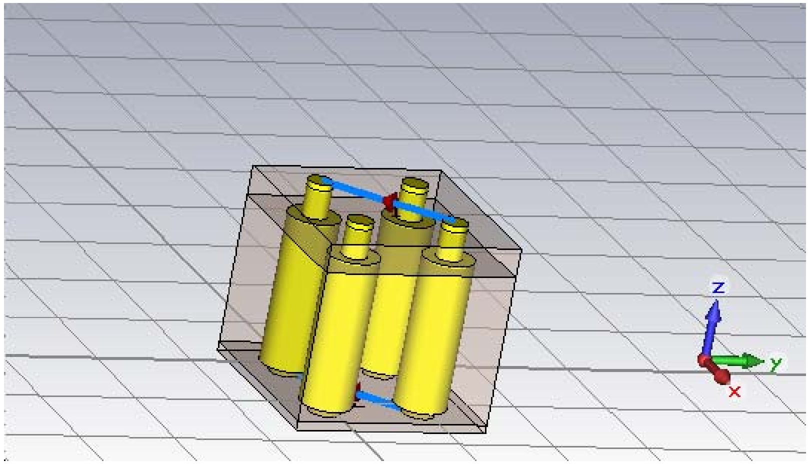
3M™ Embedded Capacitance Material Key Properties

Attribute	Value
Capacitance /Area	6.4 nF/in^2 (1.0 nF/cm^2) (14 µm) 10.0 nF/in2 (1.55 nF/cm^2) (12 µm)
Dielectric Constant	16 (14µm) / 22 (12µm)
Dielectric Thickness	0.55 mil (14 µm); 0.47 mil (12 µm)
Dielectric loss @ 1GHz	0.03
Resin system	Epoxy, ceramic filler
Temperature (TCC)	Meets X7R
Dielectric Strength	~3300 V/mil (130 V/µm) ~3000 V/mil (118 V/µm)
Breakdown Voltage	>100 V
Copper Thickness	1.4 mil (35 µm)
Flammability Rating	94V-0

Power Distribution Simulation Model

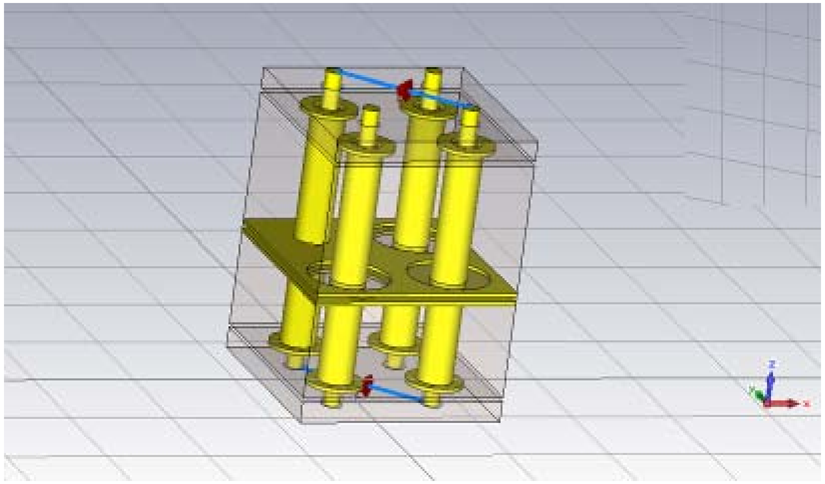


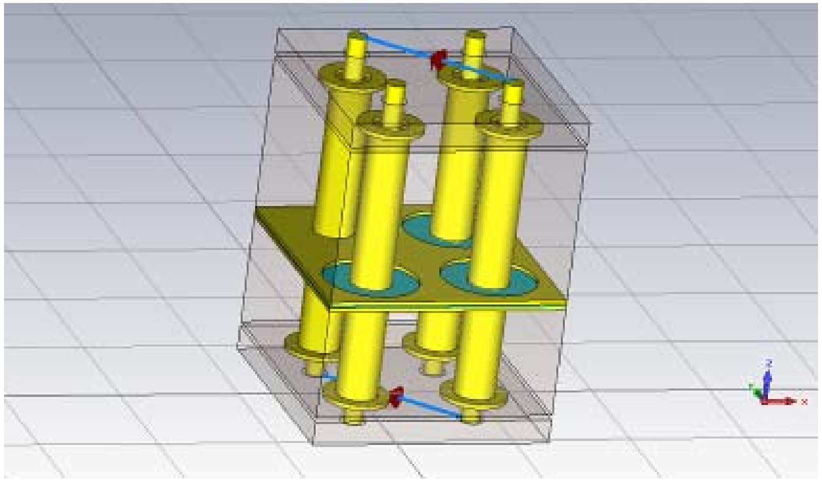
- **Long Pin**
  - **Spring probe**
    - **Sleeve Diameter = 0.3mm**
    - **Sleeve Length = 2.3mm**
    - **Total Length ~ 2.7mm**



- **Short Pin**
  - **Spring probe**
    - **Sleeve Diameter = 0.53mm**
    - **Sleeve Length = 1.53mm**
    - **Total Length ~ 1.98mm**

Power Distribution Simulation Model





- **3M FAST with P-G Planes**
  - Spring probe
    - Same as Long Pins
  - 0.05mm FR-4 between P and G planes for not only connecting ground & power, but also for capacitive effects
- **3M FAST with P-G and ECM**
  - Spring probe
    - Same as Long Pins
  - 14 µm ECM (k = 16) between ground plane and power plane

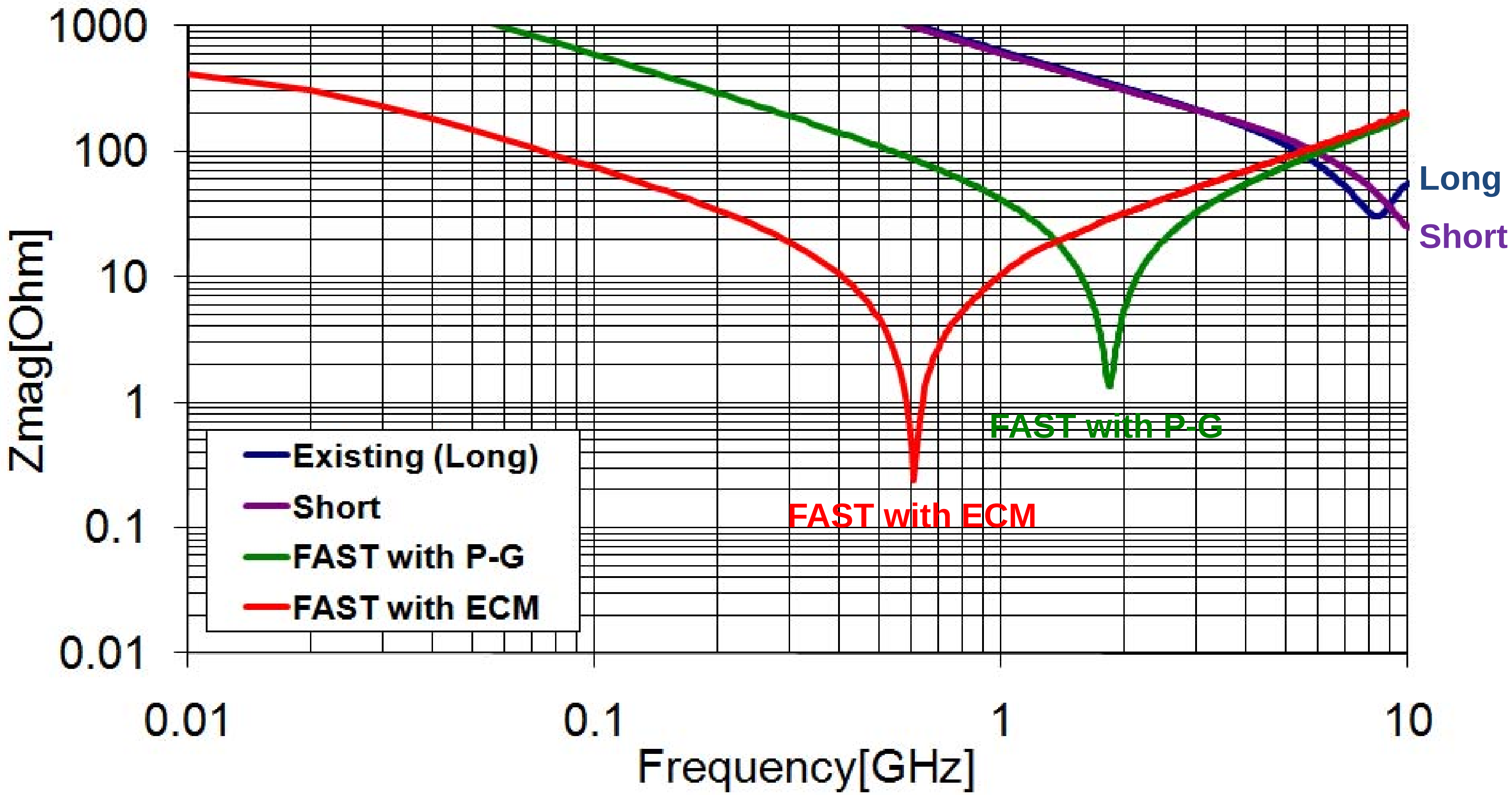
Power Distribution Simulation Model

- **4 pins are modeled**
  - **Power and ground are assigned as follows for power-ground characteristics.**

S	P
G	S

- **Simulation**
  - **Transient simulation for 0-10 GHz by CST MWS.**
  - **Periodic boundary condition in x-y directions.**
  - **Open conditions in z direction.**
  - **Spring probe model is from solid cylinder not including coil spring.**
  - **Power-Ground impedance(Z11) is converted from S-Parameter.**

Power Distribution Simulation Self-Impedance of Socket



Power Distribution Simulation Conclusions

- **Short Contact pins have the lowest impedance above the resonance frequency.**
- **Sockets having power and ground planes decrease impedance in lower frequency region.**
- **3M ECM based sockets have the lowest impedance below the resonance frequency.**
- **3M FAST Socket with P-G Only and P-G with 3M ECM**
  - **Show much lower input impedance than Short Contact Pins**
  - **Show much lower input impedance than Long Contact Pins**
- **3M FAST Socket with P-G and 3M ECM**
  - **Shows significant improvement over FAST with P-G Only**

This is conceptual simulation. The actual impedance is design dependent. Actual performance may vary from modeled simulation.

Signal Transmission Simulation Model

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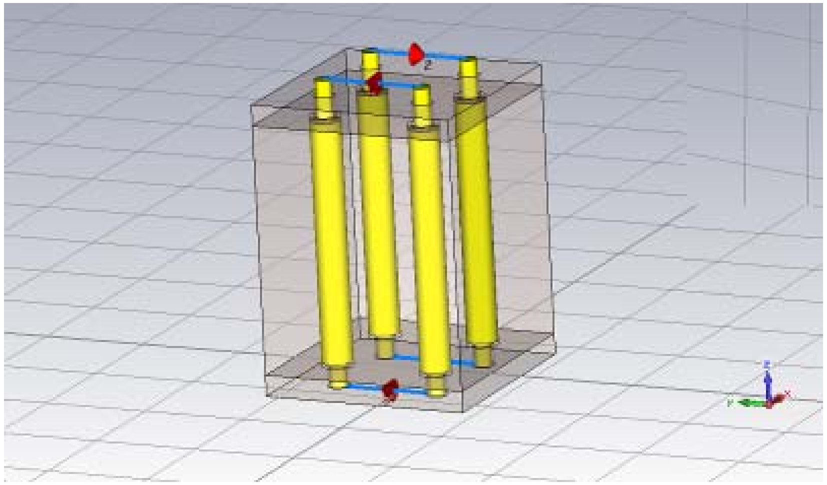
- **4 pins are modeled**
  - **Signal and ground are assigned as follows for signal transmission.**

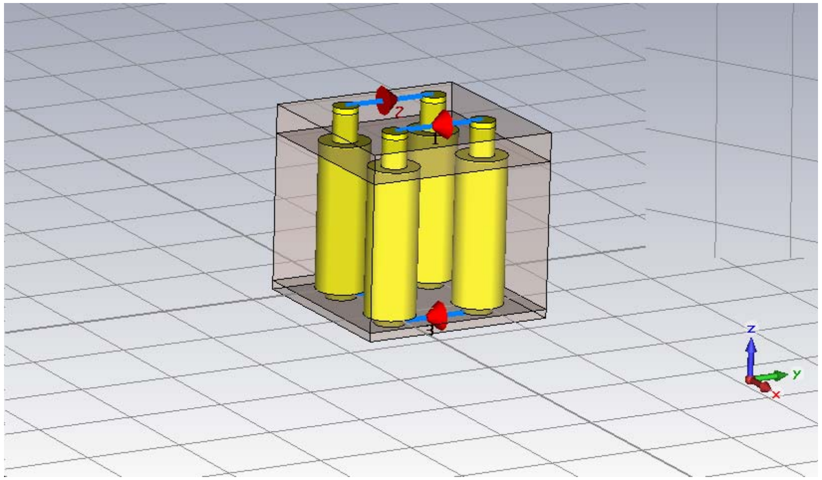
S	G
G	S

- **Simulation**
  - **Transient simulation for 0-12 GHz by CST MWS.**
  - **Periodic boundary condition in x-y directions.**
  - **Open conditions in z direction.**
  - **Spring probe model is from solid cylinder not including coil spring.**

Signal Transmission Simulation Model (1mm pitch)

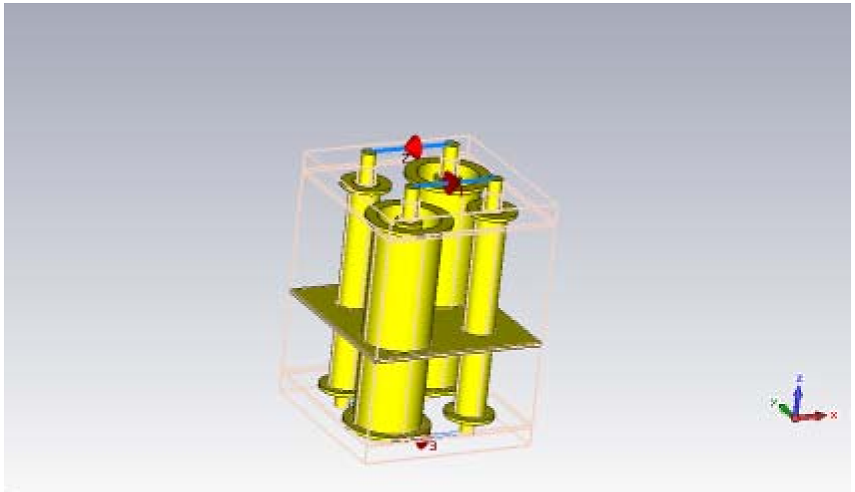


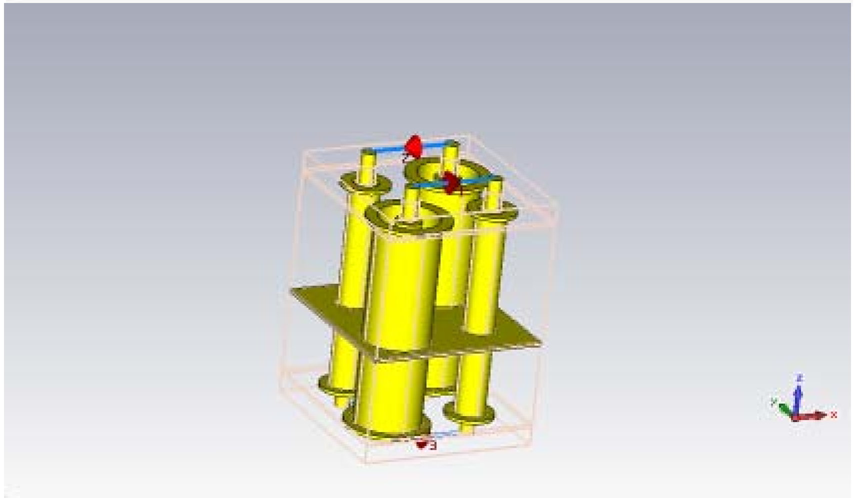
- **Long Pin**
  - **Spring probe**
    - **Sleeve Diameter = 0.3mm**
    - **Sleeve Length = 2.3mm**
    - **Total Length ~ 2.7mm**



- **Short Pin**
  - **Spring probe**
    - **Sleeve Diameter = 0.53mm**
    - **Sleeve Length = 1.53mm**
    - **Total Length ~ 1.98mm**

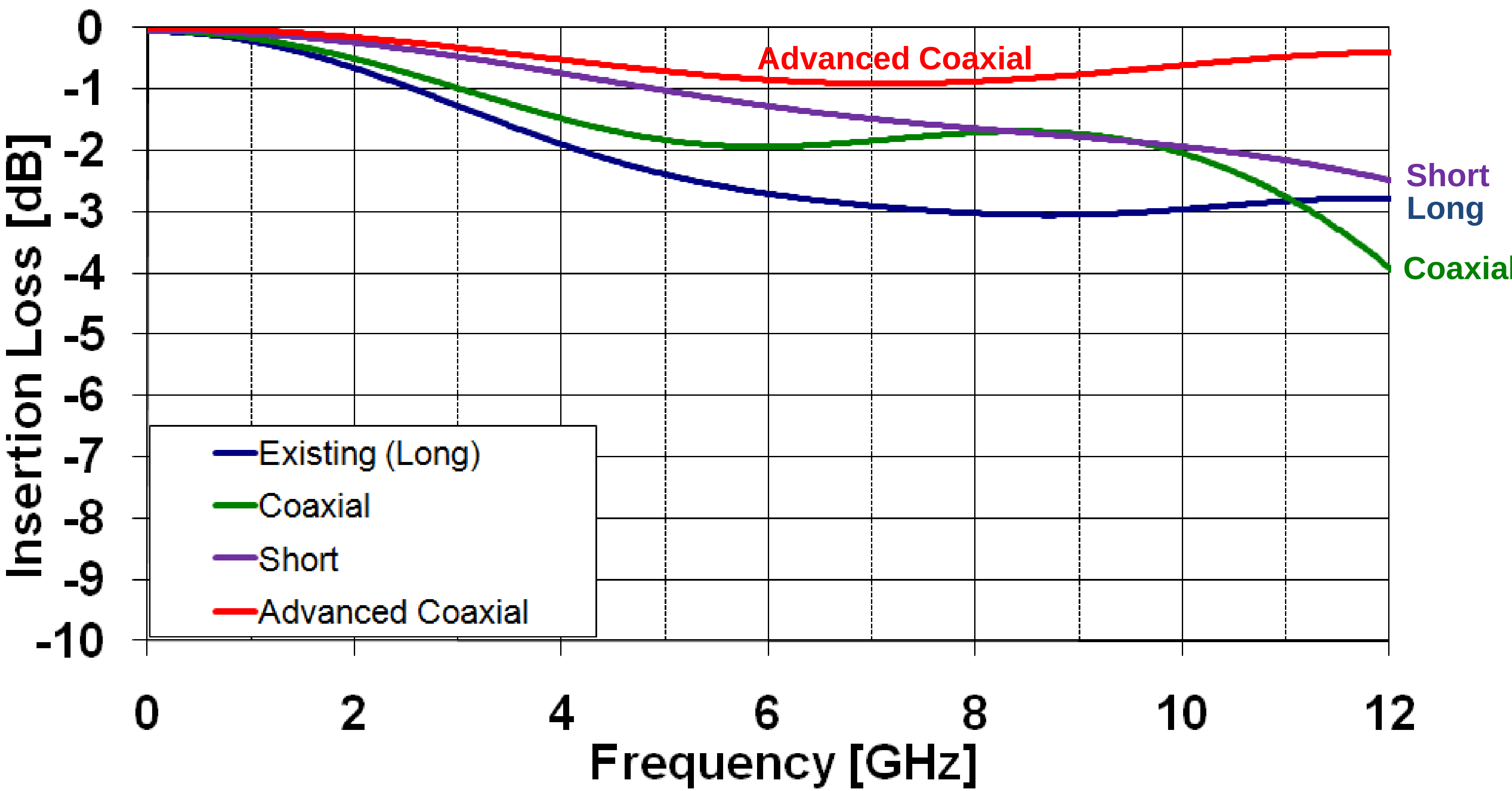
Signal Transmission Simulation Model (1mm pitch)





- **Coaxial**
  - **Spring probe**
    - **Same as Long Pins**
  - **Coaxial structure around sleeve area**
    -
- **Advanced Coaxial**
  - **Spring probe**
    - **Same as Long Pins**
  - **Advanced Coaxial Construct**

Signal Transmission Simulation Insertion Loss



Signal Transmission Simulation
Near End Crosstalk

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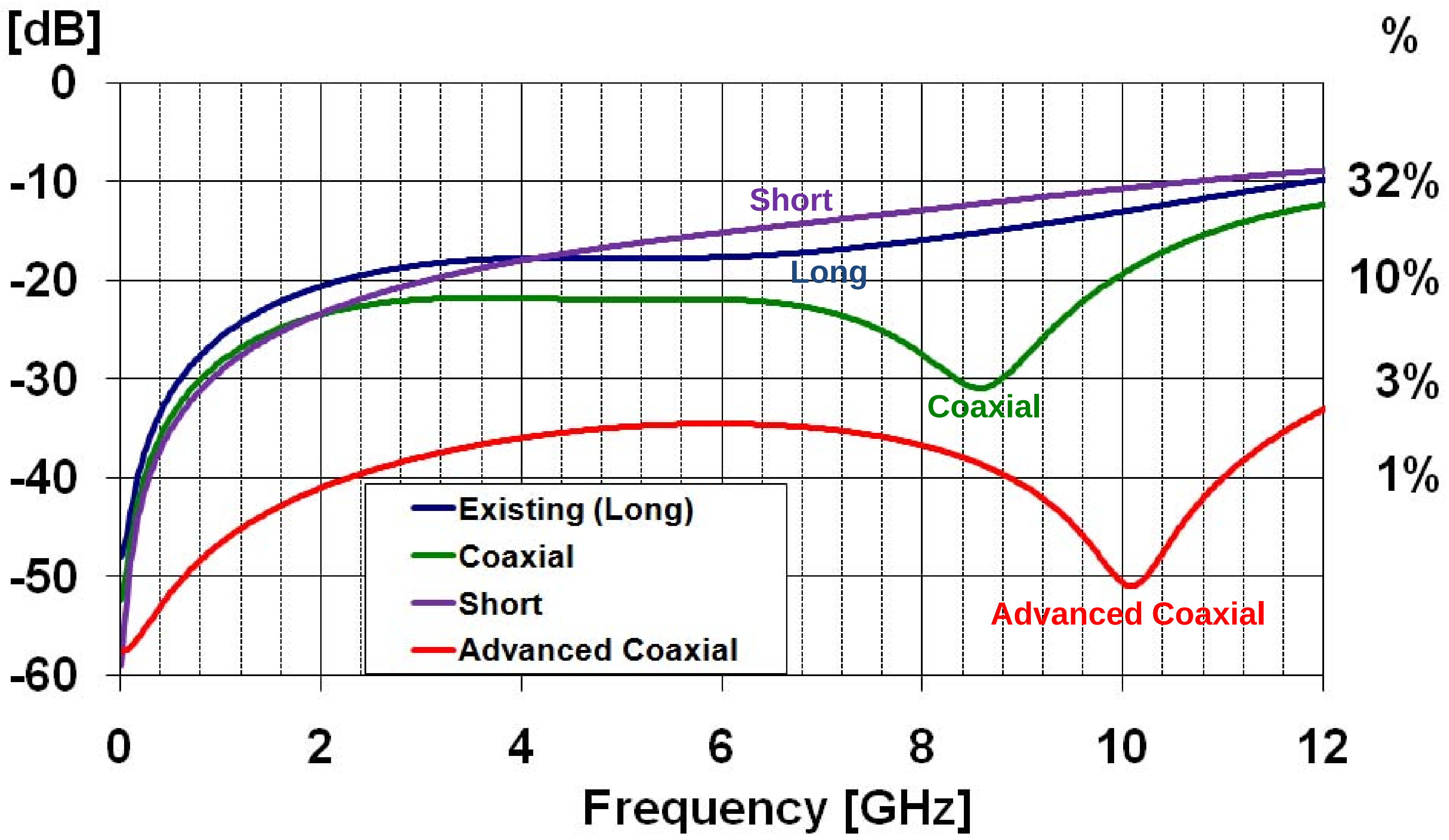
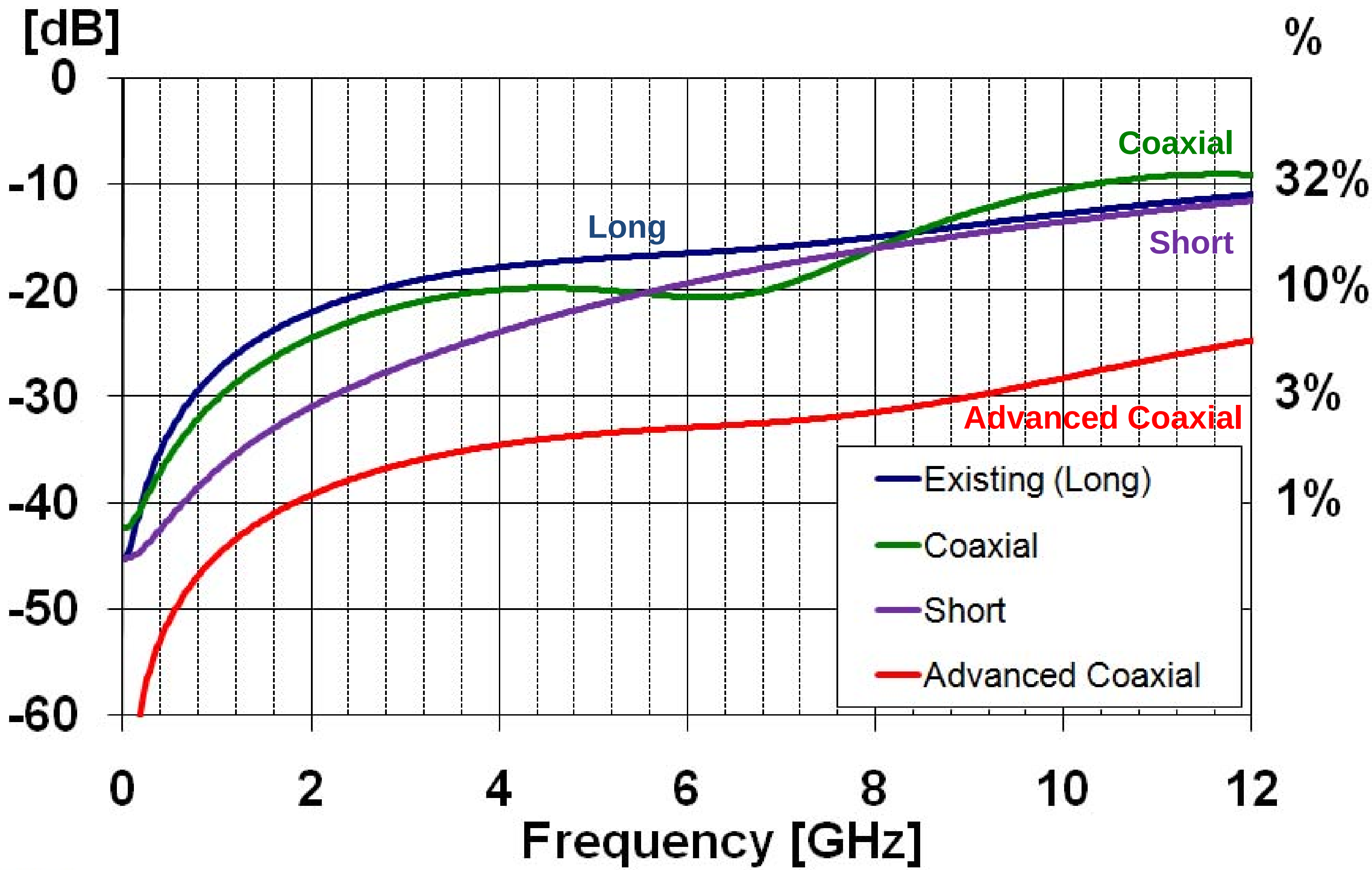


Signal Transmission Simulation Far End Crosstalk



High Speed Simulation Conclusions

- **Insertion Loss and Crosstalk can be reduced by Coax and Advanced Coax Construct.**
- **Coax Constructs enable the option to use a Longer Pin Length for Mechanical Stability.**
- **Advanced Coax Construct further improves the Electrical Performance. Based on the parameters of this modeling, it shows the potential of 12 GHz performance with less than 1 dB insertion loss and less than 7% crosstalk.**
- **3M FAST Coax Sockets enable a High Speed option for Testing.**

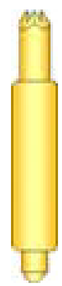
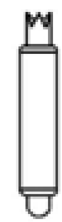
Simulation Modeling Summary

- **Power Distribution**
  - **Sockets with 3M ECM Show better Performance than existing sockets without 3M ECM.**

- **High Speed Signal Transmission**
  - **Advanced 3M FAST coaxial socket Shows Better Performance than long or short contact type sockets.**

Customer Measured Constructs Evaluated

(3M ECM used on Samples 04 and 06)

	03	04	05	06
Pin Length	3.8mm	3.8mm	2.4mm	2.4mm
Plunger Travel/Stroke	0.65mm	0.65mm	0.4mm	0.4mm
Spring Force	25gf	25gf	25gf	25gf
Mech. Cycle Life	> 100K Cycles	> 100K Cycles	> 100K Cycles	> 100K Cycles
Operating Temp.			−40 ～ +120	−40 ～ +120
CD Resistance			< 100mΩ	< 100mΩ
Self Inductance			< 1.0nH	< 1.0nH
Contact				
Socket				

Signal Sensitivity Evaluation

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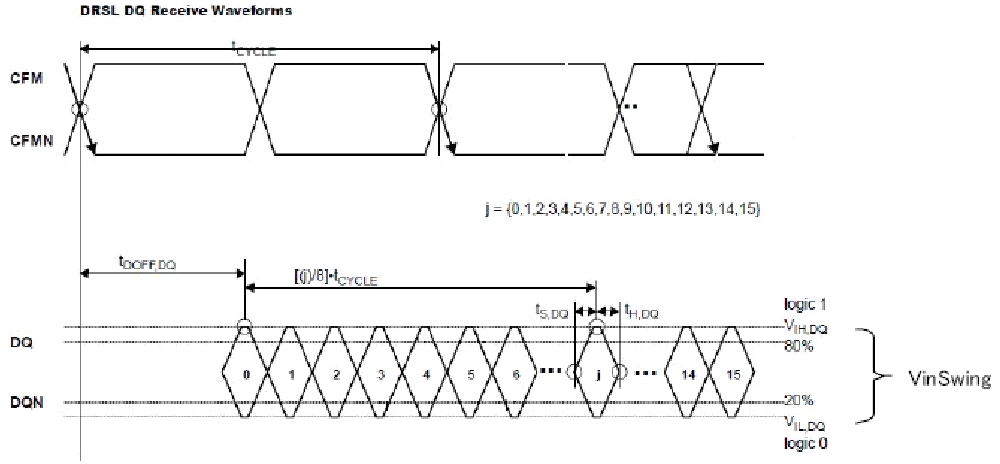
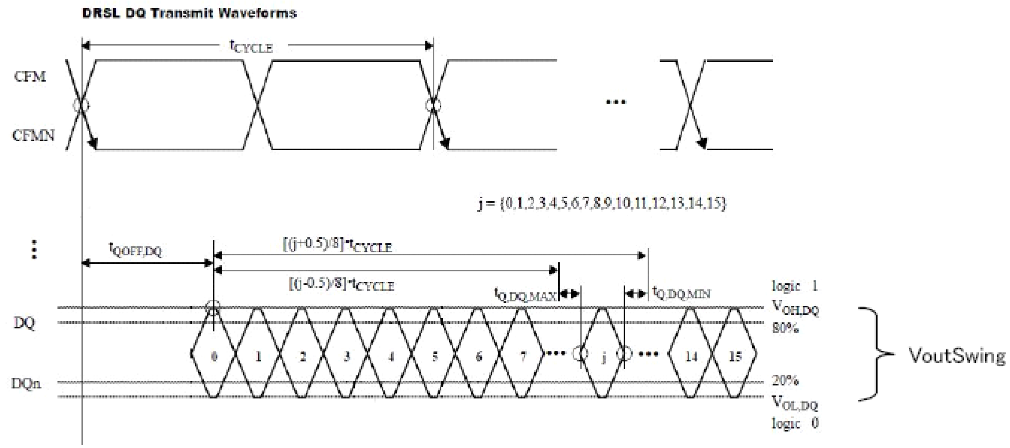
項目		概要	SPEC値 3.2GHz Min	SPEC値 3.2GHz Max	SPEC値 4.8GHz Min	SPEC値 4.8GHz Max	unit
DQ	tS,tH	**Sensitivity of Input Signal**	0.065	–	0.055	–	ns



項目		概要	SPEC値 3.2GHz Min	SPEC値 3.2GHz Max	SPEC値 4.8GHz Min	SPEC値 4.8GHz Max	unit
DQ	tQ	**Sensitivity of Output Signal**	−0.065	0.065	−0.055	0.055	ns



3M

Shmoo Plot

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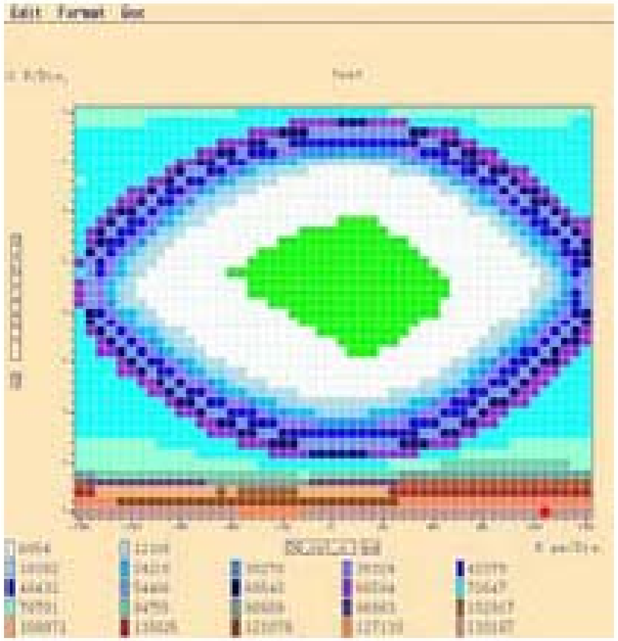
Shmoo Plot

Parameters:
- **1) Source Voltage**
- **2) Signal Input/Output Timing**
- **3) Input/Output Voltage of Signal**

X-Axis is Output Signal Timing
Y-Axis is Output Voltage



Signal Pass Tolerance vs. VDD/Signal in(out) Timing

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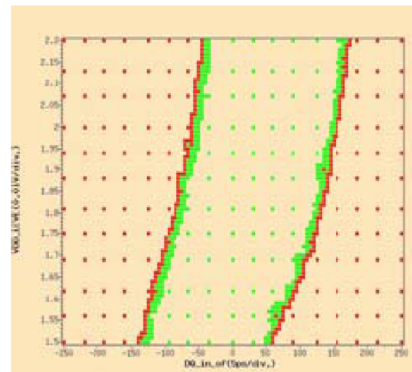
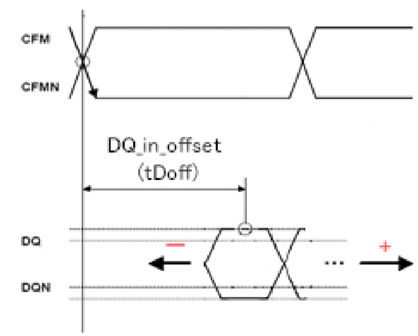
tSH_DQ

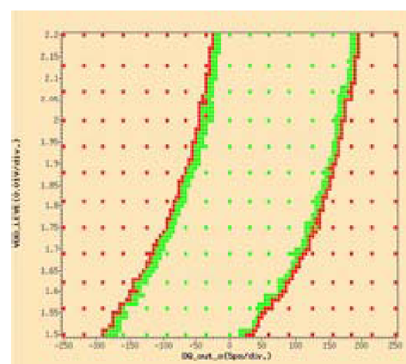
tSH_DQ is timing of input signal.
VDD is source voltage.
X-Axis is tSH_DQ. Center of x-axis is +/- 0 msec of input signal timing.
Y-Axis is source voltage.

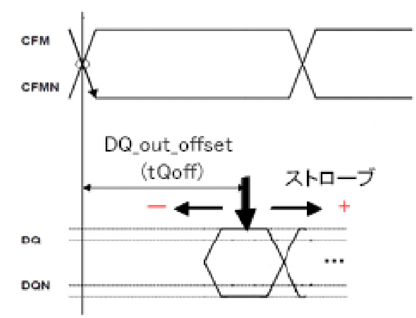




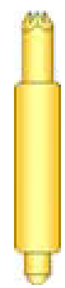
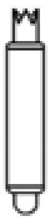
tQ_DQ

tQ_DQ is timing out of output signal.
VDD is source voltage.
X-Axis is tQ_DQ. Center of x-axis is +/- 0 msec of output signal timing.
Y-Axis is source voltage.





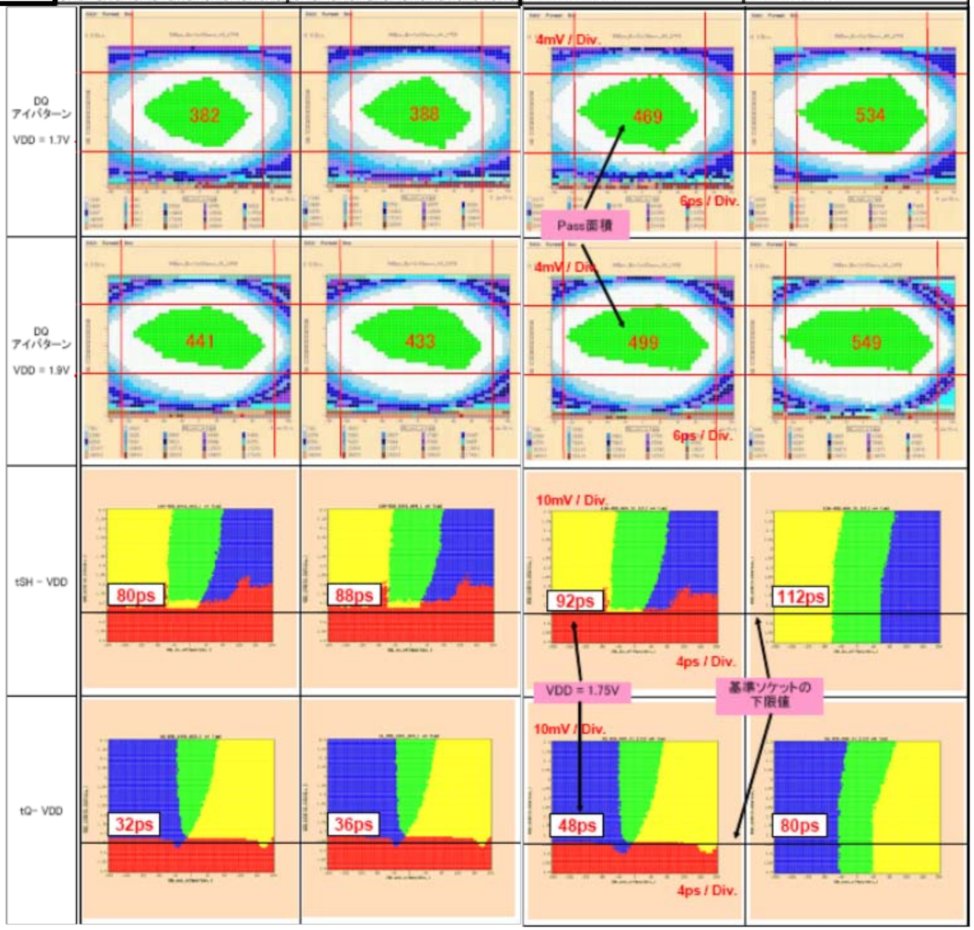
Sensitivity of Signal Transmission @ 4.8 Gbps Signal Transmission Speed

	03	04	05	06
Pin Length	3.8mm	3.8mm	2.4mm	2.4mm
Plunger Travel/Stroke	0.65mm	0.65mm	0.4mm	0.4mm
Spring Force	25gf	25gf	25gf	25gf
Mech. Cycle Life	> 100K Cycles	> 100K Cycles	> 100K Cycles	> 100K Cycles
Operating Temp.			-40 ~ +120	-40 ~ +120
CD Resistance			< 100mΩ	< 100mΩ
Self Inductance			< 1.0nH	< 1.0nH
Contact				

			03	04	05	06
tSH	1.75V		90.2	90.8	93.1	65.7
	1.85V		67.2	68.5	61.5	54.7
	1.95V		59.5	59.2	54.0	48.5
tQ	1.75V		98.2	97.6	93.3	74.5
	1.85V		75.6	75.5	68.3	62.4
	1.95V		65.3	64.7	59.7	55.8

Shmoo Plot and Signal Timing Results

	03	04	05	06
Pin Length	3.8mm	3.8mm	2.4mm	2.4mm
Plunger Travel/Stroke	0.65mm	0.65mm	0.4mm	0.4mm
Spring Force	25gf	25gf	25gf	25gf
Mech. Cycle Life	> 100K Cycles	> 100K Cycles	> 100K Cycles	> 100K Cycles
Operating Temp.			-40 ～ +120	-40 ～ +120
CD Resistance			< 100mΩ	< 100mΩ
Self Inductance			< 1.0nH	< 1.0nH



Customer Measured Results Conclusions

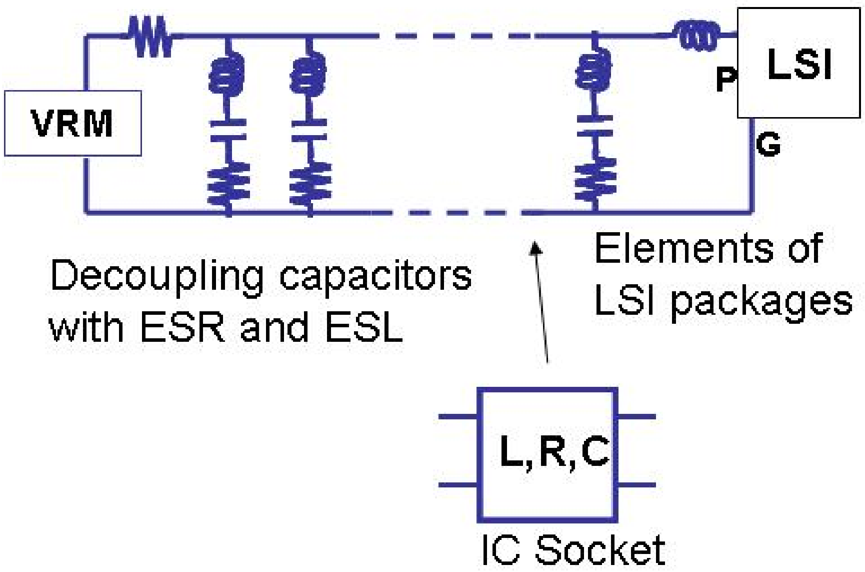
- **A short contact pin length will show the best performance relative to speed, but the tradeoff is typically reduced mechanical stability.**
  - **Mechanical Cycle Life**
  - **Higher Spring Force**
- **With 3M ECM added to the short contact length, significant improvement is achieved in order to meet requirements.**
- **With 3M ECM, a longer pin with a lower spring force may be used to achieve similar electrical performance as a shorter pin without 3M ECM while not compromising the mechanical cycle life of the contact.**

Value of 3M ECM in Test Socket

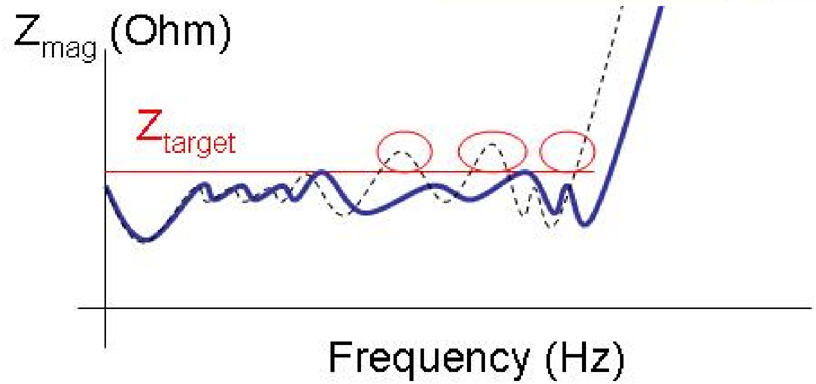
- **Impedance of power delivery network circuit (known as PDN) can be designed and controlled.**
  - **Especially needed for High Performance LSI Devices.**
  - **Some LSI suppliers propose Target Impedance and recommend Control of it.**
- **Spring probe of socket has excess Inductance and increases socket Impedance.**
- **Sockets having 3M ECM will contribute to reducing the Impedance because of the additional Capacitance.**
- **Sockets having 3M ECM will contribute to minimizing and controlling the PDN Impedance.**

3M ECM is a potential solution, but other methods may exist as well to address the Issues facing a Test Socket.

Controlling Power Distribution System



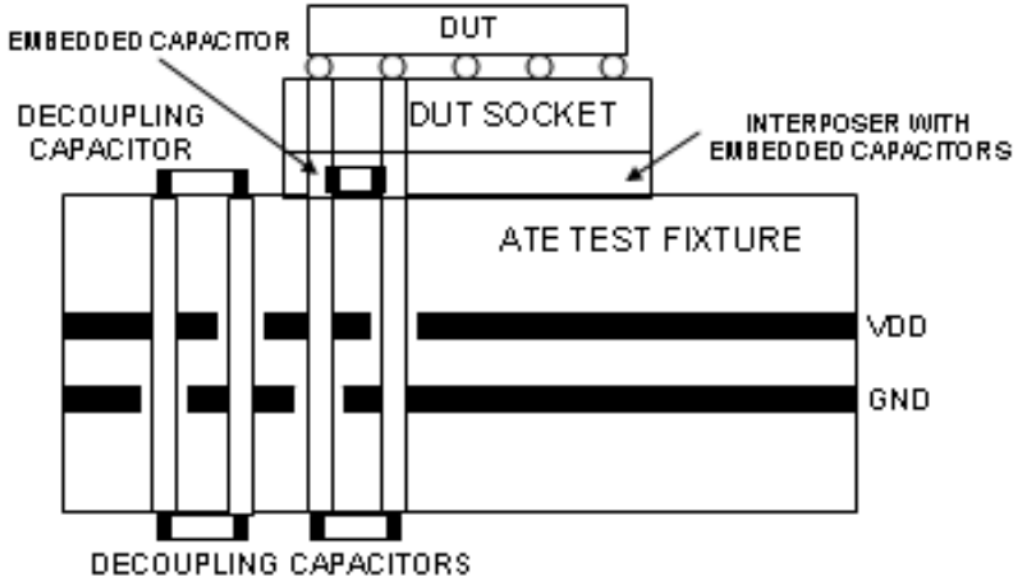
PDN Circuit Model

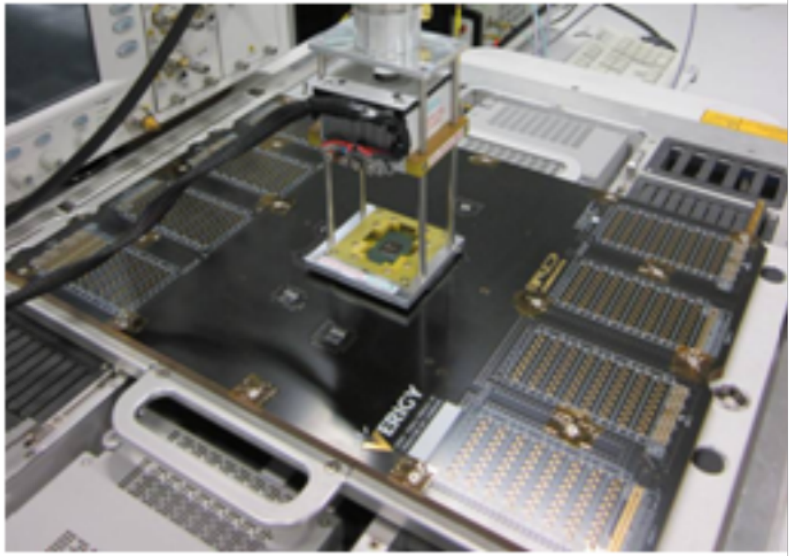


PDN Controlling in Frequency Domain

- **PDN (Power distribution network) should be designed and controlled below target impedance (Ztarget) for newer LSI devices.**
- **Long spring probes exhibit high inductance.**
- **Now what about the Test Board …**

Self-Impedance Comparison of the ATE Test Fixture PDN

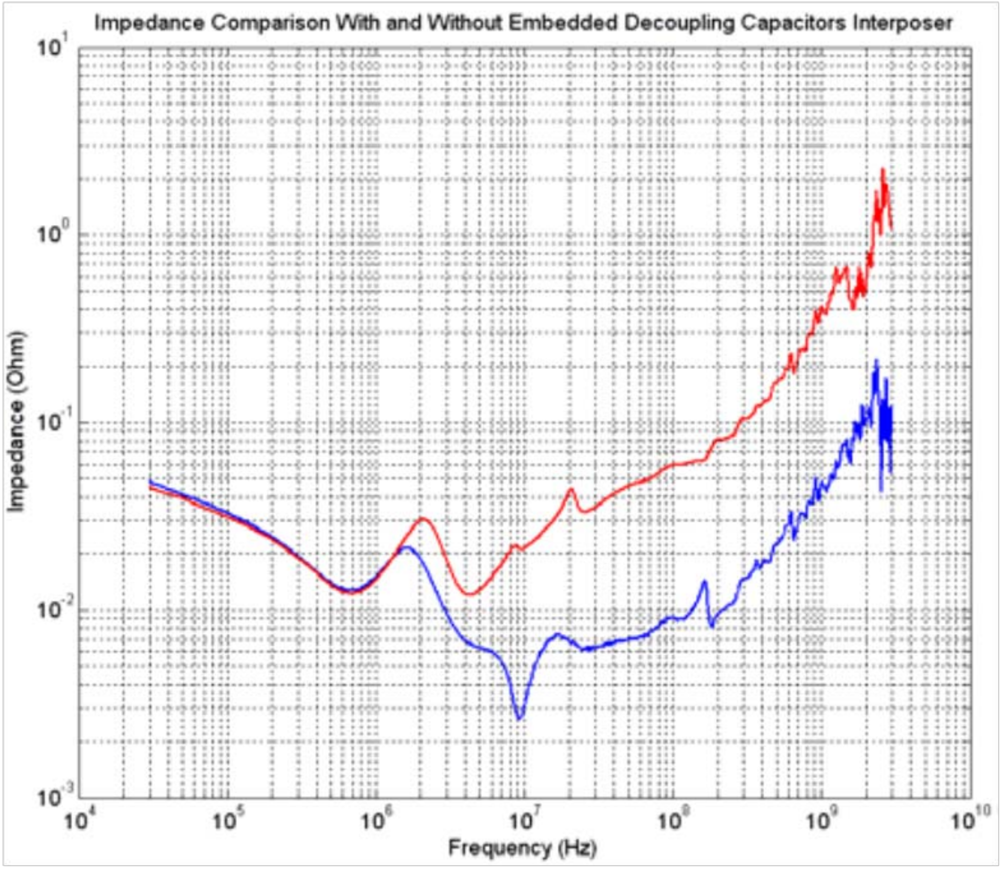




Decoupling capacitors distributed on an ATE test fixture with an embedded capacitors interposer (left) and picture of an ATE test fixture with 310 mil thick stack-up and with the two critical power planes implemented using a 14µm 3M ECM dielectric material with an embedded capacitor interposer between the test fixture PCB and socket (right). The high frequency capacitors should be placed on the interposer.

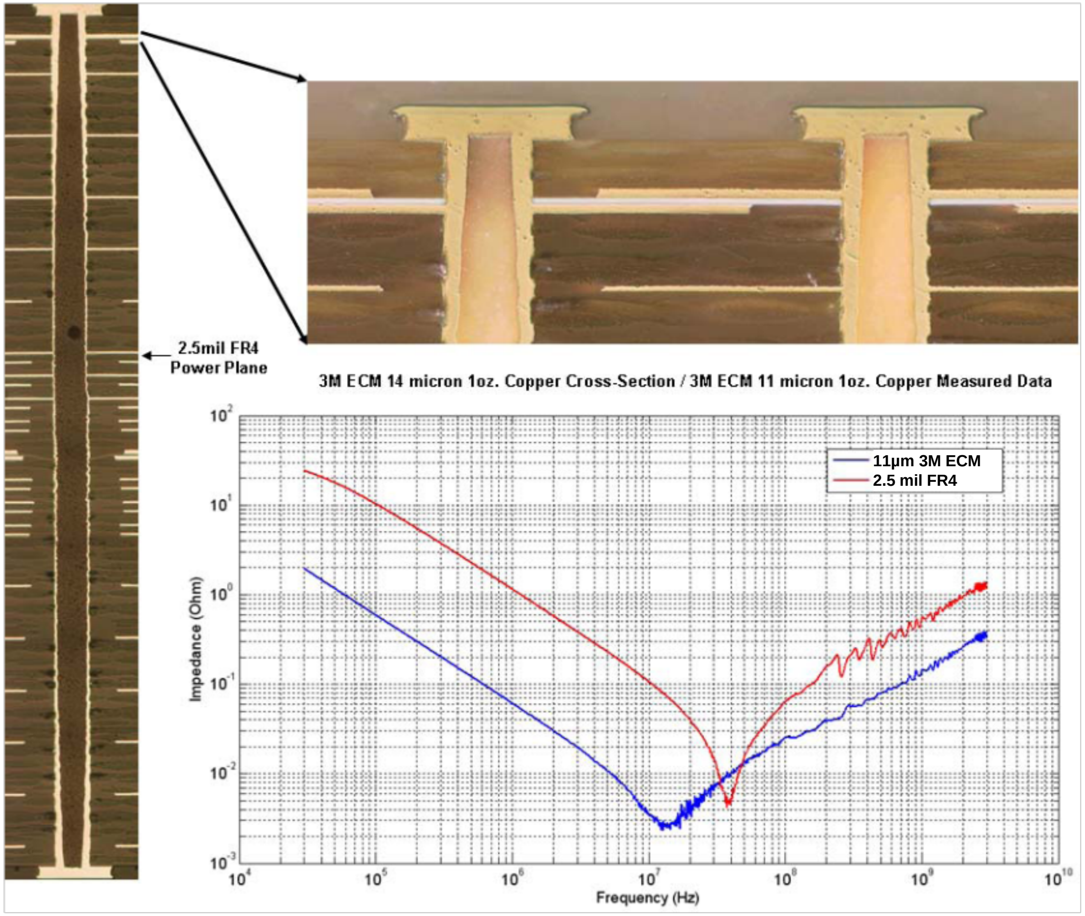
Source: PDN Design Challenges for ATE Test Fixtures, Verigy, DesignCon 2011

Self-Impedance Comparison of the ATE Test Fixture PDN
(with and without Embedded Decoupling Discrete Capacitors Interposer (Cartridge))



Source: PDN Design Challenges for ATE Test Fixtures, Verigy, DesignCon 2011

Self-Impedance Comparison of the ATE Test Fixture PDN
(with 11µm 3M ECM and without 3M ECM)



- 3M ECM has been demonstrated to provide improvements when needed for higher performance applications.

Source: PDN Design Challenges for ATE Test Fixtures, Verigy, DesignCon 2011

3M ECM Benefits Relative to the Test Board

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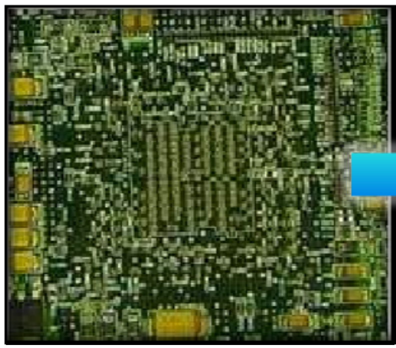
Miniaturization | **Performance** | **Component Reduction**

Backside of BGA

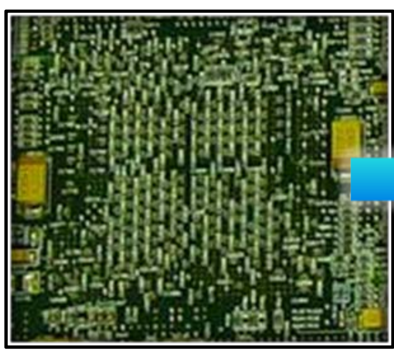
Telecom Example: Base Station

Without 3M ECM

Location 1



Location 2



With 3M ECM

Location 1

Location 2

Need

Reduction in Number of Components
Better Power Distribution Management

Solution

3M ECM

Results

50% Reduction in Discrete Component Count

Power Distribution Significantly Improved

Why 3M ECM for the Test Board?

(Future Evaluation Work for Test Board Environment)

- **3M ECM in the Test Board will likely enable not only Higher Frequency Performance, but also help eliminate capacitors on the PCB surface.**
  - **Help control the Test Board Impedance of the PDN**
  - **Elimination of Capacitors …**
    - **May make it possible to increase the number of test sockets per board**
      - **Improving Throughput**
    - **May make it possible to shrink the PCB**
      - **Reducing Total PCB Cost**

Conclusions

- **With 3M ECM and 3M FAST Socket platform, you have more options relative to the tradeoffs between Mechanical and Electrical Performance.**

- **3M ECM can also be applied to the Test Board, to potentially improve electrical performance, increase throughput and reduce the total cost.**