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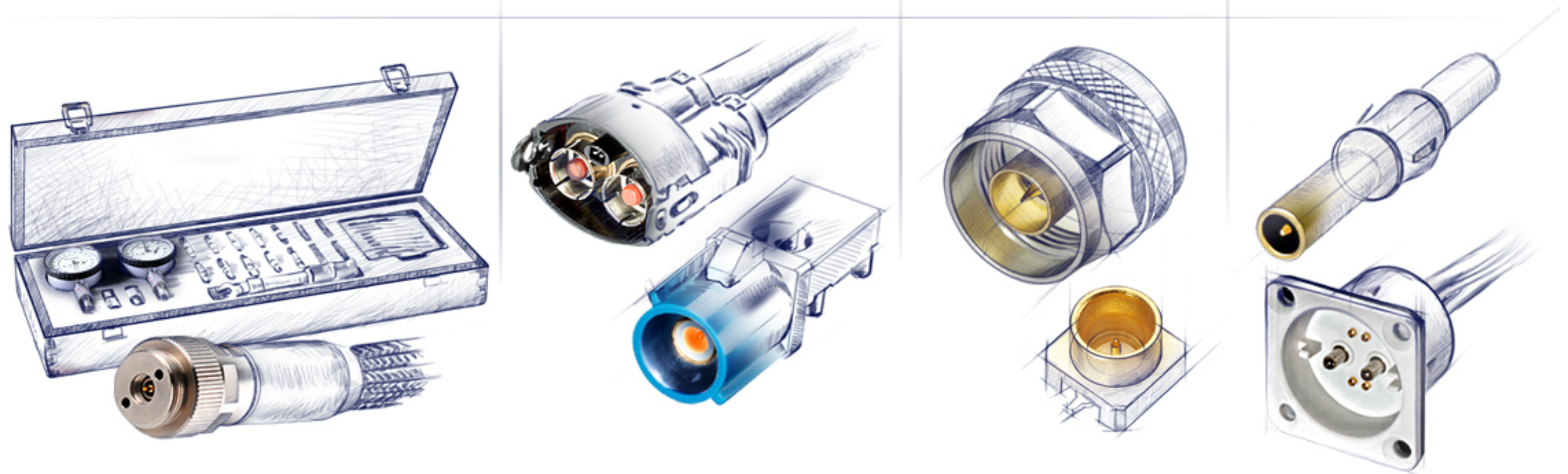
Coax Wire Bond High-frequency Interconnect Technologies



Moore's Law applied to increasing signal speed and packaging size

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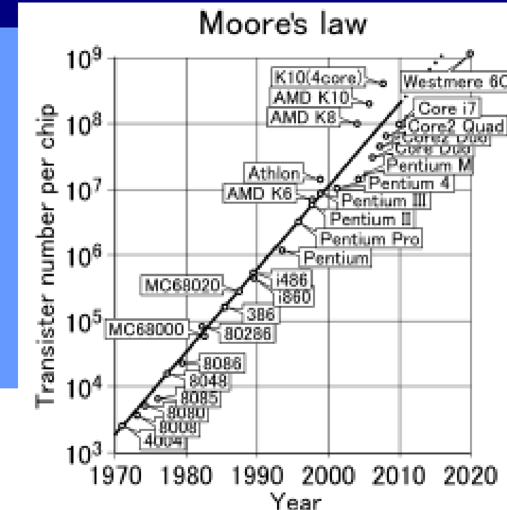
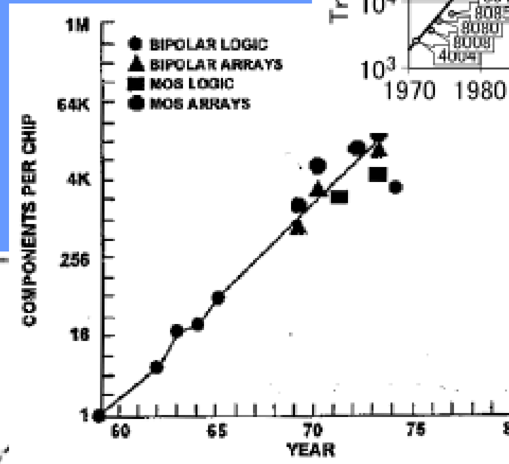
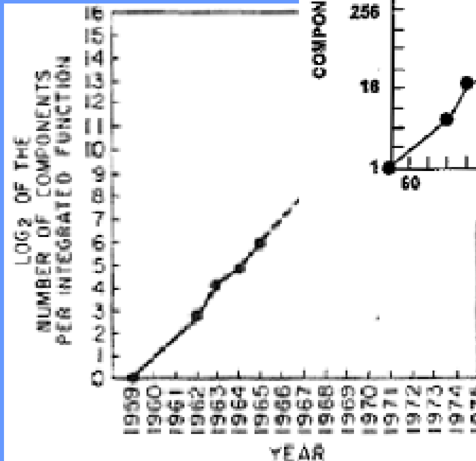
Moore's Law – The Driver for the Semiconductor Industry

When asked,
"What would you like your legacy to the world to be ?"
Dr. Moore replied:
"Anything" but Moore's Law"

- Has been the driver for the semiconductor industry for more than 4 decades
- More well known than Murphy's law







1975
Components/IC will double every two years

1965
Components/IC will double every year

Source: Spectrum and Anderson School UCLA

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Moore‘s Law applied to increasing signal speed and packaging size

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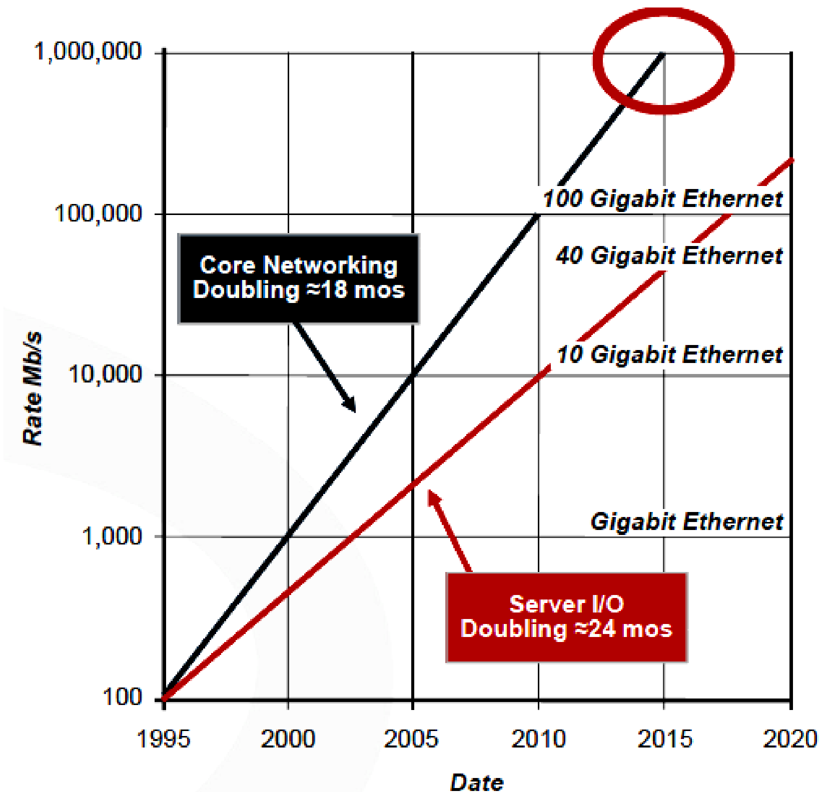
Growing bandwidth demand

- Many studies show 40-50% annual growth in global Internet traffic
- High-definition video and high-speed broadband penetration and consumer IP traffic responsible for majority of the traffic growth
- Enablers: smart & media devices, social networks, 3D content, cloud computing and services

Increasing gap between network traffic and hardware development

- Network traffic 2x in 18 months
- Server I/O 2x in 24 months



Source:[Cisco Visual Networking Index 2008]

What is Coax Wire Bond?

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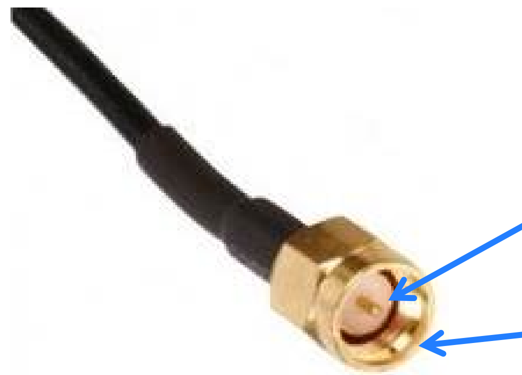
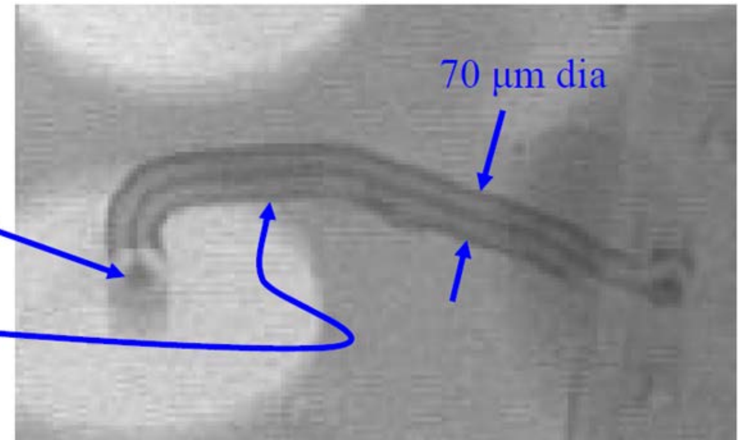
- Wire bond transformed into impedance-matched coaxial cable
  - 10,000x smaller cross-section than typical coax
- Compatible with common wire bonded SMT packaging
- Exceptional bandwidth, cross-talk, EMI performance
- Fits standard pick/place machines – automated assembly
- Patented Solution (2 issued; 1 pending)



Center conductor

Ground shield



Coax Wire Bond (x-ray image)

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Semiconductor Packaging Process with Coax Wire Bond

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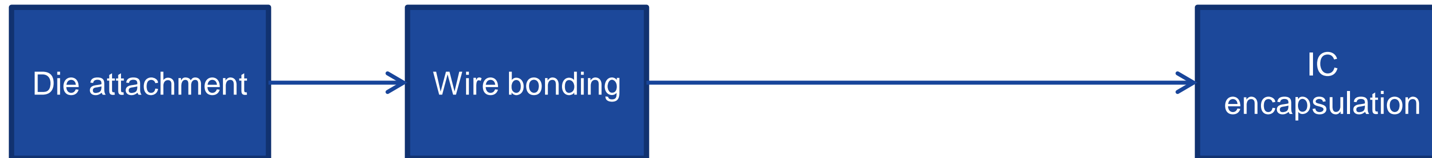
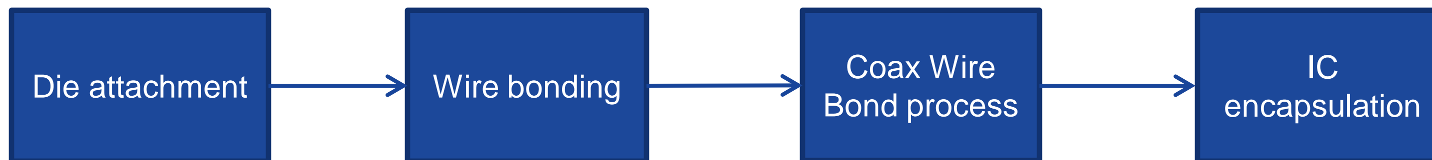
- Traditional semiconductor packaging process:



- Coax Wire Bond enhanced semiconductor packaging process:



- Coax Wire Bond is an additional process step.
- Process uses standard Semiconductor equipment
  - Laser-vias, plasma cleaning, batch deposition

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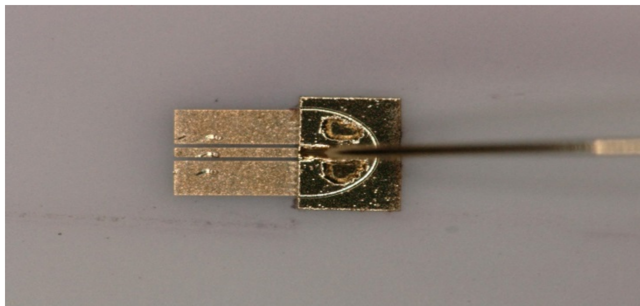
CWB Teststructure

CT Video of CWB in real

CWB Footprint for controled impedance launch



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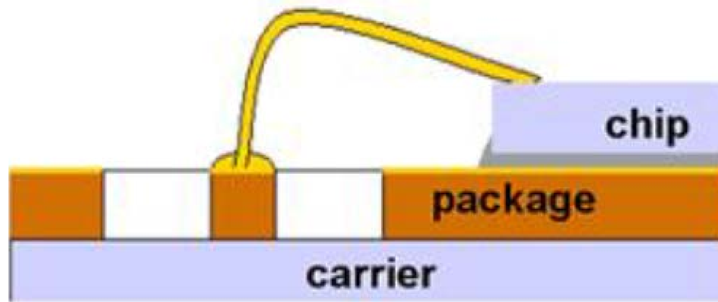
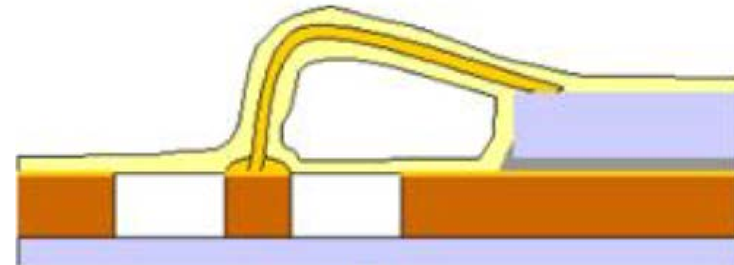
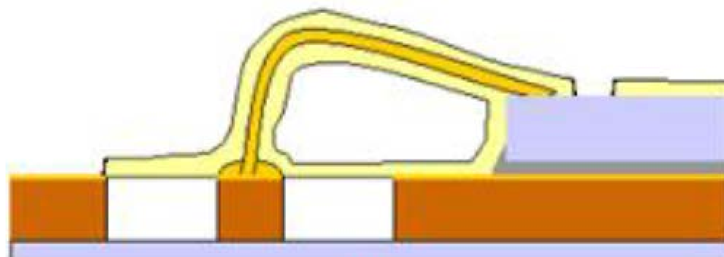
Coax Wire Bond – Basic Principle



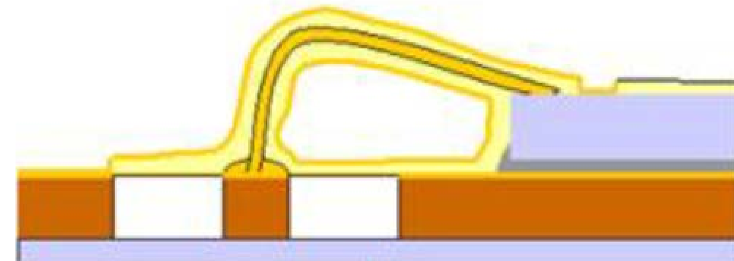
1) Die attach and wire bond



2) Conformal dielectric coating



3) Laser cutting of vias to allow metallic contact



4) Metallization of ground shield

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The Leadframe

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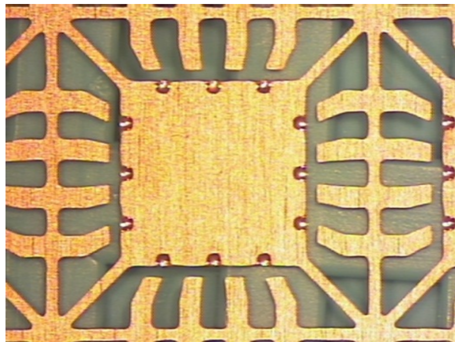
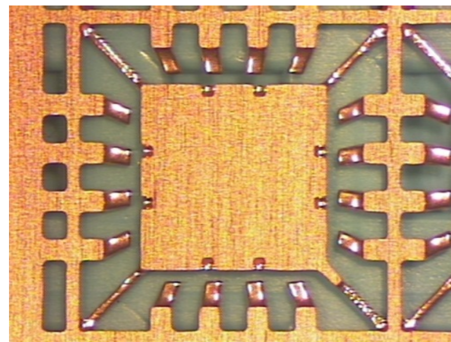
- The leadframe
  - Cu alloy sheet metal is used to make leadframes
- Vendor used to etch copper sheet into leadframes is QPL
  - http://www.qpl.com/eng/about/about.html
  - Common leadframe thickness is 8mils (0.2mm) and the feature etching occurs from both sides



Leadframe
Top



Leadframe
Bottom

One package site top and bottom

Open Cavity QFN

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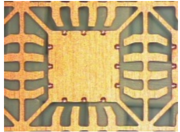
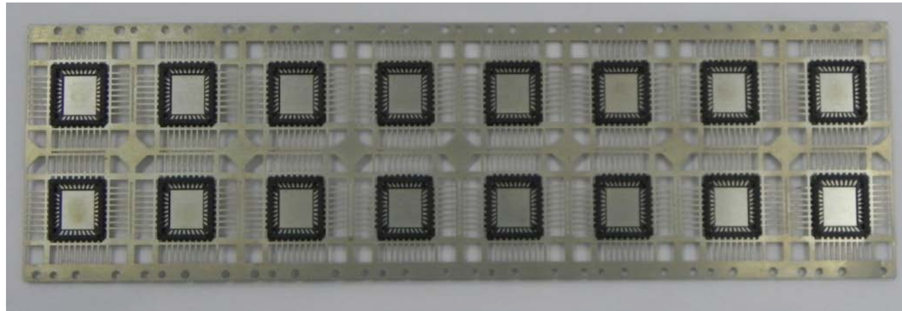
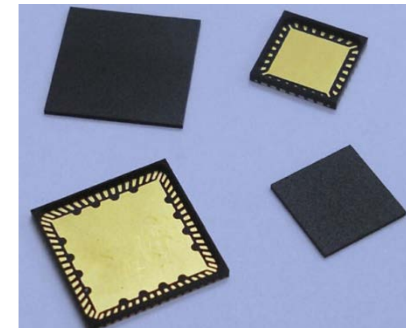
- Leadframe



- Leadframe strip with molded open cavity QFN packages



- Examples open cavity QFN packages



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Coax Wire Bond High-Frequency Interconnect Technologies

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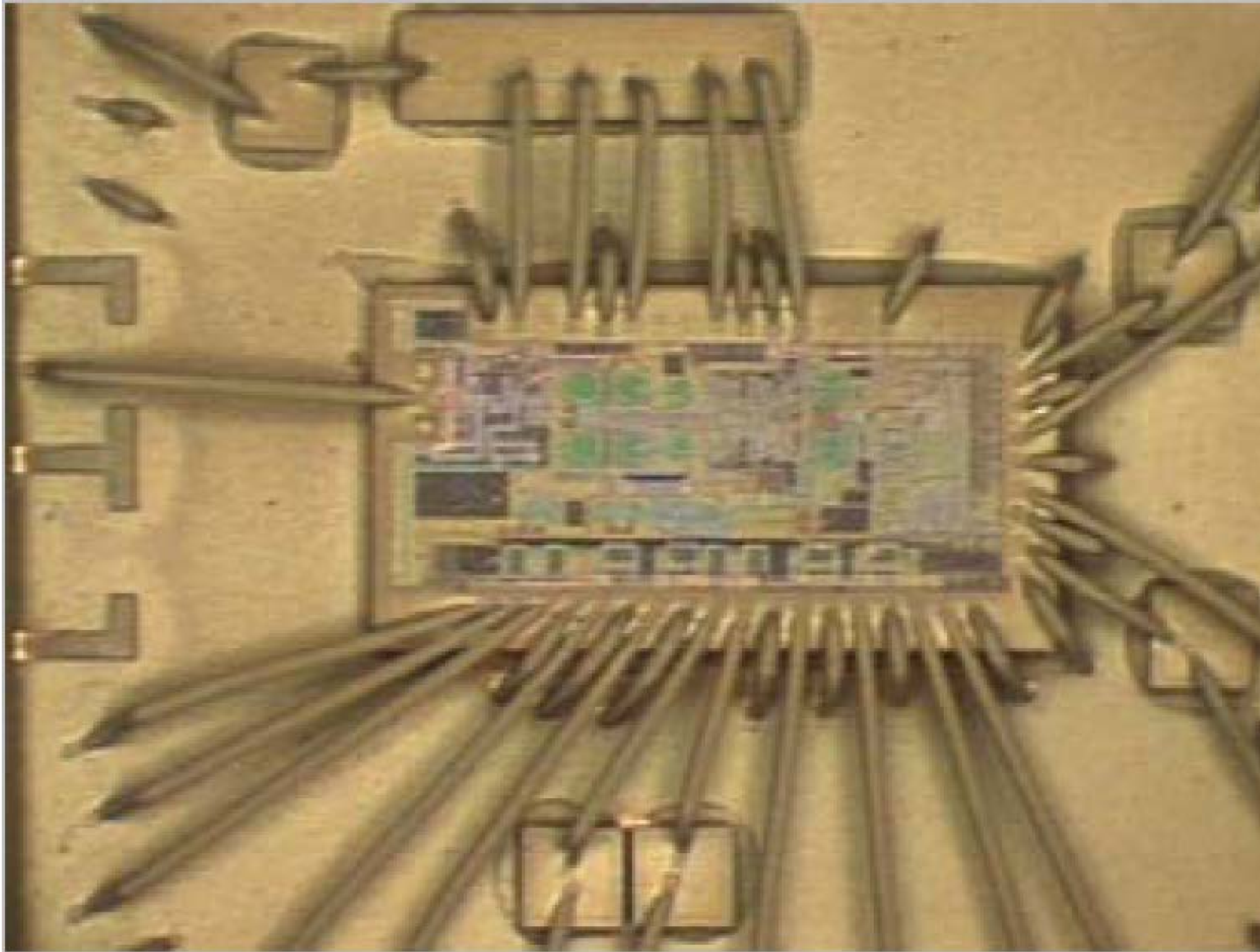

Why Use Coax Wire Bond?

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Interconnect technology does not keep up with Moore's Law

- As on-chip speeds increase, connections become a bottleneck
  - Bandwidth limited due to inductance
  - Reflections due to mismatch
  - Radiation to neighbors – crosstalk, EMI, SSN
- Unaddressed issues remain
  - Flip chip and Cu pillar micro-bump utilize short connections
  - No impedance match and no shielding
- Yet wire bond remains the dominant interconnect solution (>90%)
  - Inexpensive
  - Convenient

→ Leverage the low cost of wire bond with performance exceeding flip-chip

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High Bandwidth Solution for Multiple Problems

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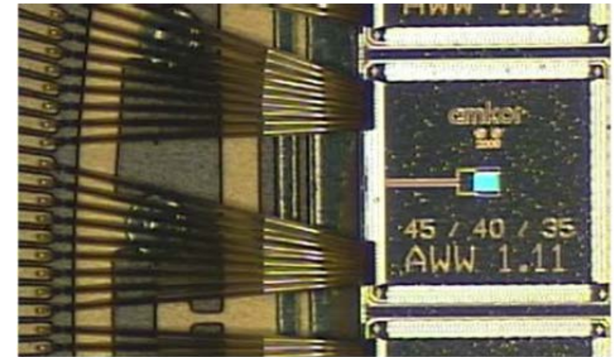
Wire bonded QFP, QFN, BGA, OSA problems:

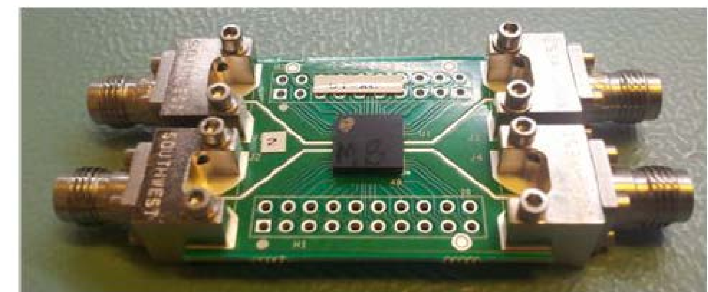
- Transceiver Signal Degradation above 3 GHz
- Cross-Talk & Simultaneous Switching Noise (SSN) even at 100's MHz (e.g., DDR speeds affected)
- Routing traces difficult – no crossing of bond wires
- Only narrow band interconnects above 40GHz
- Poor Power Distribution – high bare wire inductance
- Can't have bandwidth and thermal isolation

All improved dramatically by Coax Wire Bond

- > 100 GHz bandwidth
- 25 dB reduction in cross-talk
- 16X reduction in SSN
- Bandwidth not limited by distance



60 micron pad pitch mC-BGA



SMT mounted mQFN
40GHz differential limiting Amplifier

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Benefits of Coax Wire Bond

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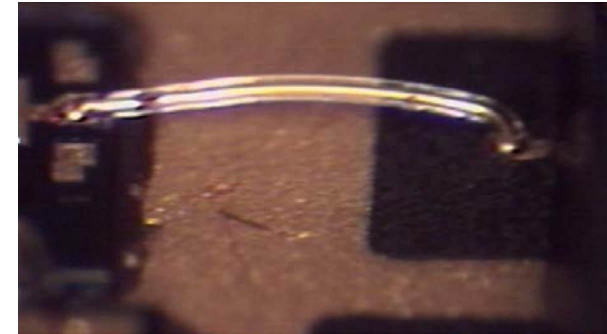
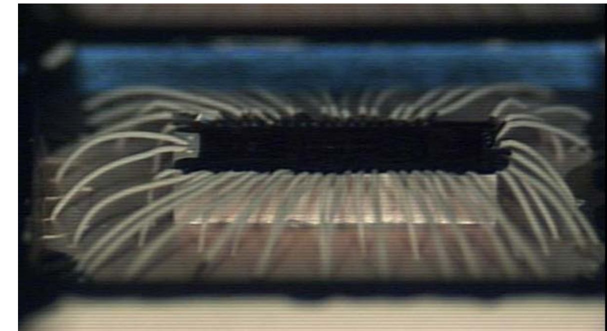
- Extremely long wires without wire sweep or signal degradation
- Allows crossed and nested wires – another layer of interconnect
- Tunable Impedance (5 Ω to 75 Ω)
- Coax shield provides robust ground interconnect
- Common materials used to make Coax Wire Bond
  - Room temperature vacuum conformal coating and sputtered metal
- Process uses standard Semiconductor equipment
  - Laser-vias, plasma clean, batch deposition
- Once process is established, Coax Wire Bond enables low-cost, high performance packaging of high-speed semiconductors
- Greater levels of serialization


Bond with dielectric coating


Bonds after metallization

Sectional view

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Coax Wire Bond - Potential Applications

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- MMICs (Monolithic Microwave Integrated Circuits, as packaged devices and MCMs (multi-chip modules))
- Military/Defense RF
- Automotive radar
  - 24 GHz – Up to 10 million units annually of QFN-packaged chip sets for automotive radar and defense applications
  - 77 GHz/79 GHz looming
- High Speed Communications (WiGig / 802.11ad)
- Fiber optic modules (laser/driver interconnect)
- FPGAs & other digital ICs
  - For elimination of switching noise/crosstalk and where connection to DDR3 memory is necessary
  - Estimated millions of units annually for several mid-level product lines
- New connectivity solutions for micro structures with RF requirements in general

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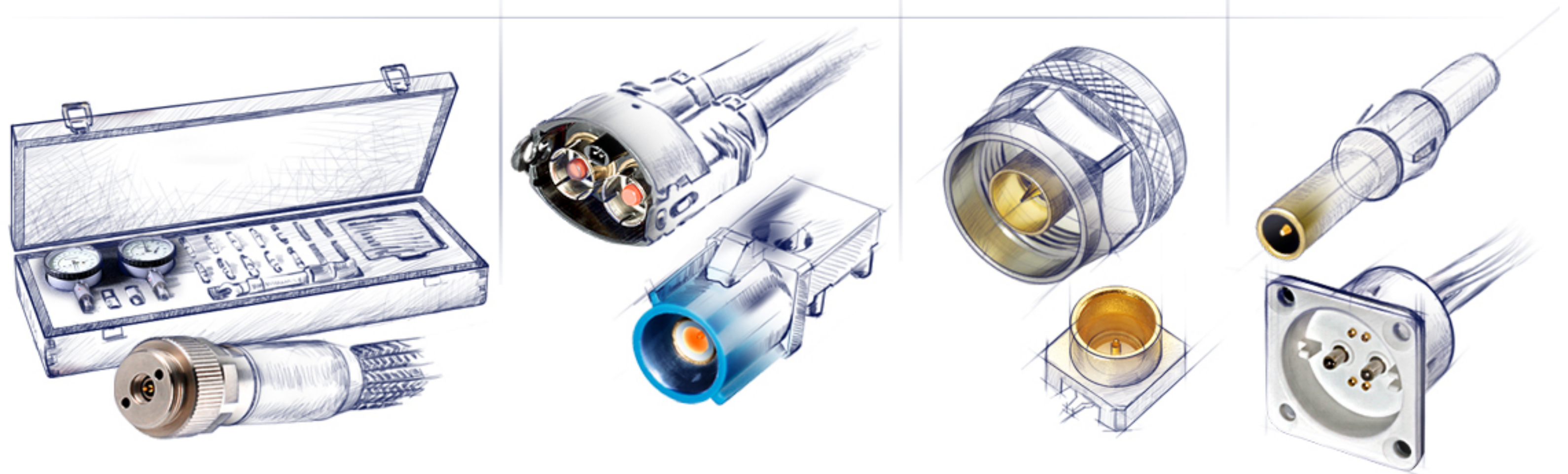
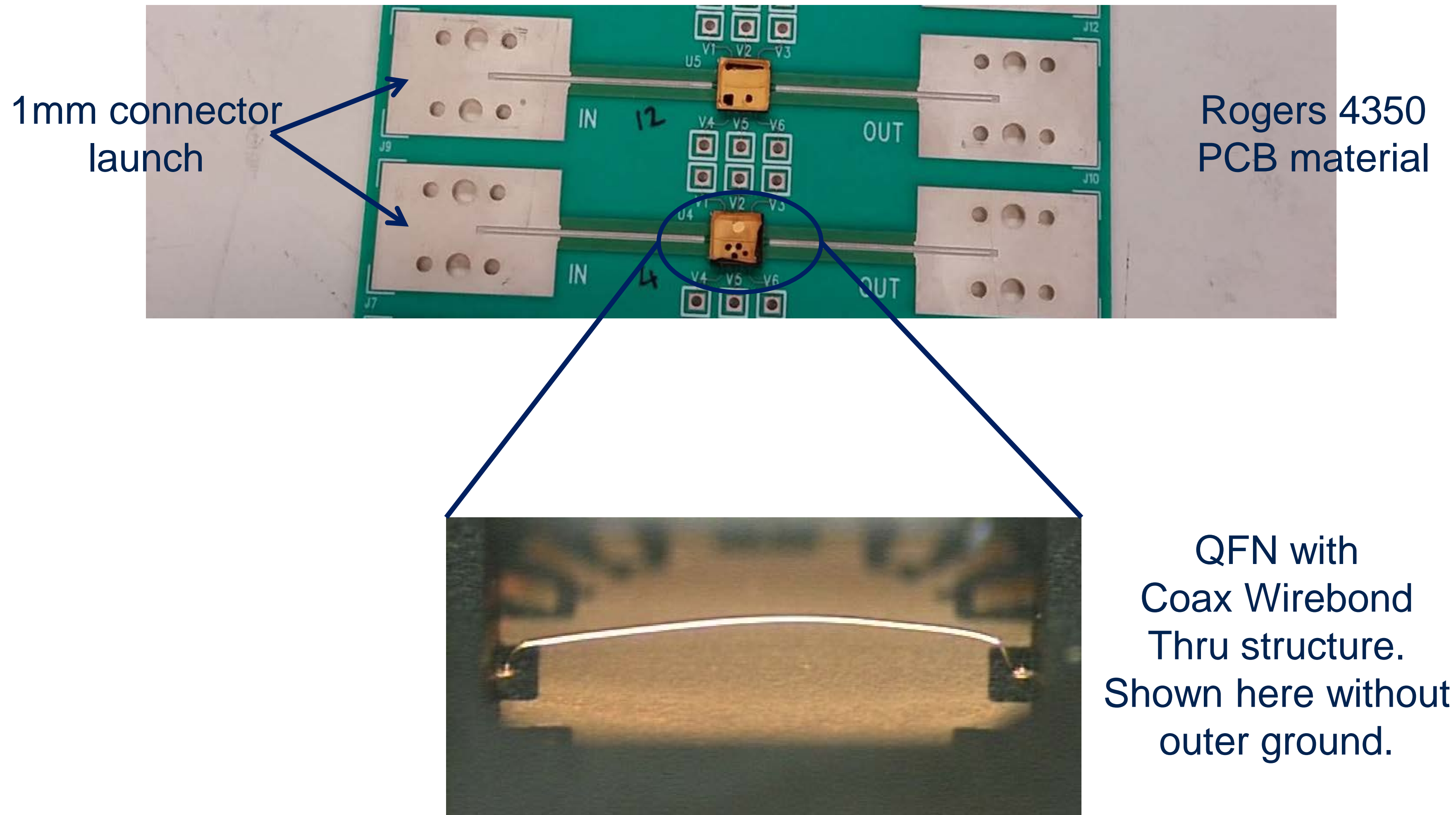
Coax Wire Bond QFN Electrical Measurements



Coax Wire Bond in QFN Measurements Structure

1mm connector launch

Rogers 4350 PCB material



QFN with Coax Wirebond Thru structure. Shown here without outer ground.

Coax Wire Bond in QFN
Measurements Structure

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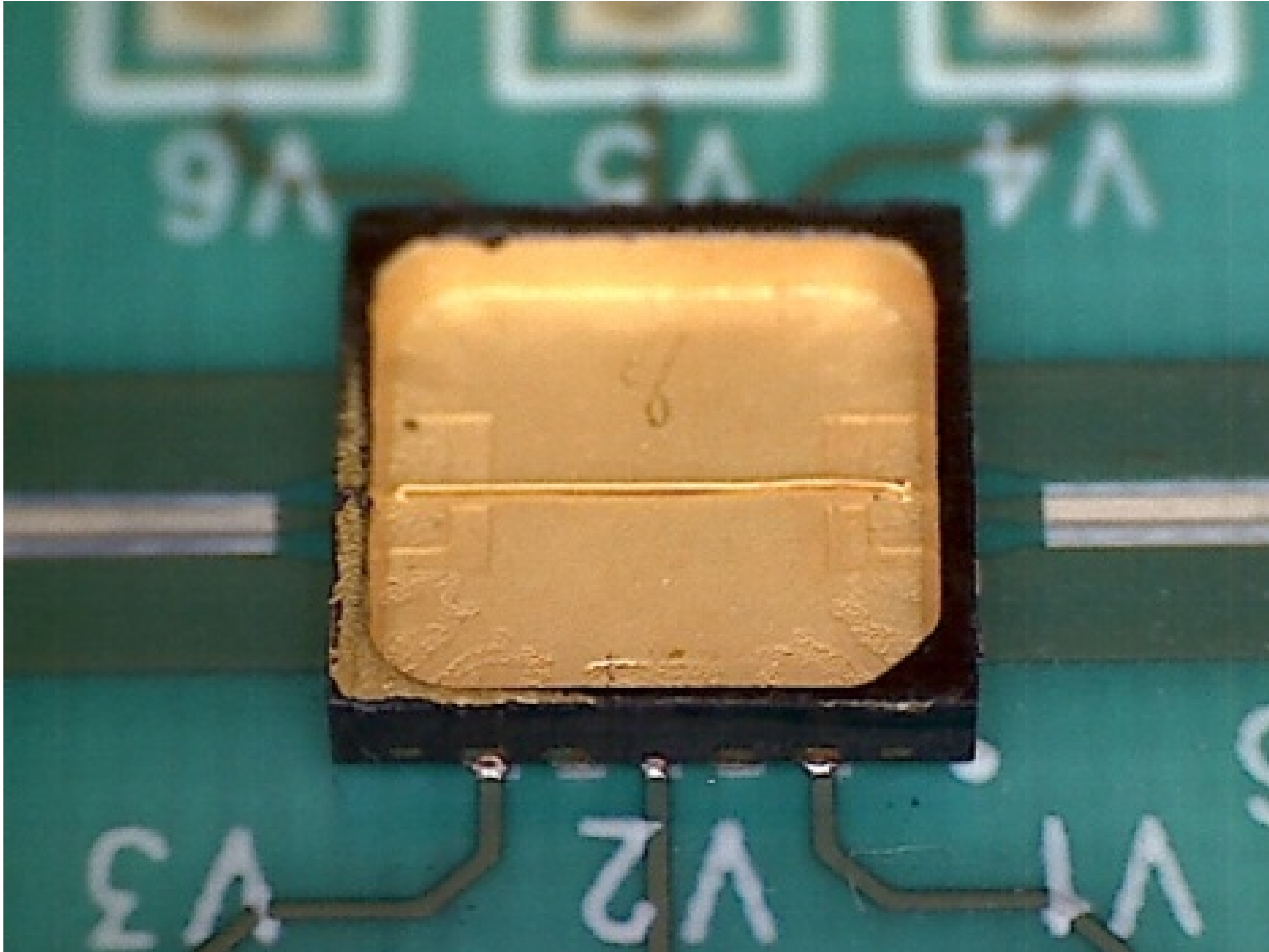

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S-parameters

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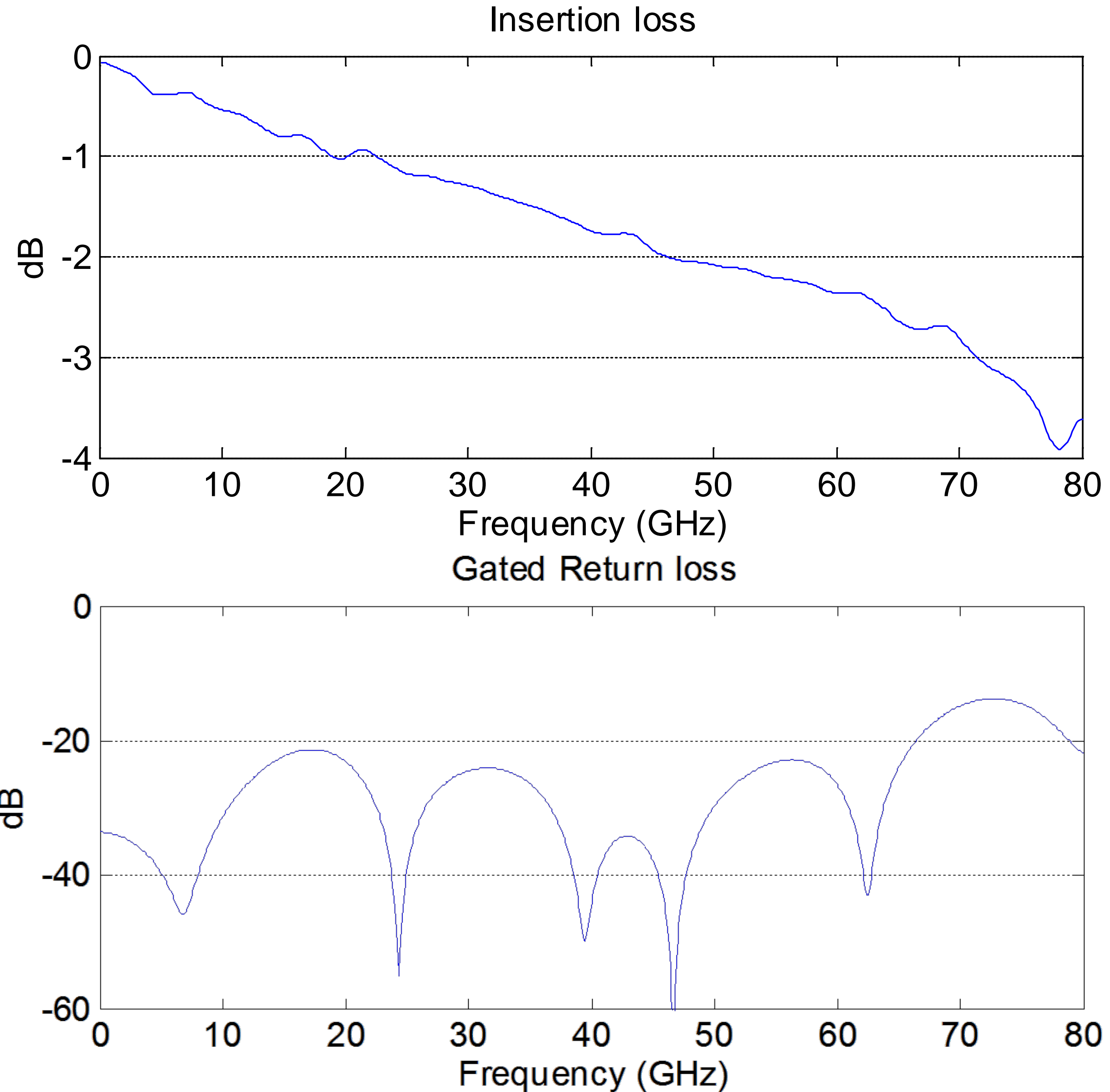
Measurements include:
(Approximately
500 um PCB trace
+ QFN launch) x2
+ QFN with 4.5mm
Coax Wirebond



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S-parameters

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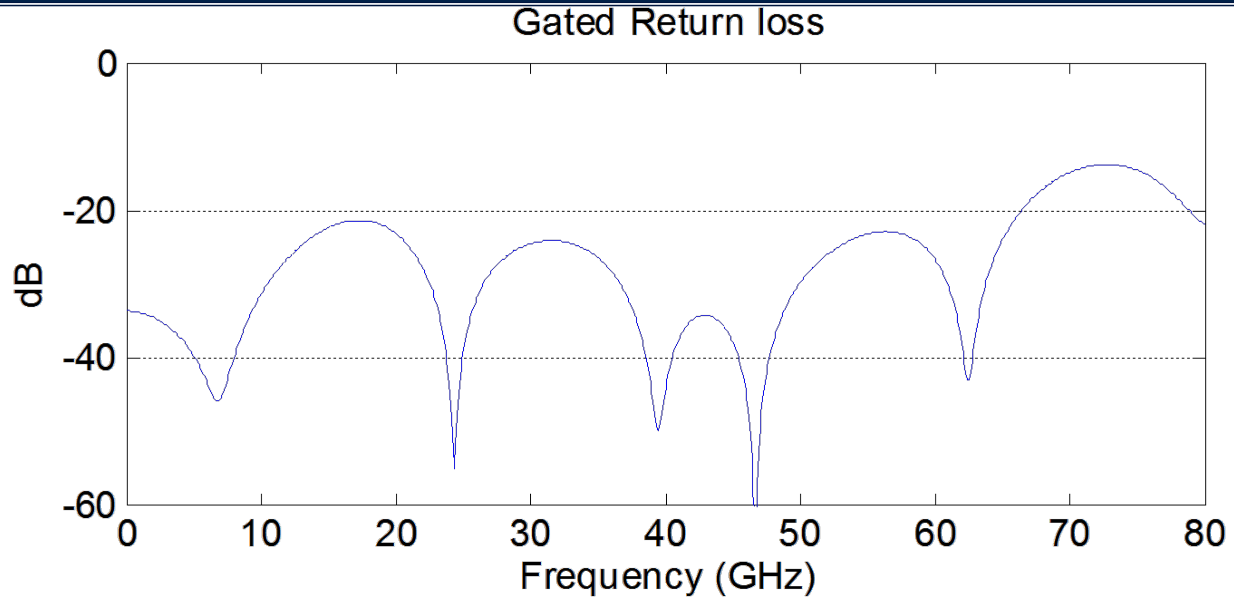
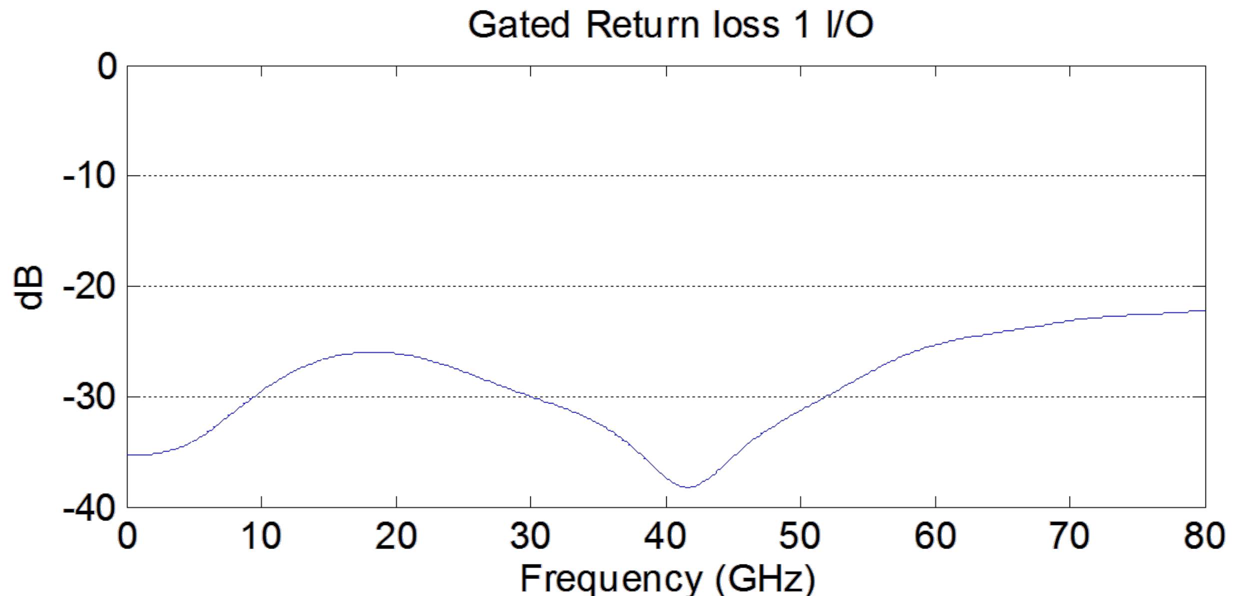
Gated Return Loss:
(Approximately
500 um PCB trace
+ QFN launch) x2
+ QFN



1 I/O Return Loss:
Approximately
500 um PCB trace
+ QFN launch
+ Half QFN
Coax wirebond



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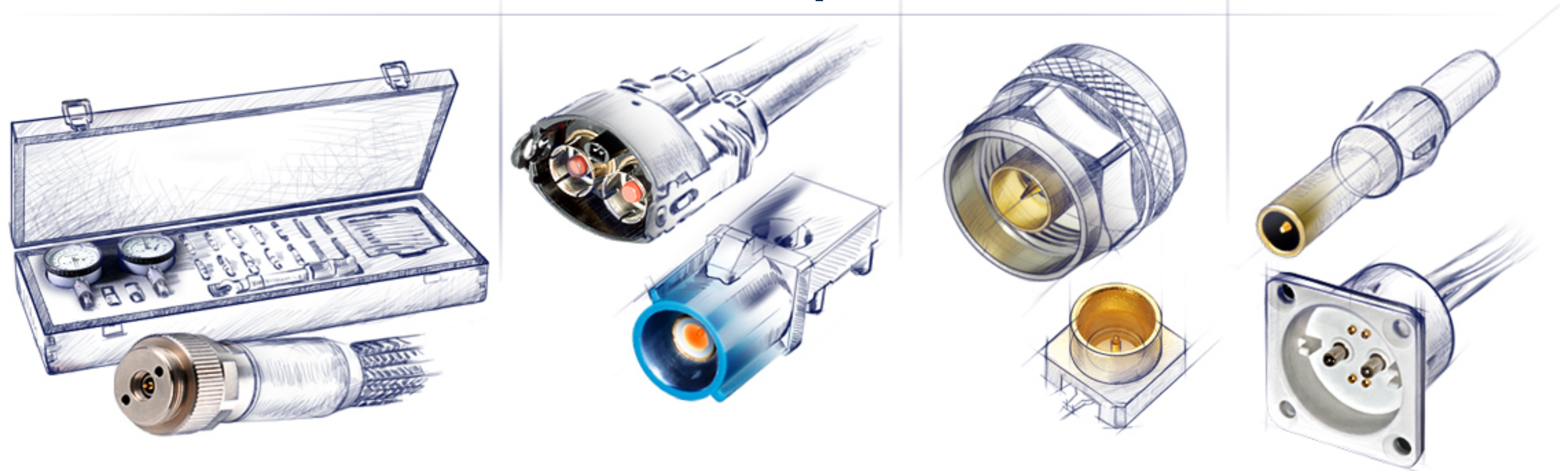
Bridge Connector

Lateral Board to Board Connection
- Concept -



Bridge/ lateral inter PCB connection with MCI and Coax Wire Bond

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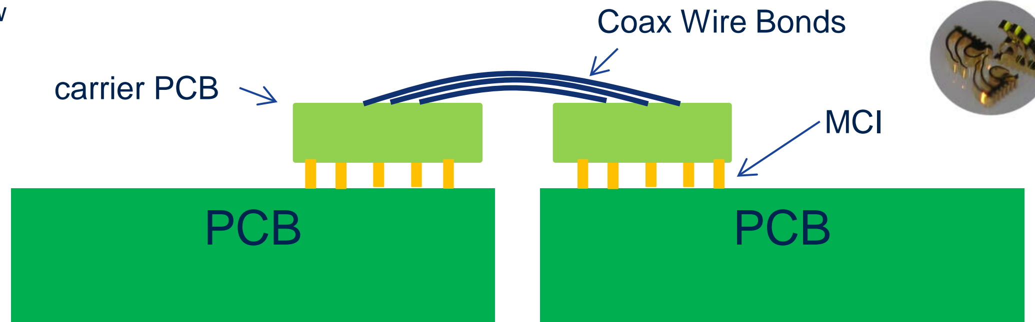
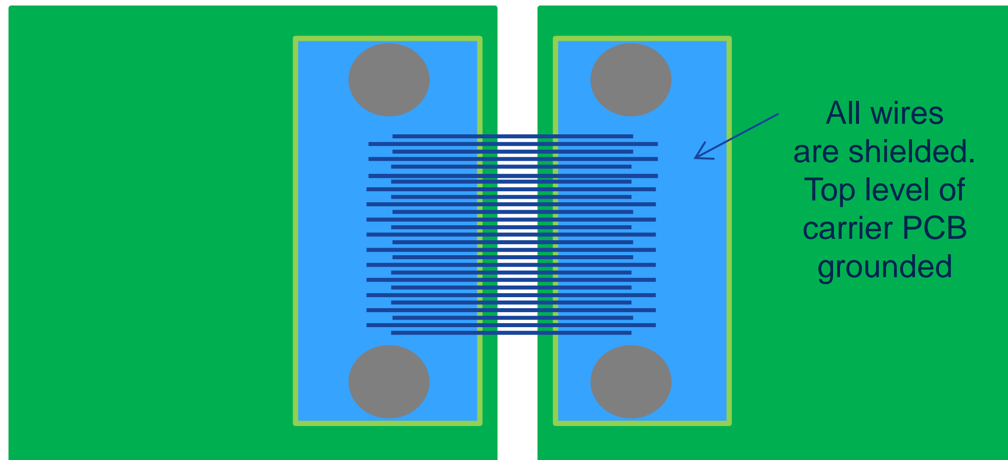
side view



top view



MCI (=Monolithic Compliant Interconnect) pins are soldered on carrier PCB and provide short signal path (~0,5mm) for good signal integrity

A carrier PCB with via-structures is used to transfer signals from the impedance controlled pin pattern to coaxial structures

The board is made of multi layer low loss material to minimize loss and cross talk

The carrier PCBs are screwed onto PCB boards.
Alternatively it could be snapped into the PCBs with an U-shaped stiffener element.

Coax Wire Bond connections are coated and metallized standard bond wires

Coax Wire Bond offers the possibility to re-route signal lines if required (crossing of wires is possible)

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Coax Wire Bond
in lateral board to board connection

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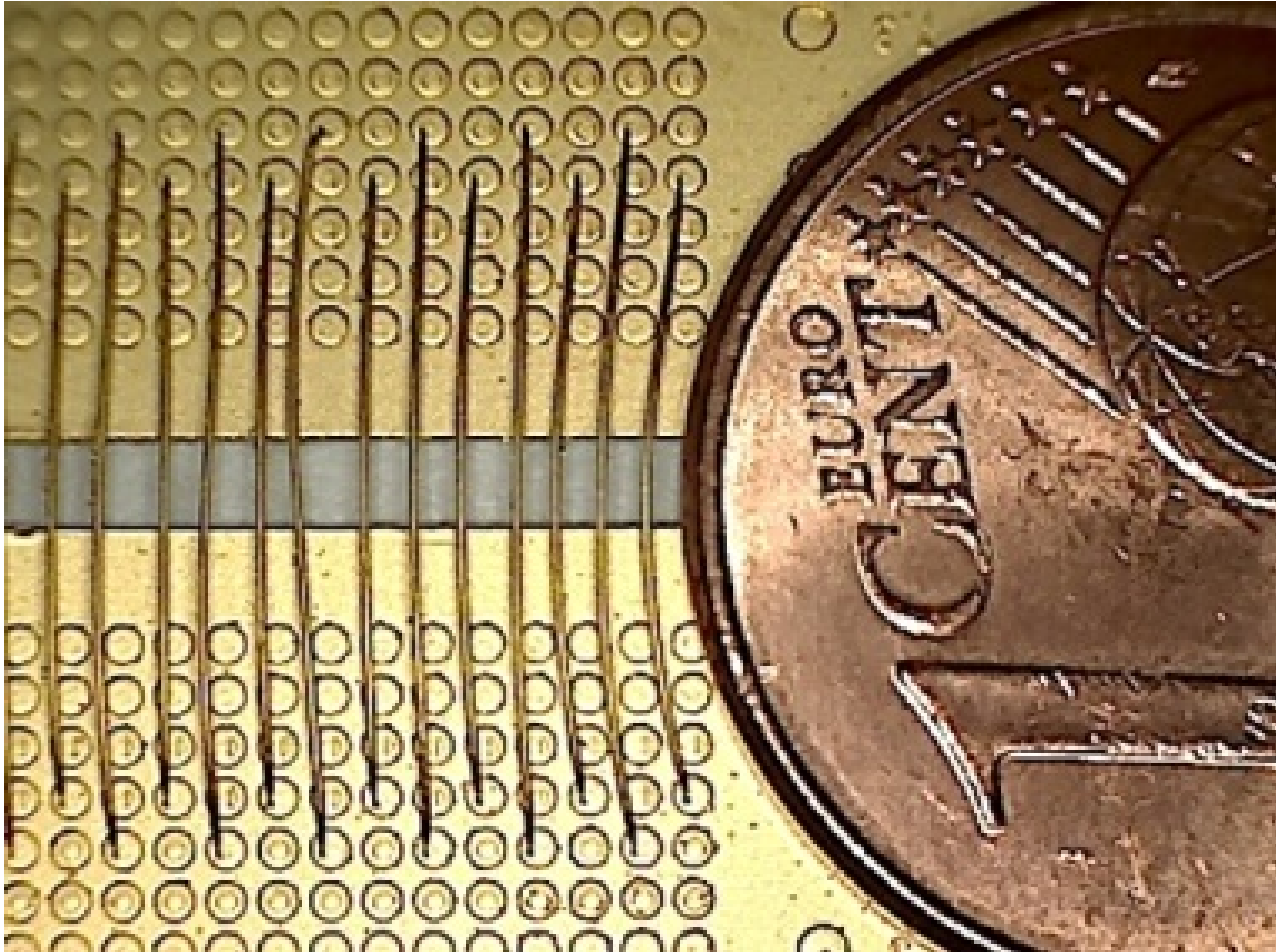

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Bridge, initial test set up

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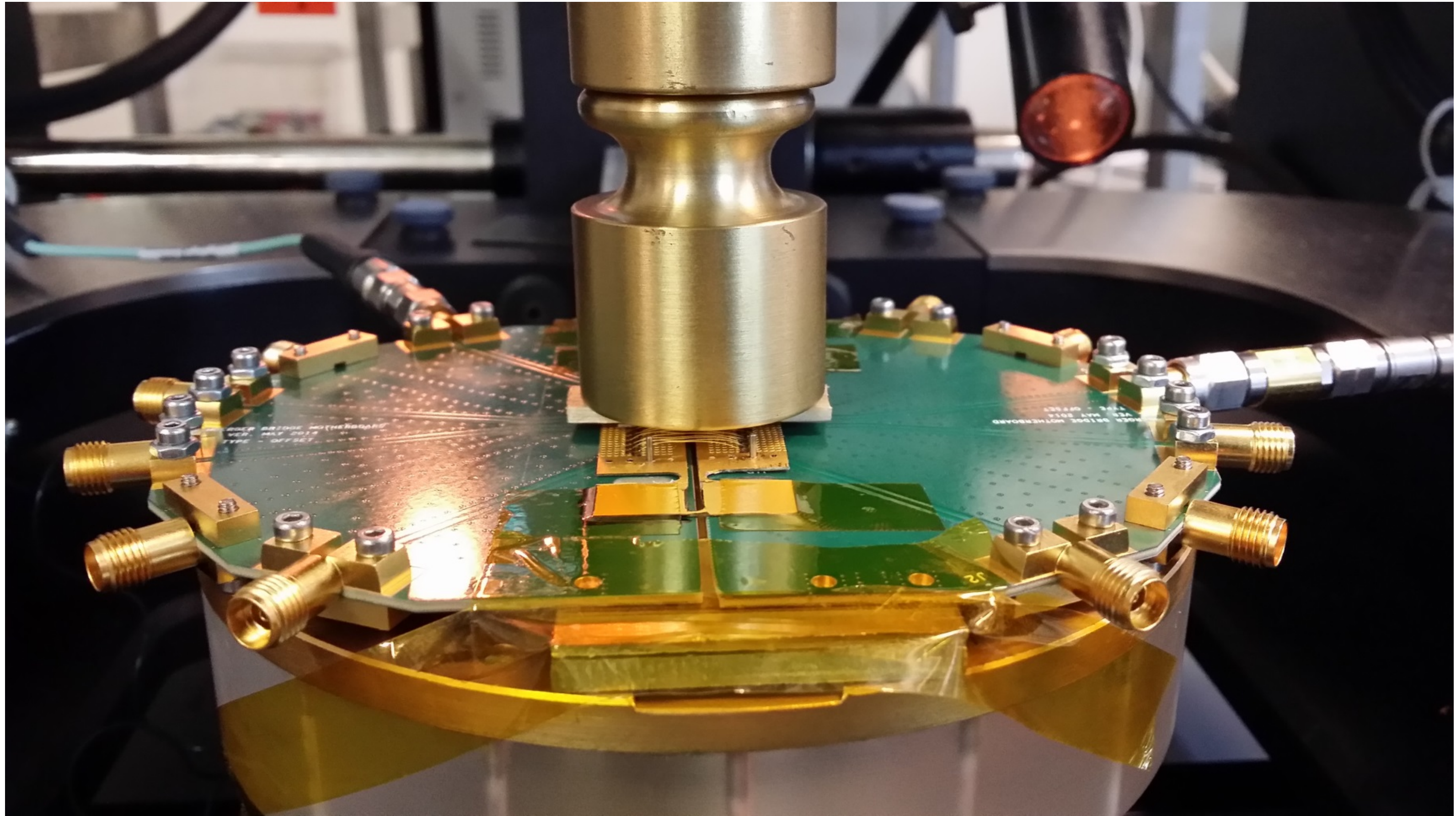

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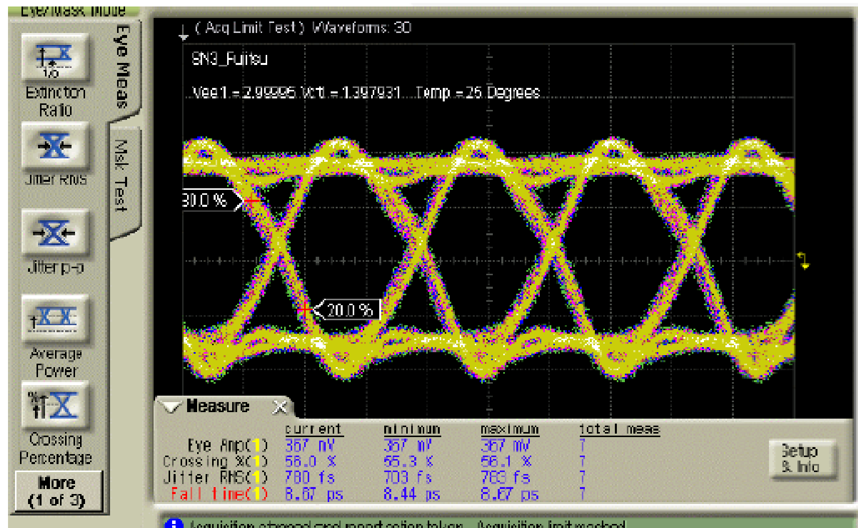
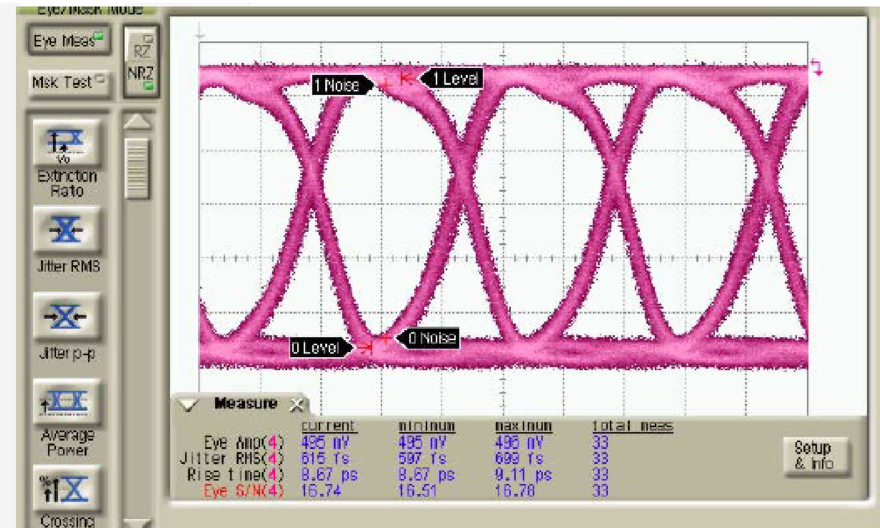
µCoax Improves Performance of Digital ICs Rosenberger

- 40 Gbs data transfer test
  - Eye is more open; pulses more squared
  - Performance is *superior* to costly custom package



Digital IC in custom LTCC package

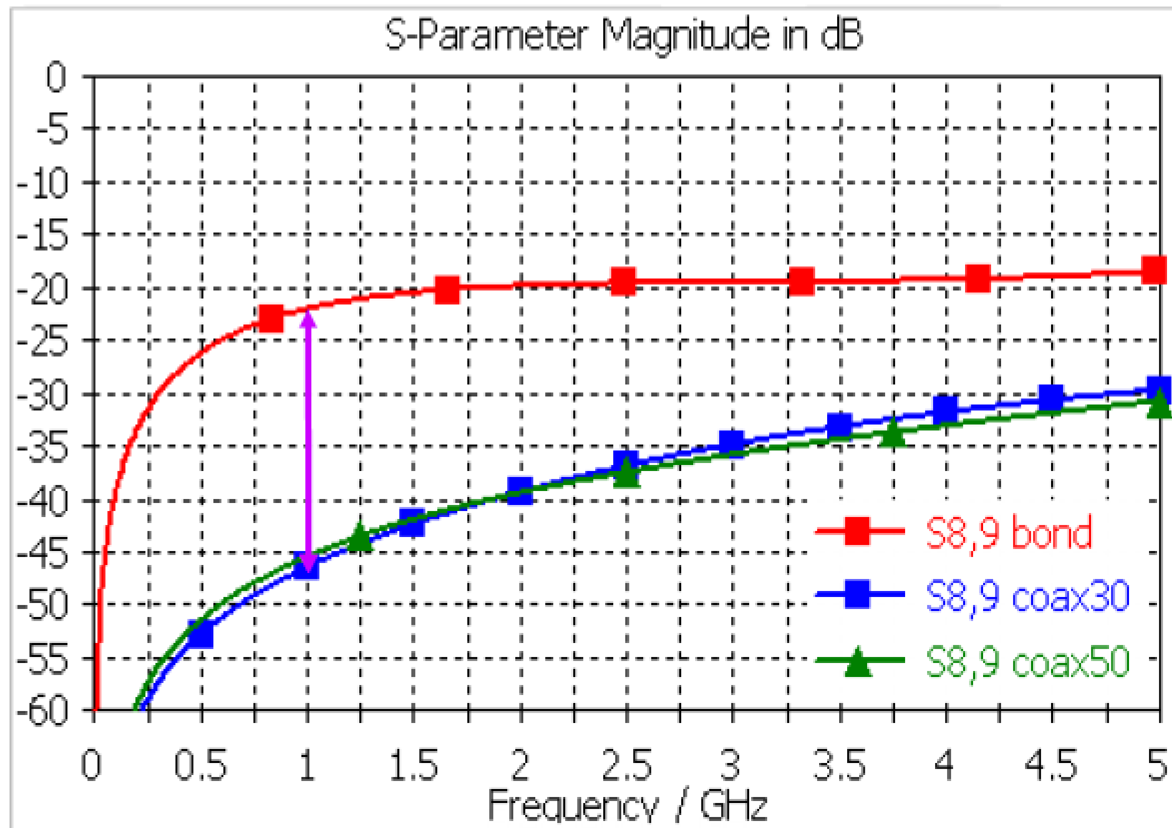


Digital IC in microCoax QFN package

Reduced I-O Cross-talk in BGA-packaged FPGA

Rosenberger

- Cross-talk improved by >25 dB
- Shielding is more important than perfect match
  - 50 Ω vs 30 Ω coaxes produce nearly identical results



Simulation results

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Reduced Simultaneous Switching Noise

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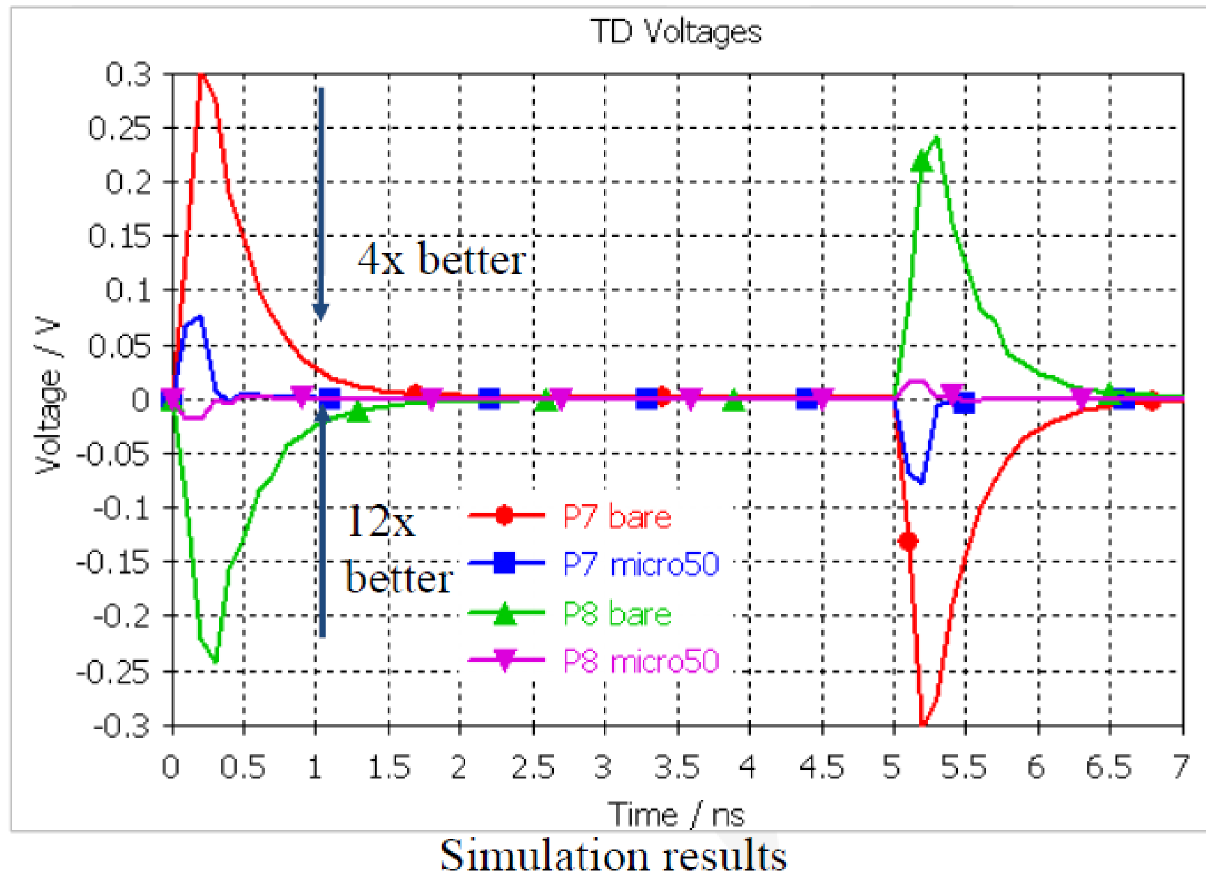
- 1 V input on Aggressors induces spike on Victim
- Significant reduction of induced voltage with µCoax
  - 12x improvement at chip pad and 4x better at ball!
  - 7x improvement of settling time



Simulation results

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Thank you!