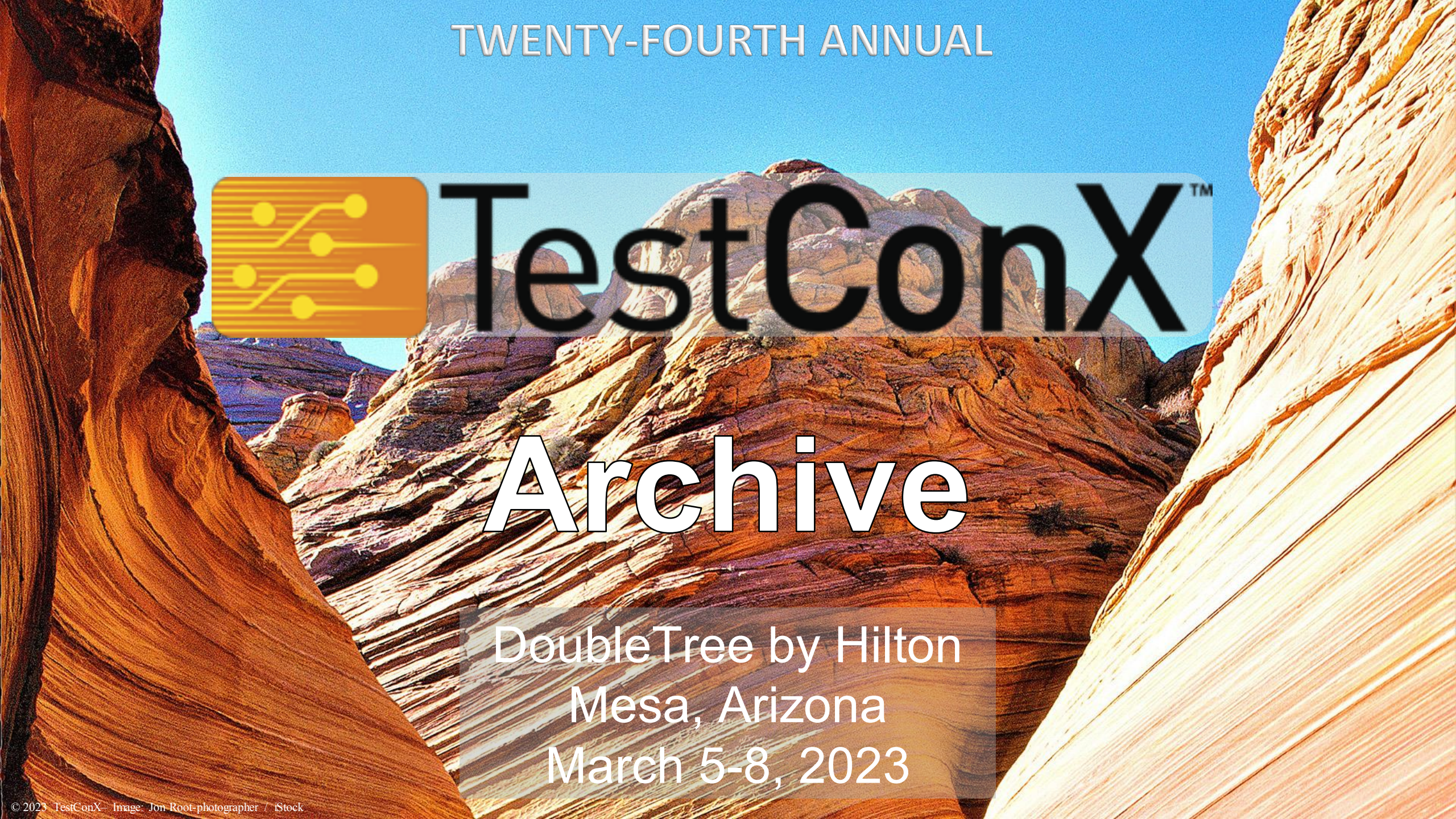

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A Treatise on RF Probes

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Probe Test Solutions Ltd. (PTSL)

TestConX™

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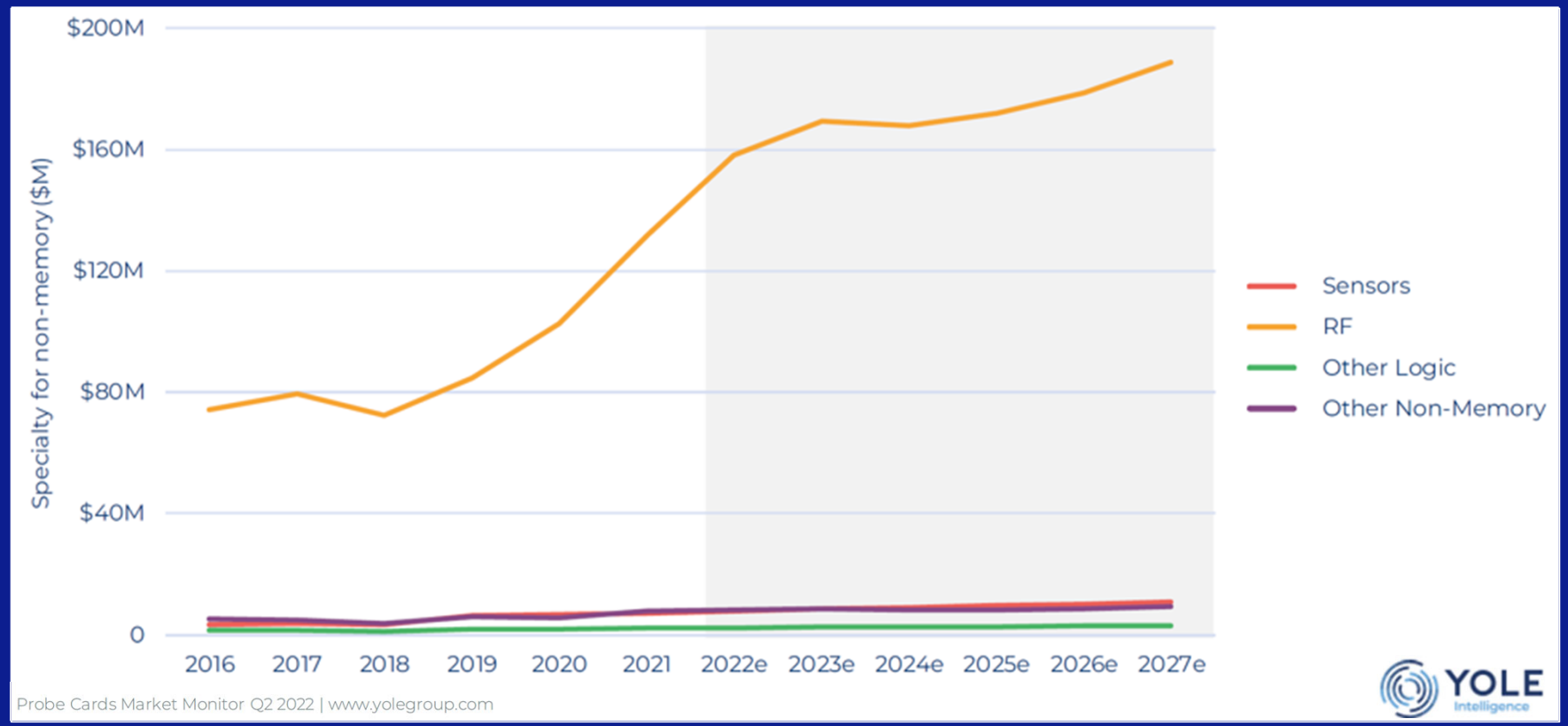
Overview

- The RF wafer probe market has a variety of solutions and doesn't lend itself to a single one-size-fits-all probe technology
- My goal is to layout the different solutions in the market that exist today as well as show where gaps appear to exist
- PTSL is starting to design RF wafer probe solutions, so it is an interesting discussion to see where current paradigms may be lacking

Market Growth – Specialty RF Probecards



An Overview of RF Probing

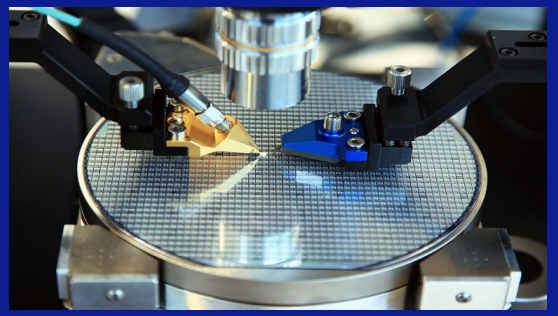
RF wafer probing is more important than ever due to several trends:

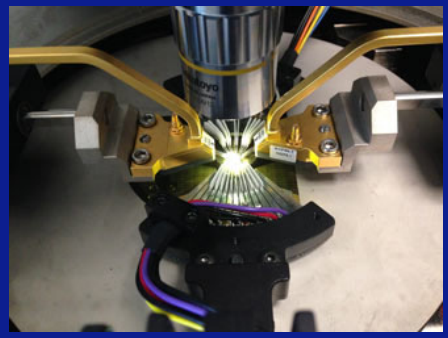
- 5G and 6G cellular
- Antenna in Package (AIP) due to higher frequencies
- Increased multi-chip modules, especially in the cellular market

Unlike traditional high-density probing, RF probe solutions vary significantly depending on application. Is important to understand the limitations and strengths of various probe solutions at a system level.

In this presentation I will layout the map of what we can do today, where we want to go in the future

RF Wafer Probing Has Always Been Needed





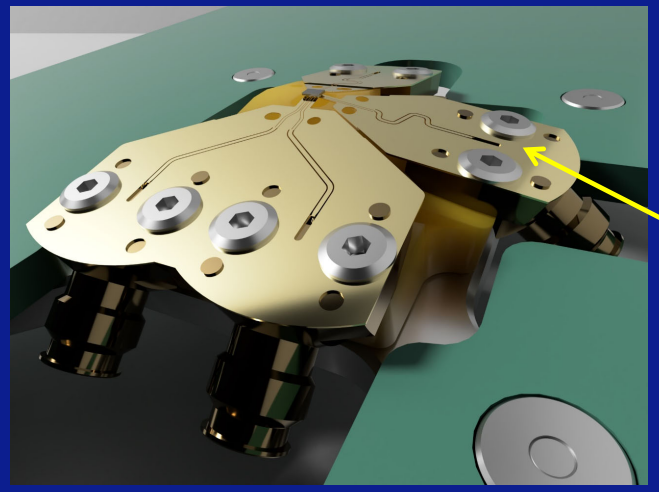
- The most basic RF probing method is a simple single-channel wafer probe. This can be combined with other low performance probes to power up a device and test individual chips.
- While this method is quick and flexible, this is typically a prototype tool and rarely used in production except on the simplest or lowest volume ICs
- Due to their simplicity, these types of probes can achieve the highest performance on the market, including some waveguides that are good into the terahertz range

RF ATE Market Space

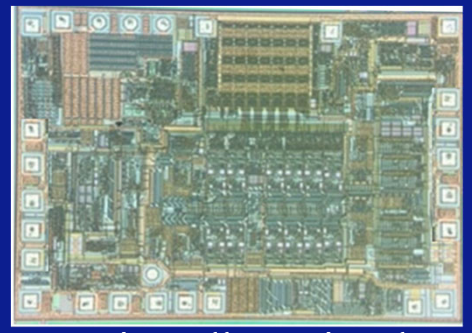
Partial-site probes are great for engineering, but bad for high volume manufacturing

Periphery Probing

- The next step is towards high volume manufacturing is done with periphery pad probing
- These are application specific solutions that are laid out in a single routing layer structure



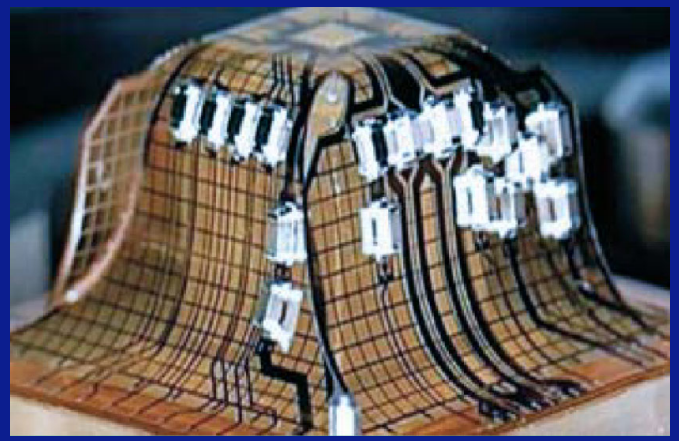
Rf signals are routed away from probe using a coplanar waveguide trace



Requires all RF signals to be located on perimeter of die

Periphery Probing

- Periphery probes sometimes go straight to coax a connector without touching the PCB, and sometimes they land on the PCB
- RF probing channels often want circuitry after coming off the chip. Examples of typical RF probing circuitry:
  - Impedance matching
  - BALUNs (Single ended to differential conversion)
  - Splitters
  - Filters
  - Switches
- Switches are very useful as RF channel count increases for resource sharing on testers
- Circuits can be built either directly on the CPW trace structure or on the probe card itself



Picture from High Speed Digital: How to Optimize a Probe Card for PAM4 Signaling to a non-50 Ω device

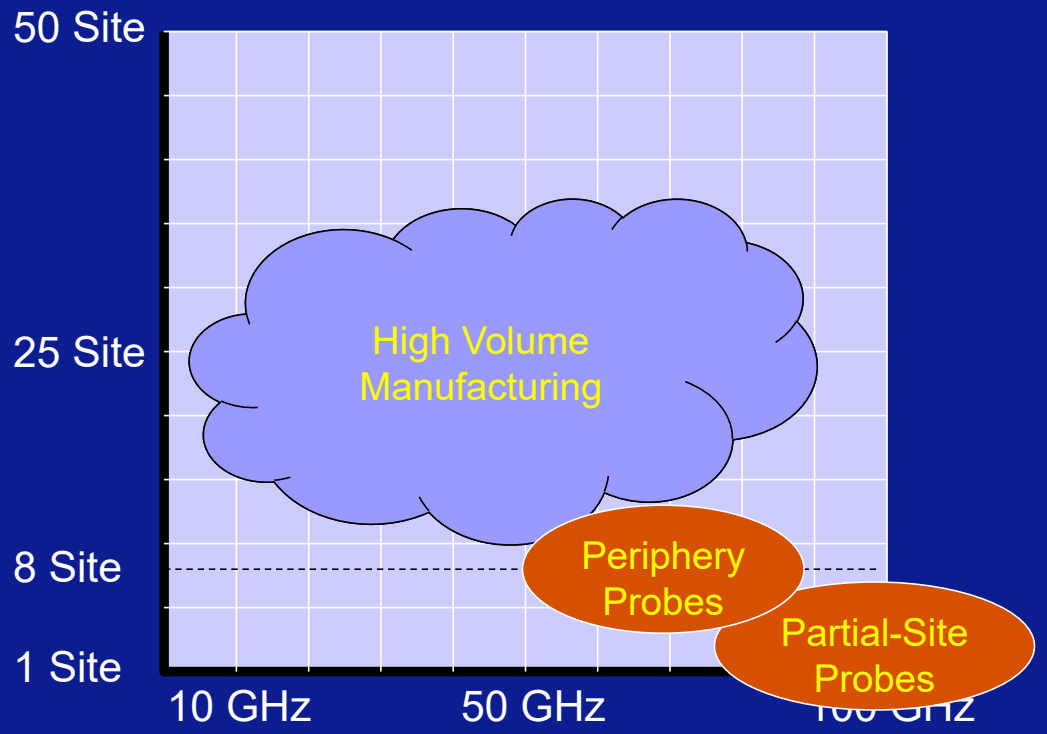
Periphery Probing

- Periphery probing is the current dominate product for RF IC probing at volume

Strengths:
- Mature and well characterized technology
- High performance > 80 GHz

Weaknesses:
- Poor scalability; single diagonal DUT / site arrangement testing only
- Periphery probing only for RF signals
- Need alternate probing solution for array pad patterns

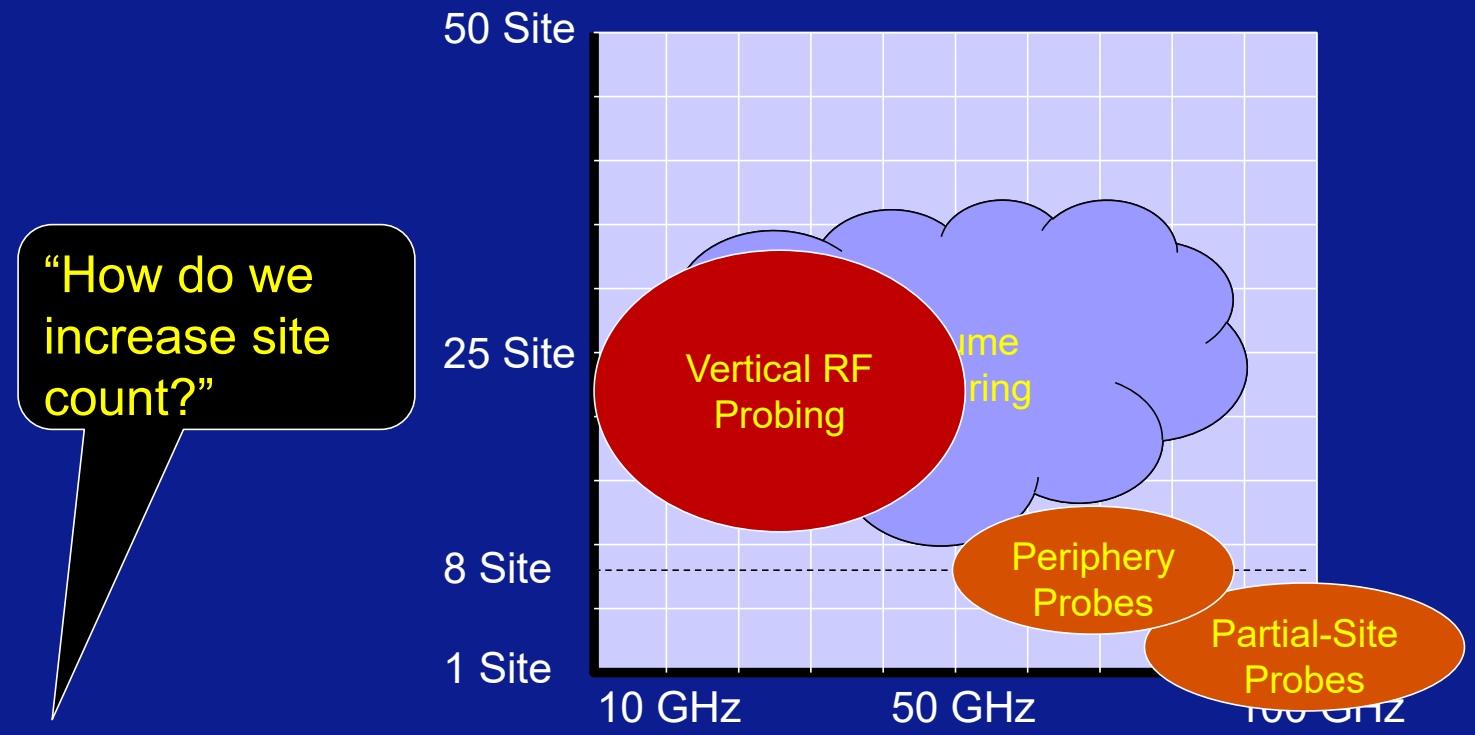
RF ATE Market Space



Periphery Probes are the primary high volume manufacturing solution today

… but they are not an ideal solution

RF ATE Market Space



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Vertical Probing

- Is it possible to make vertical probing work for RF?
- What are the challenges of high-speed probing?
- ~~Is it possible to make a vertical probe short enough to work for RF?~~

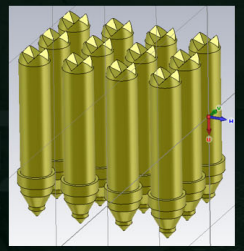
Probes, Pitch and Impedance

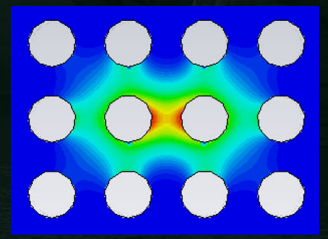
- Vertical probes can be selected to match the pinout & pitch of the device to dial in correct impedance
- This is strongly limited by device pinout and pitch
- Without a coaxial surround, RF noise maybe an issue for critical channels
- Works best for SERDES designs

Interposer Impedance Explained

1. $Impedance = \sqrt{\frac{Inductance}{Capacitance}}$
2. Inductance is a function of the pin diameter (inversely proportional)
3. Capacitance is a function of ground metal to signal metal AND dielectric material *(Combination of pitch, pin diameter, and dielectric material)*

Differential impedance in a pin field





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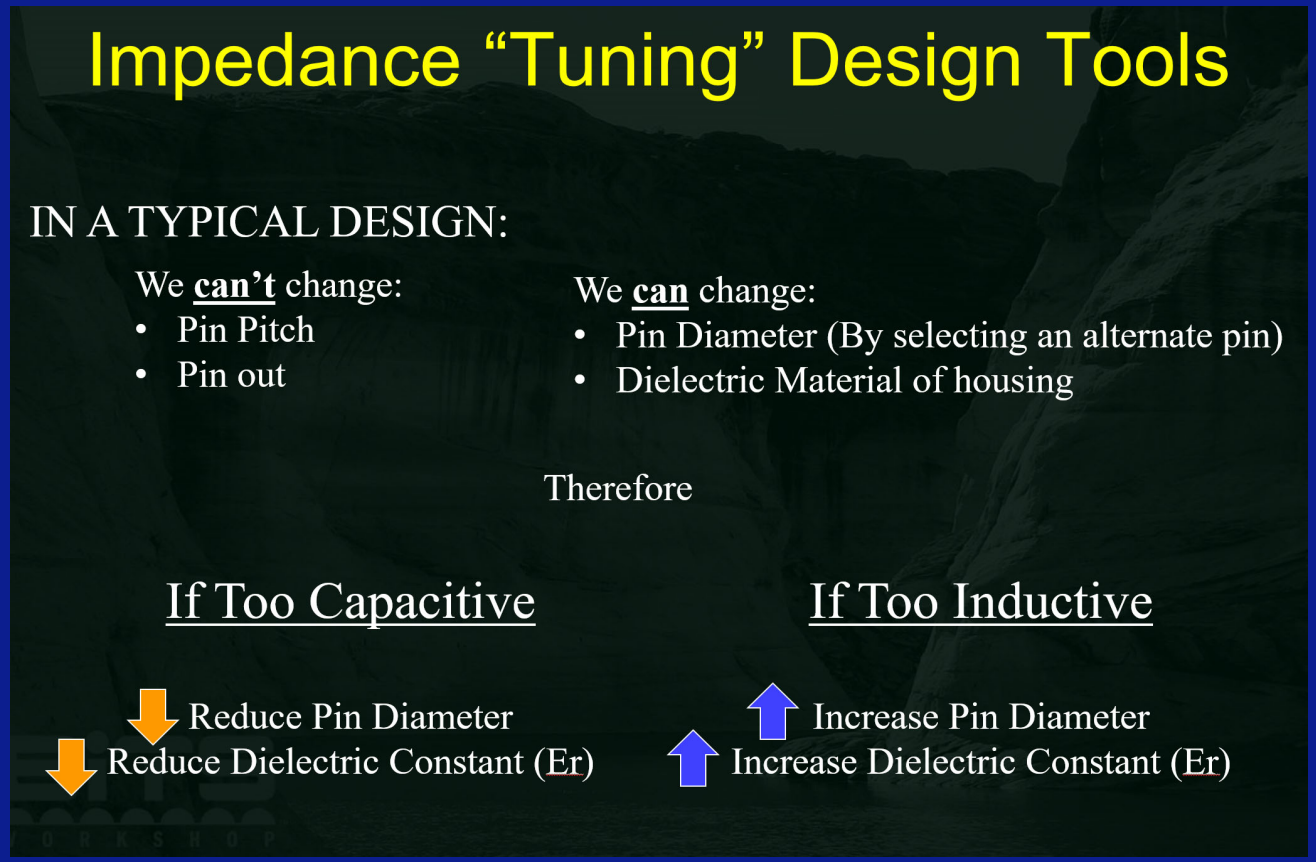
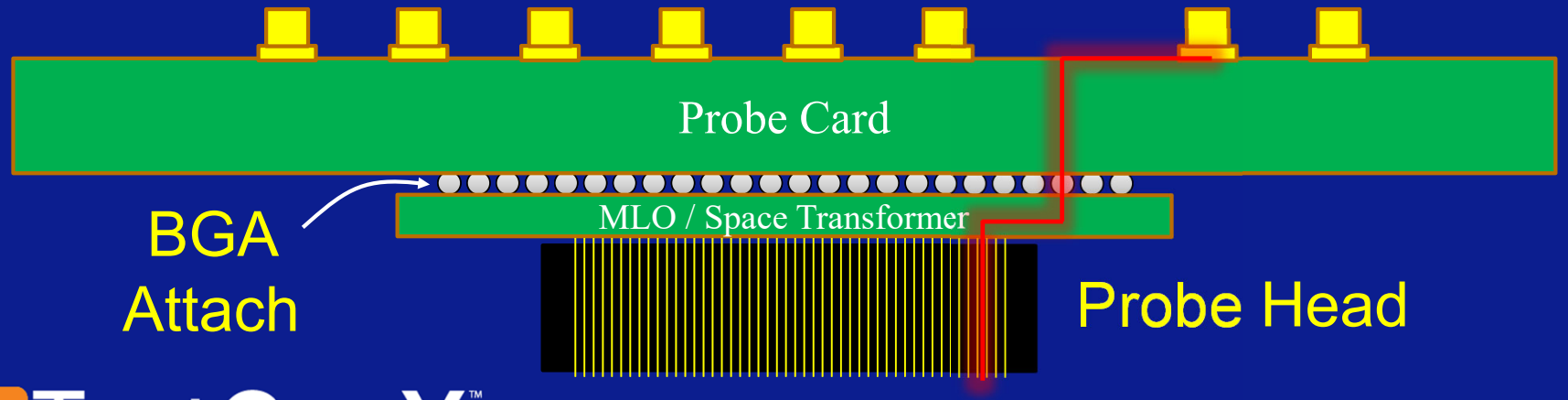
Impedance Tuning

- This should be done in conjunction with IC manufacturer to provide options for pinout modifications where needed
- Vertical pins are often the best option for impedance tuned probe-heads



Vertical Probing + MLOs and PCBs

- A big part of the RF vertical probe challenge is the part of the system above the probe head. With a vertical probe head the SI signal must route from the footprint of the probe head, through the MLO, through the BGA interconnect, and through the probe head.
- Half the RF challenge is routing the signal from probe head to connector



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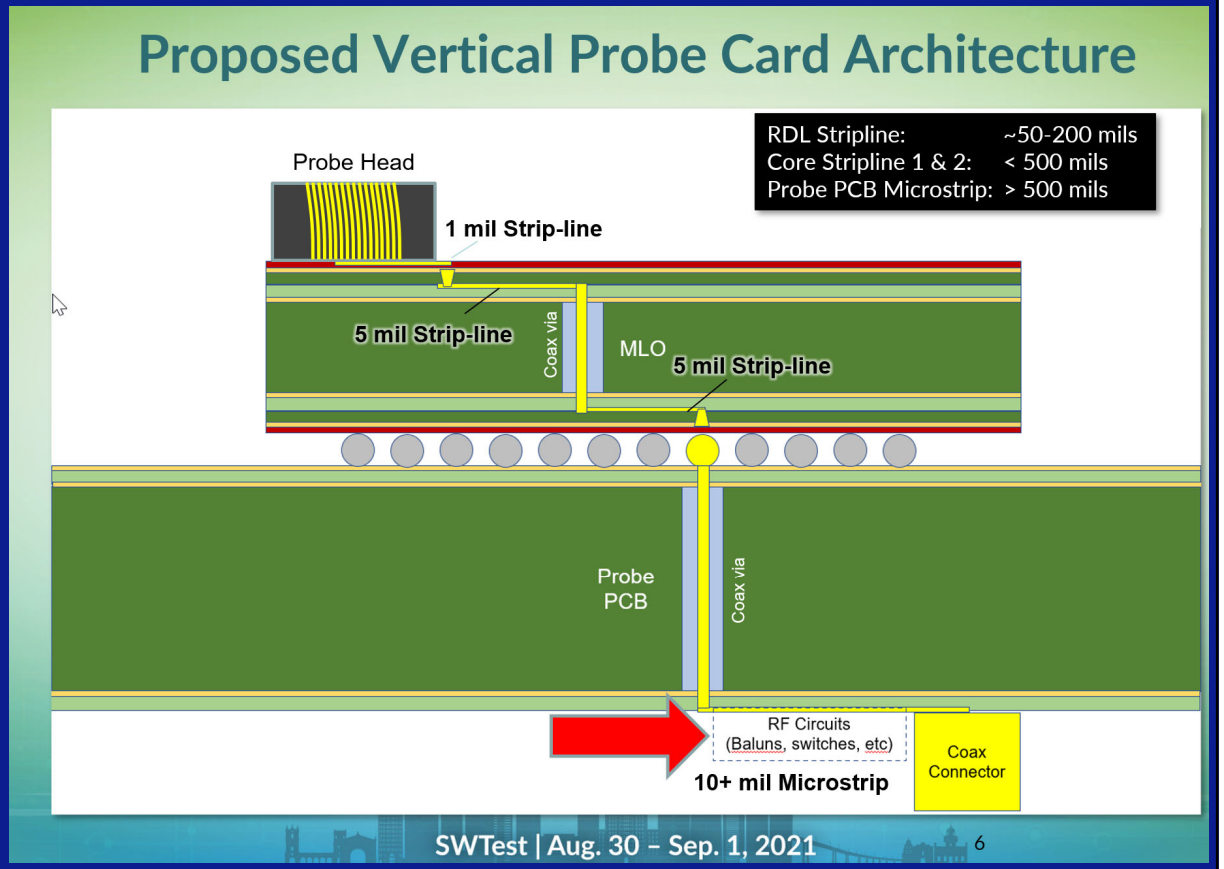
MLO & Probe Card Capabilities

- In "*A Vertical Probe Solution for High-Density RF*" presented at SW Test 2021, laid out a path to get to 50 GHz MLO and Probe Cards
- This provides a high site count solution with tester resource sharing



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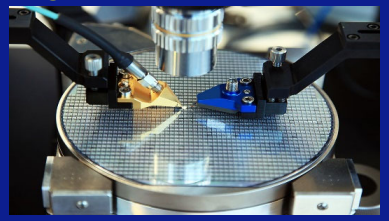
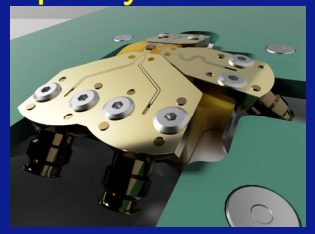
Technology Comparison

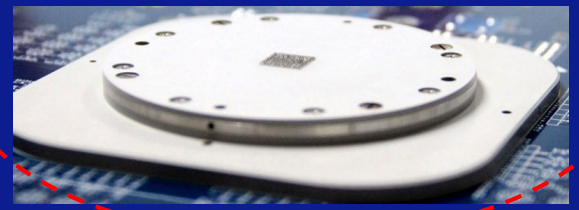
Single Channel Wafer Probe



Periphery Pad Probing



RF Vertical probing



This fills the gap in the market for high-site count testing

	Per Resource Probe	Periphery Probing	RF Vertical Probing
Frequency	125+ GHz	Up to 90 Ghz	Up to 50 GHz
Parallelism	1 site	1-8 sites	50+ sites
Cost	$	$$	$$$$
Launcher	To Coax	To Coax, PCB, or circuit	To PCB or circuit

A Summary of the Challenges

- Need high speed vertical probe technologies
- Need impeccable RF design and manufacturing in space transformers and PCBs
- Need tester resource sharing on the probe card
- Need the engineering skills to juggle everything above in a timely manner

This is not easy

Summary

The existing RF probe solutions provide high quality RF solutions but have significant limitations when moving to high volume manufacturing

5G and 6G RF wafer probing will have economies of scale that will reward the people who make this happen

The market is waiting for a reliable solutions to appear