Optimizing Scribe Street RF Parameter Measurements

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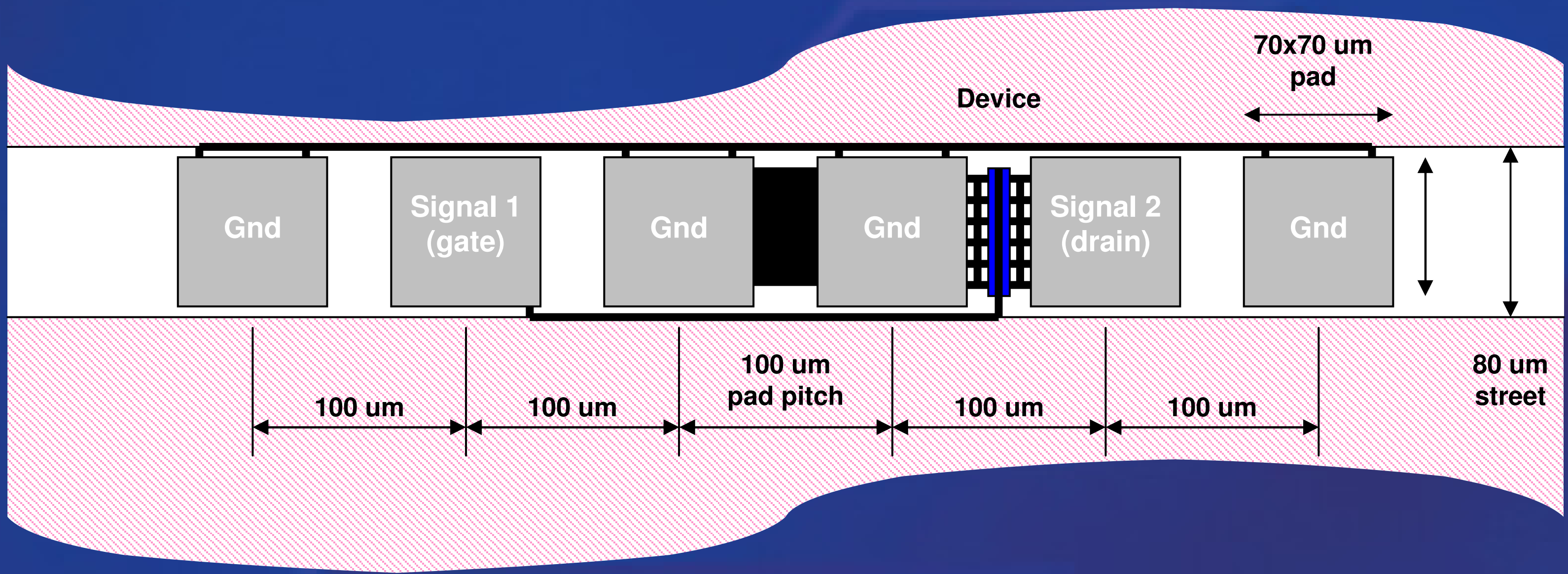
Goals and Challenges

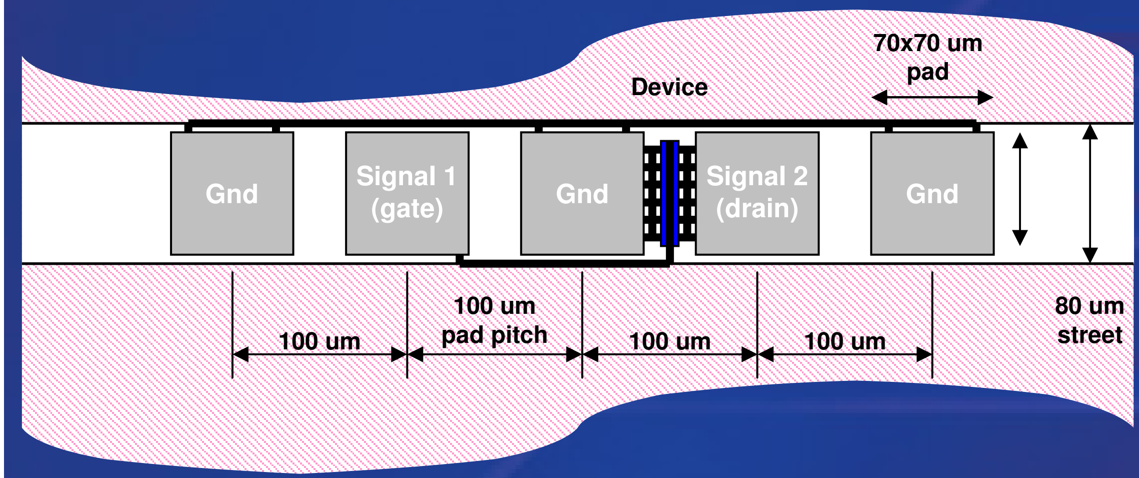
- Goals
  - Reduce the amount of Si real-estate space required for process control monitoring
  - Make accurate and repeatable Process Control Measurements
- Challenges
  - Devices located in device streets need to be in-line
  - This requires something different to conventional GSG probes for high frequency measurements
  - Isolation between signals can be significant
  - Calibration requires different techniques

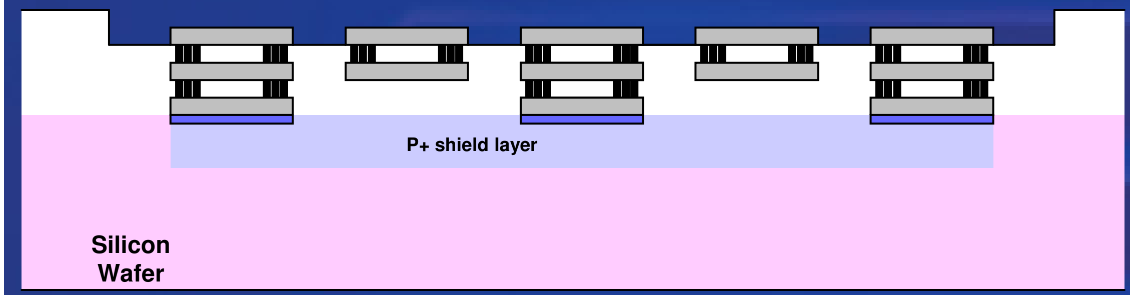
Typical scribe street test pattern



- J.L. Carbonero, et. al., "On-Wafer High-Frequency Measurement Improvements," *Proc. IEEE ICMTS*, pp. 168-173, March 1994.
- T.G. Ivanov, M.S. Carroll, "In-line Ground-Signal-Ground (GSG) RF Tester" US Patent #6,194,739, Lucent Technologies, issued Feb. 27th, 2001. Contact John Hurley, jphurley@lucent.com, Tel: +1(908) 582-2532.

Recommended Minimum size GSGSG Configuration





- GSGSG-100 probe configuration examples:
  - I50-D-GSGSG-100
  - Pyramid Probe Card
- Alternative design choices
  - 150 um pitch
    - Wider pad, street, and/or passivation window is less demanding on probing system
  - Shielding options…

Shielding Options

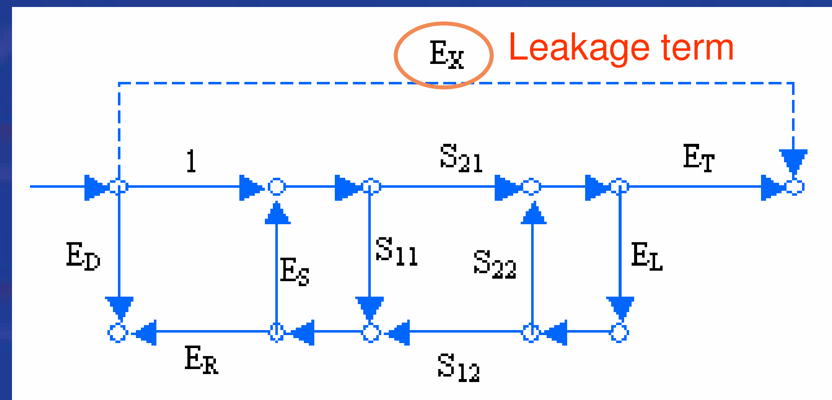
goal: reduce signal coupling to lossy substrate

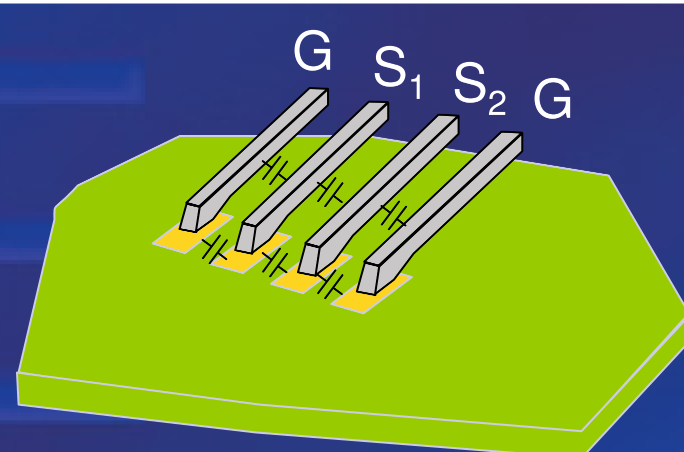
Process capabilities dictate choices:

1. Signal pads and lines in metal level(s) furthest from substrate (always!)
2. P+ under signal pads and lines
3. 1st level metal under signal pads and lines
   Possibly subject to Lucent patent
4. Shallow/Deep trench isolation under signal pads
5. Depleted junction isolation under signal pads
   S. Lam, et.al., "High-Isolation Bonding Pad with Depletion-Insulation Structure for RF/Microwave Integrated Circuits on Bulk Silicon CMOS," *Proc. 2002 IEEE IMS*, pp. 677-680, June 2002.
6. This topic is under investigation, look for future developments

Probe Cross Talk Limitations

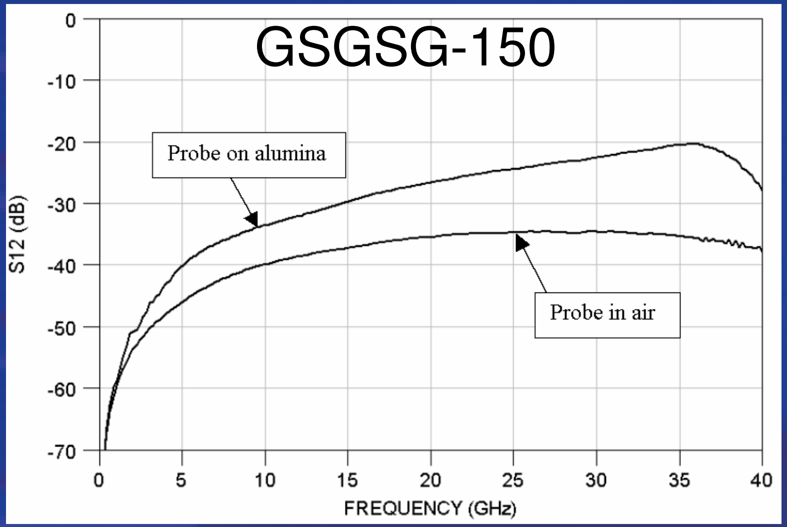
- VNA calibration error model doesn't support fixture crosstalk
- Crosstalk is inherently present in probing fixtures and pads
- When does crosstalk limit measurement accuracy?

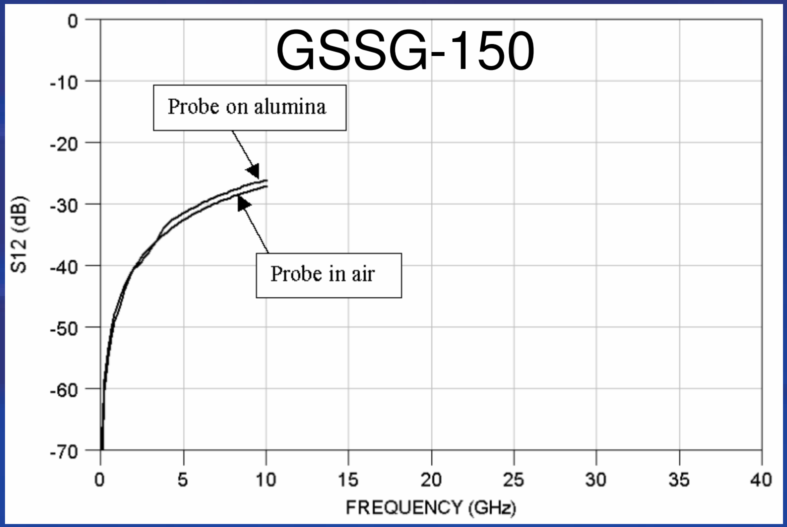




Conventional dual-signal probe limitations

- Uncorrectable crosstalk
- GSGSG
  - OK for many applications up to 15 GHz
  - Crosstalk limitations
    - Applications above 15 GHz
    - Very sensitive applications
- GSSG
  - OK for some applications only up to about 10 GHz
  - Crosstalk limitations
    - Applications above ~10 GHz
    - Sensitive applications
- Need to do better!





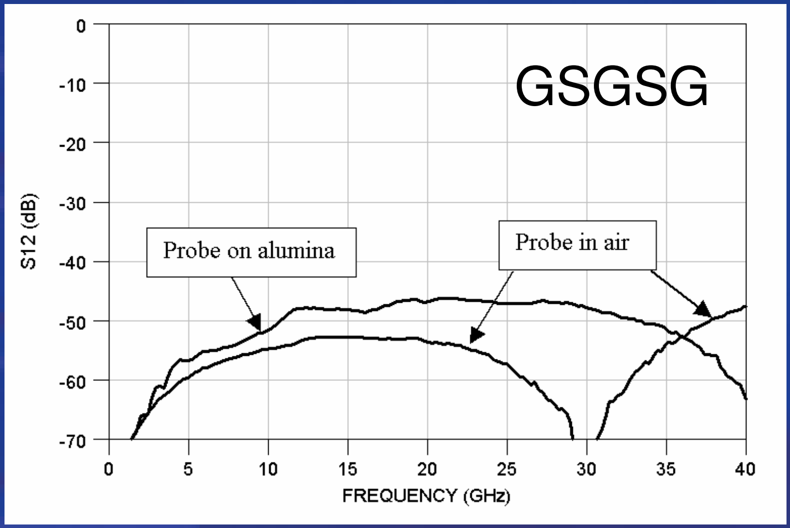
CASCADE MICROTECH

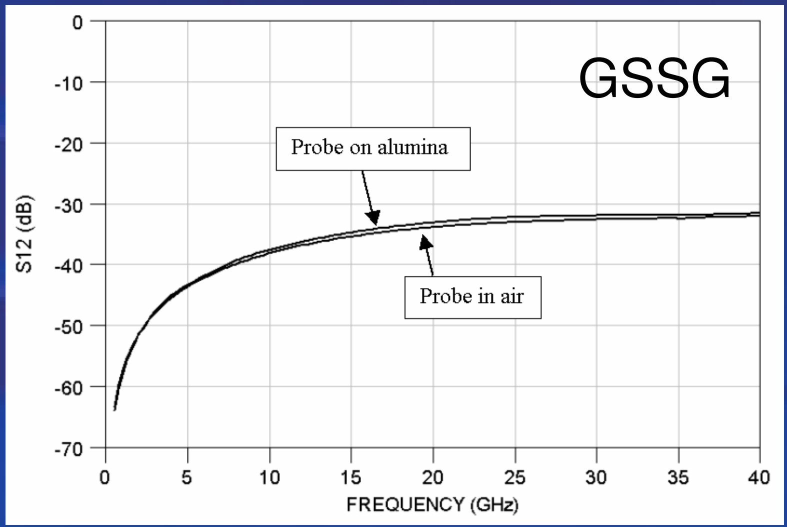
Dual-signal Infinity Probe™

- Photo-lithographically defined thin-film membrane tip
  - Microstripline with ground shielding to the contacts
  - Tightly confined fringing fields
  - Small contact area allowing minimum 50x50 um pads
  - Low and stable contact resistance on planar Al pads
  - GSGSG and GSSG configurations available to 67 GHz

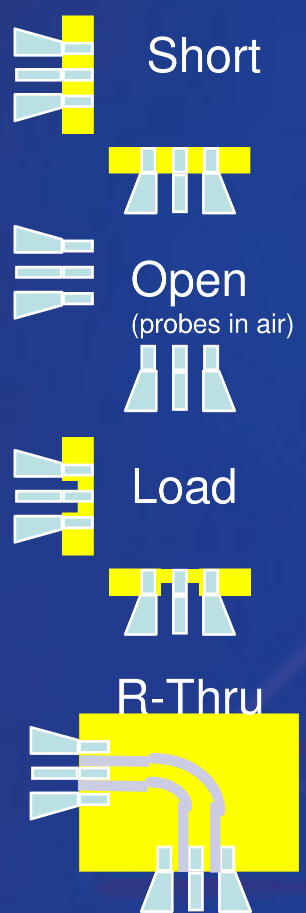
Dual-signal probe/pad crosstalk

- Infinity probe performance
  - State-of-the-art
- GSGSG
  - Isolation > 40 dB to 40 GHz
- GSSG
  - Isolation > 30 dB to 40 GHz
- Isolation in application limited by DUT pad configuration
- Is 30 or 40 dB isolation enough for ‘good’ measurement results?



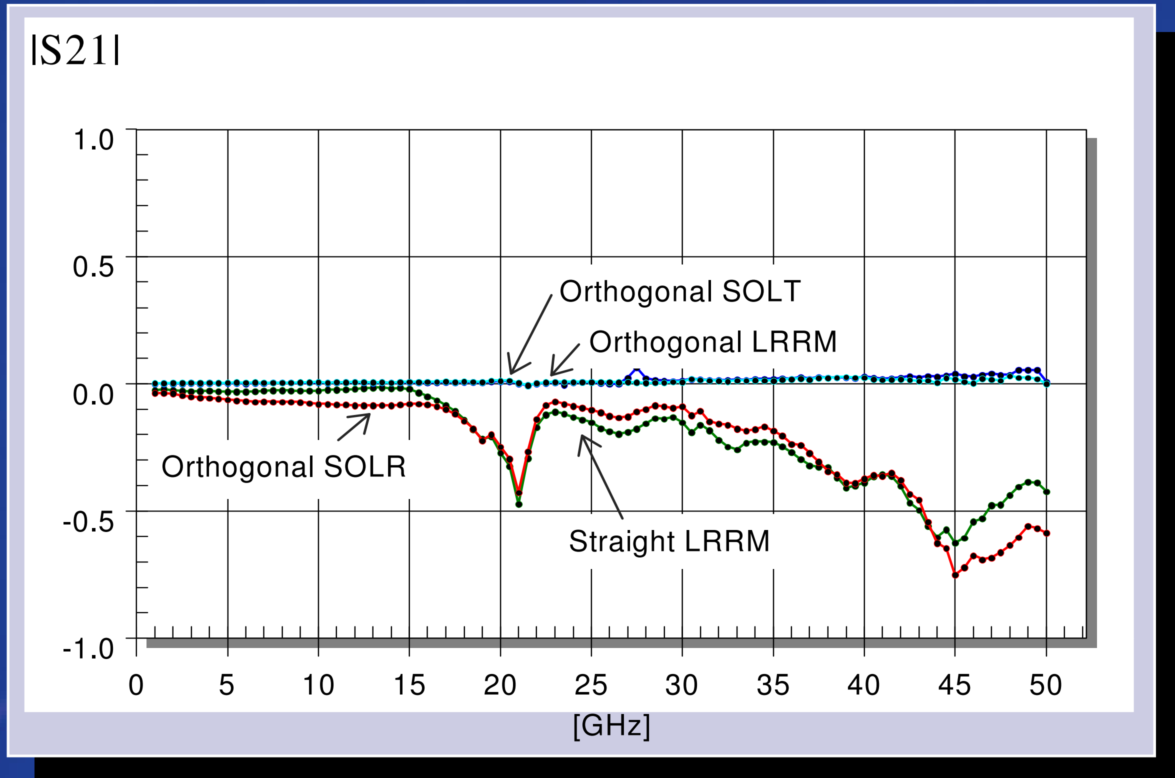


SOLR calibration



- Short-Open-Load-Reciprocal Calibration
  - Like SOLT but with Unknown Thru standard
    - reciprocal thru $S_{12} = S_{21}$
    - tolerant to high loss or highly reactive insertion standard
  - convenient for use with probe cards
    - **fixed probe spacing would otherwise require custom standards**
  - not available on vector network analysers
    - **requires Cascade Microtech software (WinCal)**
  - still needs accurate models of calibration standards

SOLR Calibration



- Insertion loss measurements made of an orthogonal CPW thru' line using straight LRRM and orthogonal LRRM, SOLT and SOLR calibrations

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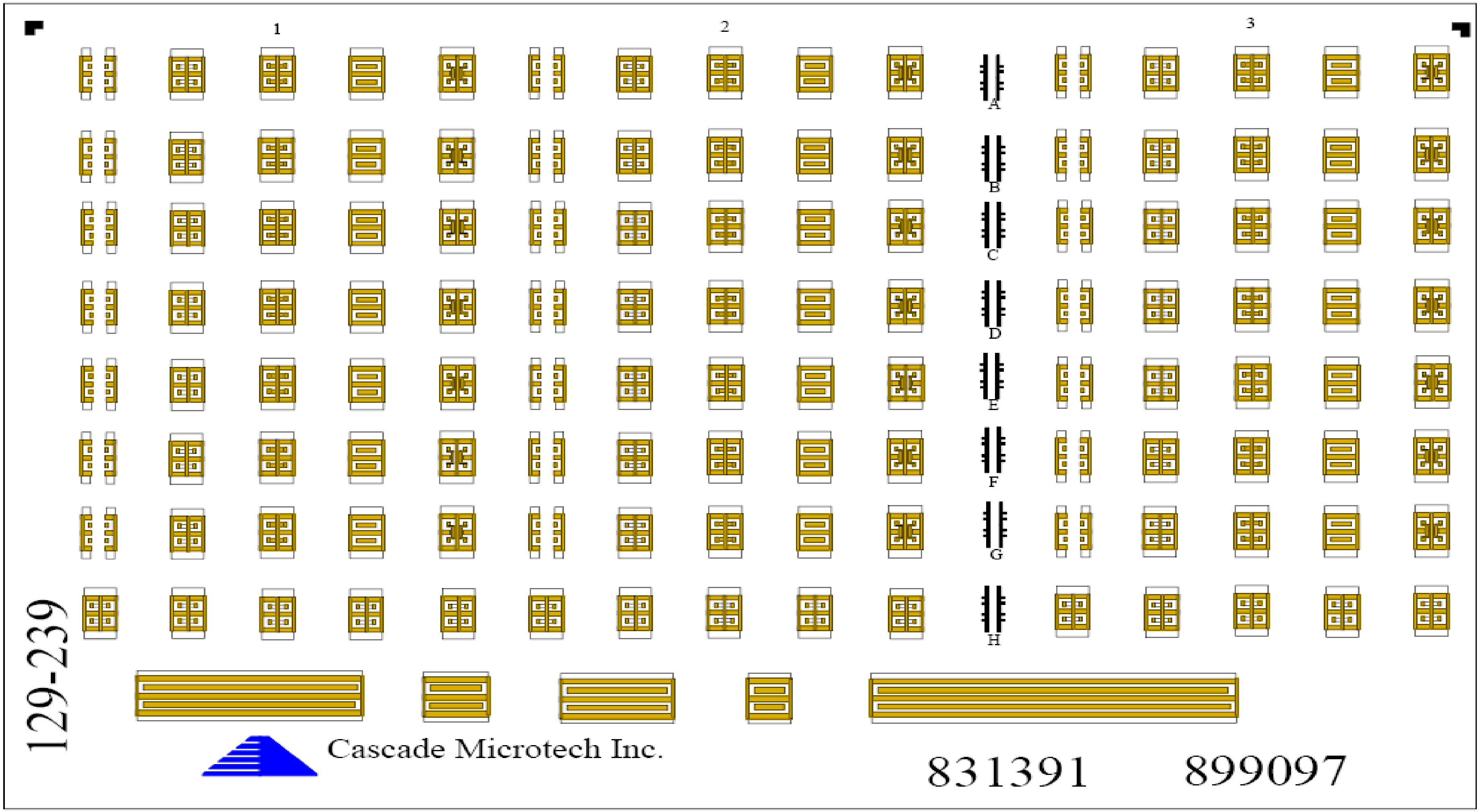
Dual Probe Calibration Standards

Impedance Standard Substrate

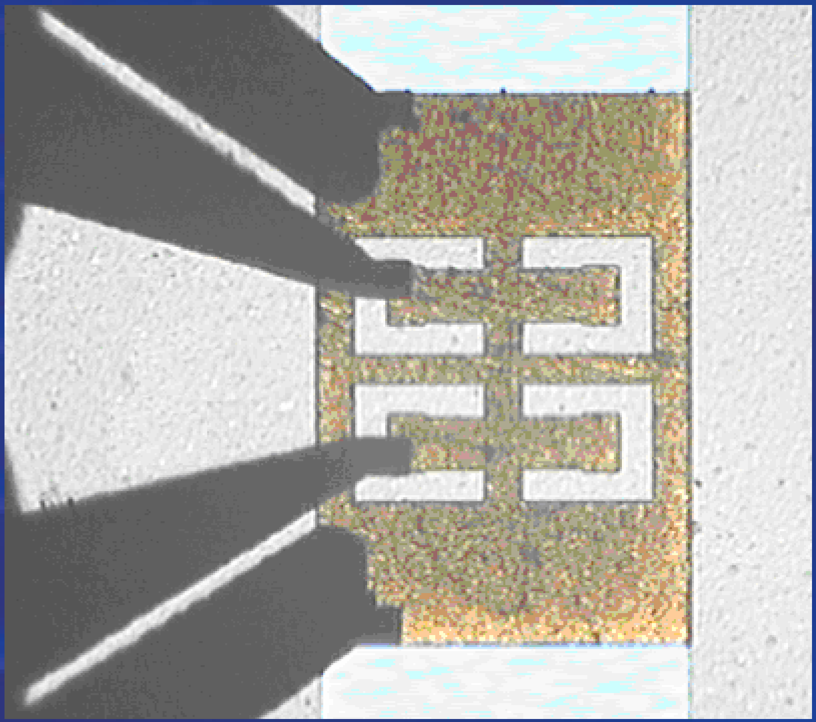
(**Pitch:** 100 µm – 125 µm, **Configuration:** GSGSG, GSGS, SGSG, SGS)

P/N: 129-239; **S/N:**



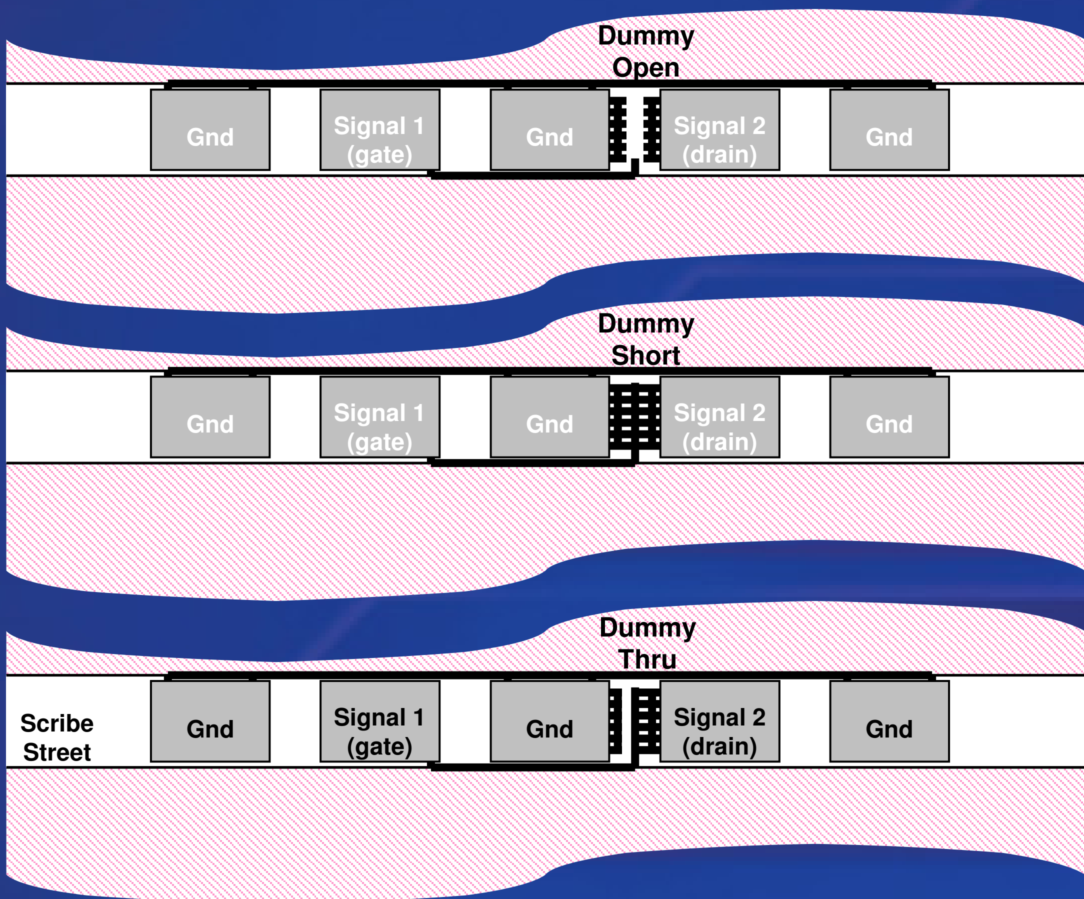
High-isolation standard design

- Improved isolation short standard
  - Design techniques reported at Fall 2003 ARFTG, “Optimized impedance standard substrate designs for dual and differential applications”
  - Electrostatic shield between signal pads
  - Optimized thru standards
    - Straight, cross, loop-back



Y-Z Pad Parasitic Removal Structures

goal: extract intrinsic device performance w/o pads

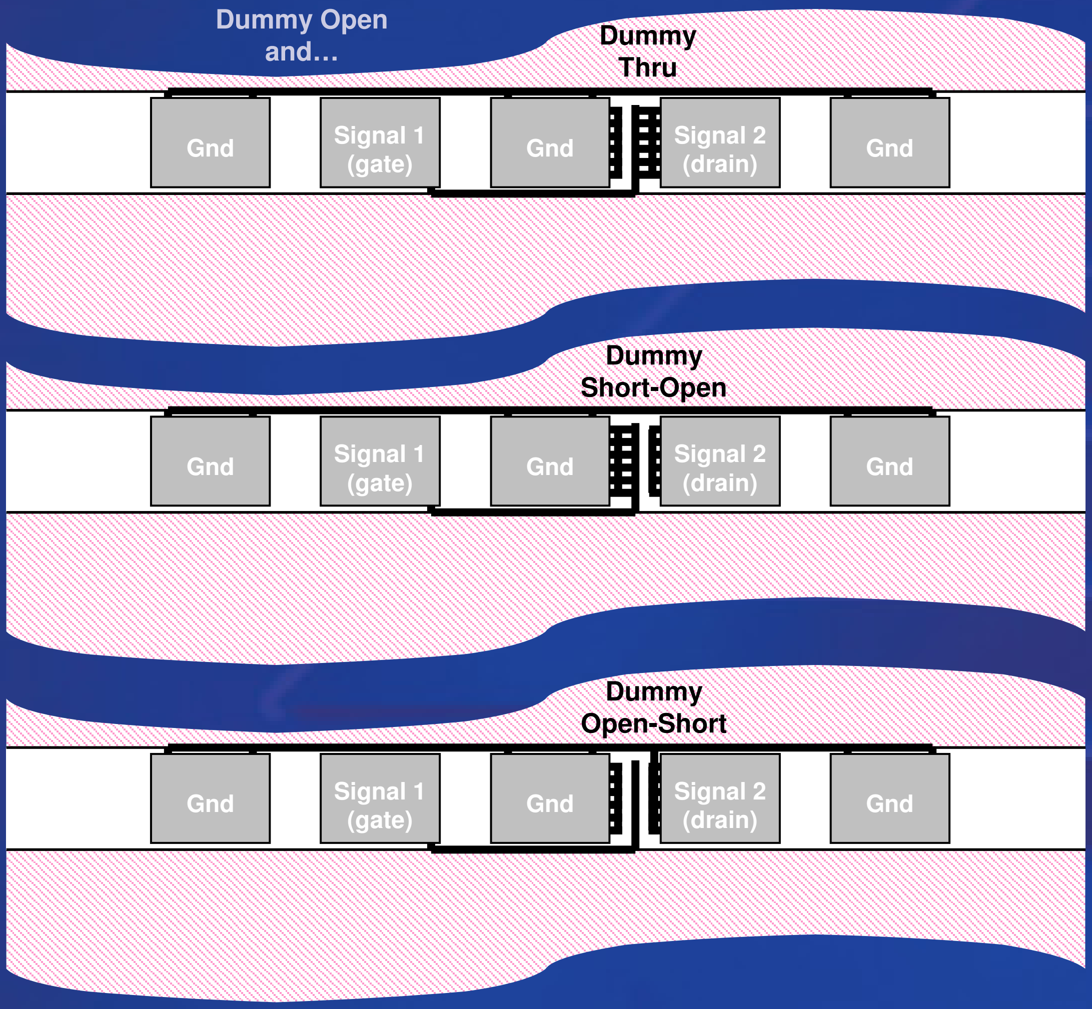


- Dummy Open circuit pads
  - For Y-parameter subtraction of shunt and crosstalk admittances
- Dummy Short circuit pads
  - For Z-parameter subtraction of series and common-ground impedances
- Dummy thru
  - For verification or better t-line extraction
- Otherwise identical to device test layout

Koolen, et al, "An improved de-embedding technique…," *Proc. BCTM*, pp. 188-191, Sept. 1991

3-Step Pad Parasitic Removal Structures

goal: extract intrinsic device with larger parasitics



- Dummy Open circuit pads
  - Same as Y-Z
- Thru structure
- Dummy Short-Open
- Dummy Open-Short
- H. Cho and D. Burk, "A Three-Step Method for the De-Embedding of High-Frequency S-Parameter Measurements," *IEEE Trans. on Electron Devices,* Vol. 38, No. 6, pp. 1371-5, June 1991.
- Vandamme *et al*, "Improved Three-Step De-embedding…," *Trans. ED*, April 2001 for corrections and enhancements

Conclusion

- The dual-signal Infinity Probe provides a significant advance in dual probe calibration accuracy
  - Superior isolation performance
    - Highest frequency GSSG and GSGSG
  - Low and stable contact resistance on Aluminum pads
- Dedicated dual-signal calibration standards
- Characterize in-line devices with confidence

"Infinity Just Got a Little Bigger"