FormFactor™

Production Test RF Calibration Methods for Probe Cards

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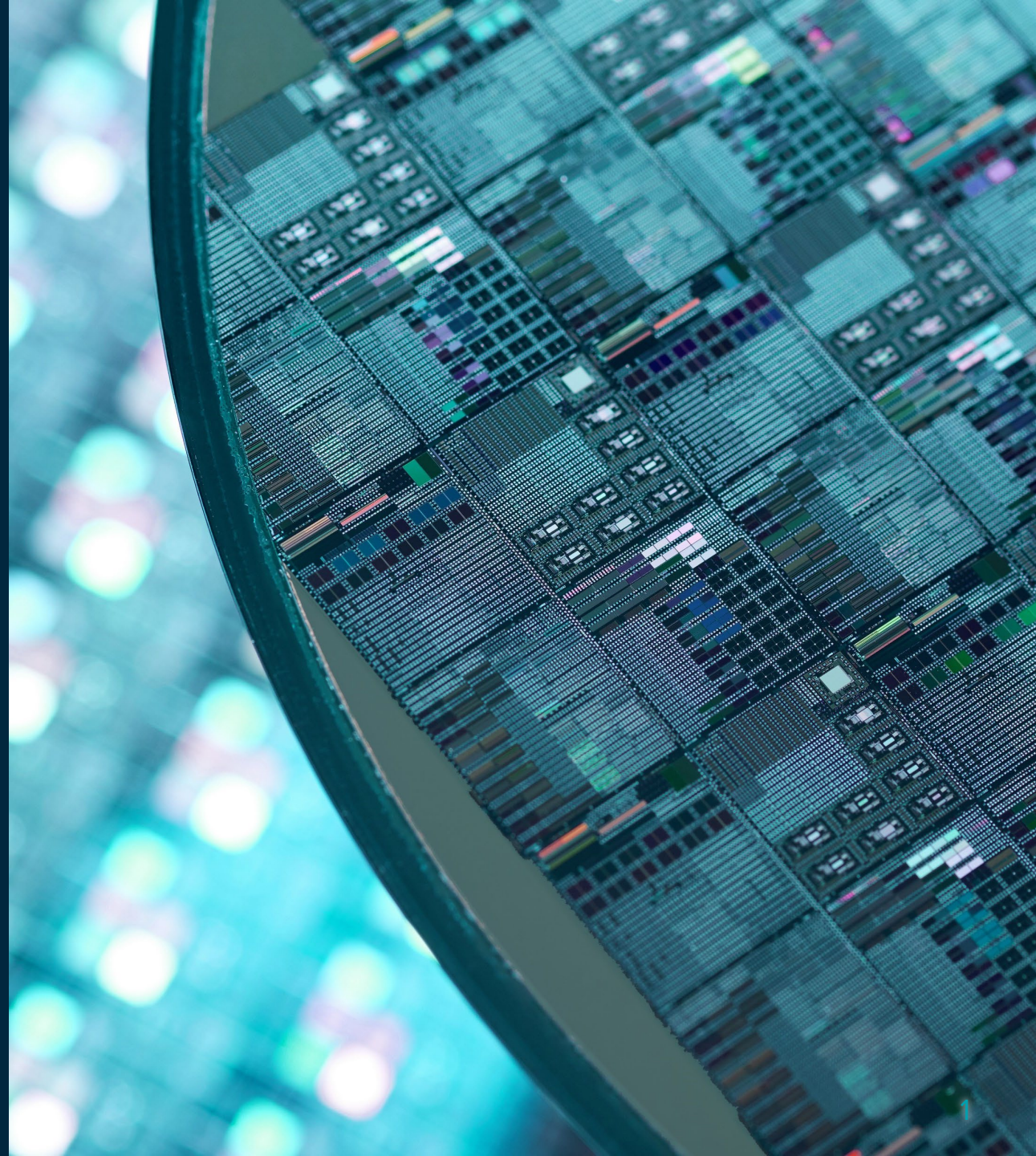
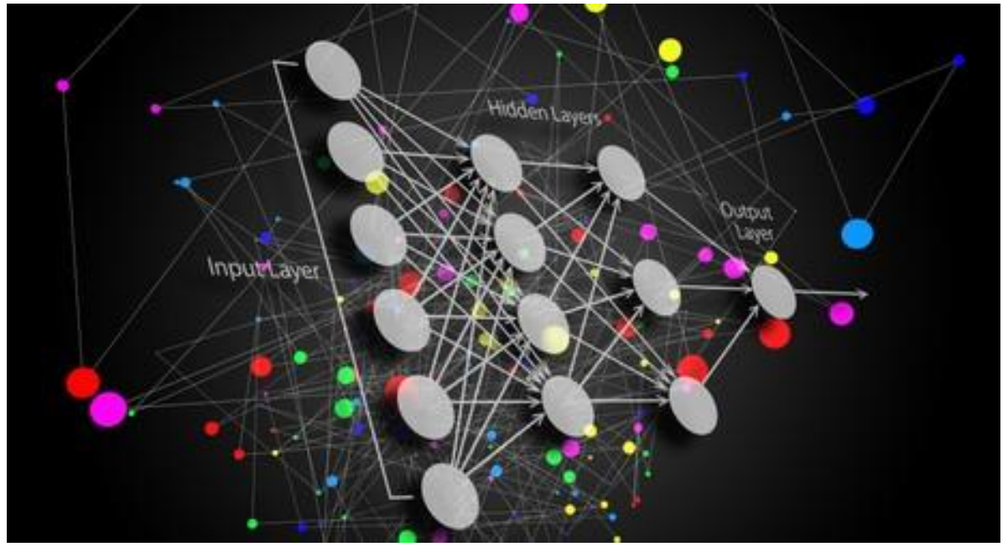


Overview

- Market Drivers
- Test Setup
- Comparison of Cal Methods
- DUT measurements
- Conclusion

Market Drivers

- The main drivers that are starting to emerge for data rates are coming from the growth in AI/NLP
  - Chat GPT, Bing AI
- The largest models today have more than a trillion parameters
  - For understanding, that is roughly the same number of synapses that are in a mouse
- In order for these complex models to operate, the data transfer speeds need to increase at the same rate as the models are increasing in size



What is driving increases in Data Rates?

ChatGPT fuels digital infrastructure boom

Jenny Wiggins
Infrastructure reporter

Updated Mar 7, 2023 – 3.48pm,
first published at 3.14pm

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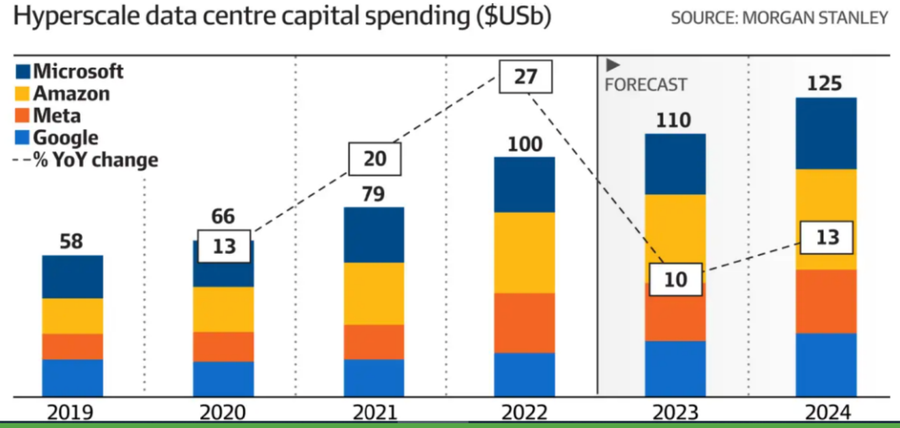
Artificial intelligence is fuelling a boom in data centres and fibre optic networks, says the chief investment officer of infrastructure specialist HRL Morrison & Co, which is positioning itself to take advantage of billions of dollars of spending on new technology such as ChatGPT.

The lifeblood of artificial intelligence is data, and companies that use it need to get data, shift it around, store it and compute it, said William Smales, who helps manage some $27 billion of infrastructure for New Zealand-founded investment group Morrison & Co.



Data center bandwidth growth accelerating

Source: Marvell estimates based on industry analyst forecasts

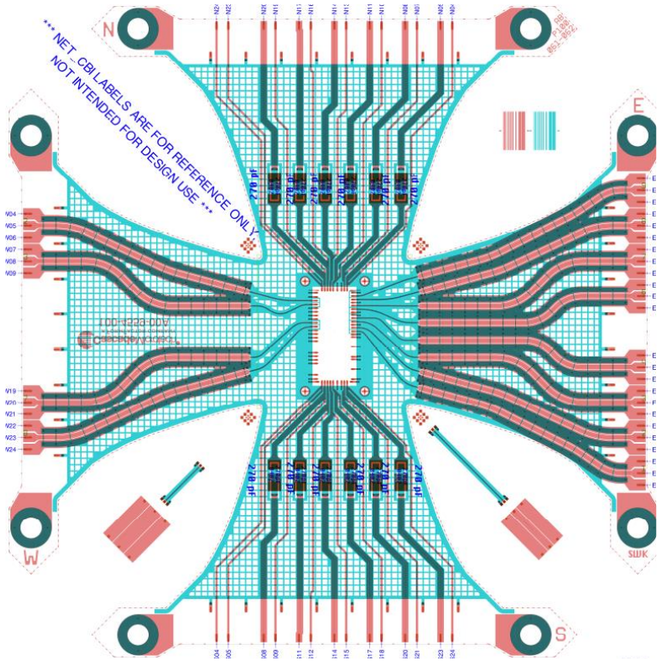
Wafer Test – Why differential measurements?

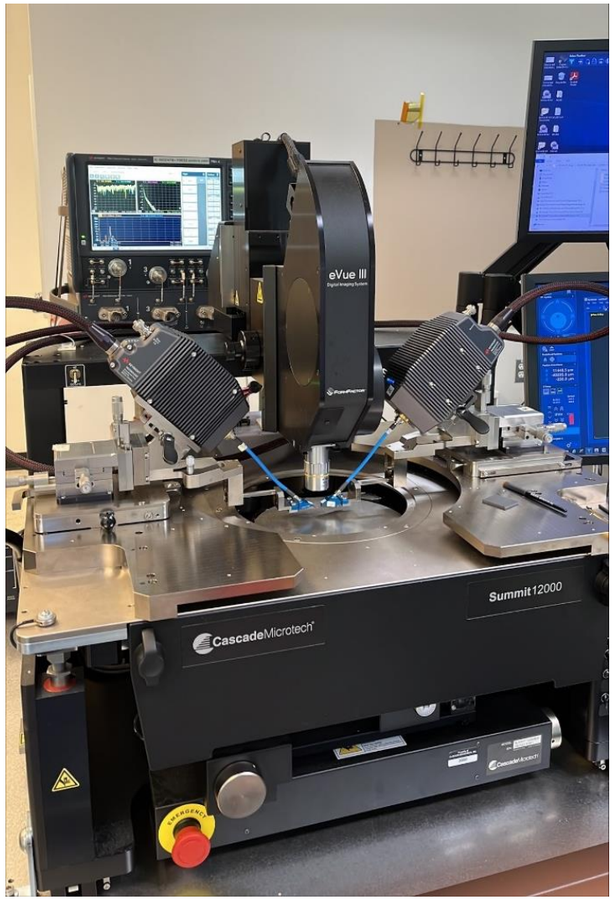
- Most Transimpedance Amplifiers (TIA) devices and Laser Drivers operate as differential digital signals
  - Differential signaling improves noise reject as well as increase BW

- Therefore, appropriate calibration methods need to be evaluated that will maintain a good RF Calibration

Test Setup

- FFI Summit 12000 semi-auto station
- Keysight PNA with 4 port capability
  - 50 MHz – 67 GHz
    - 201 points
- Use the Keysight internal calibration methods
  - SOLT and SOLR
- ISS: 310-0117-02
- Core: 700-3791-01

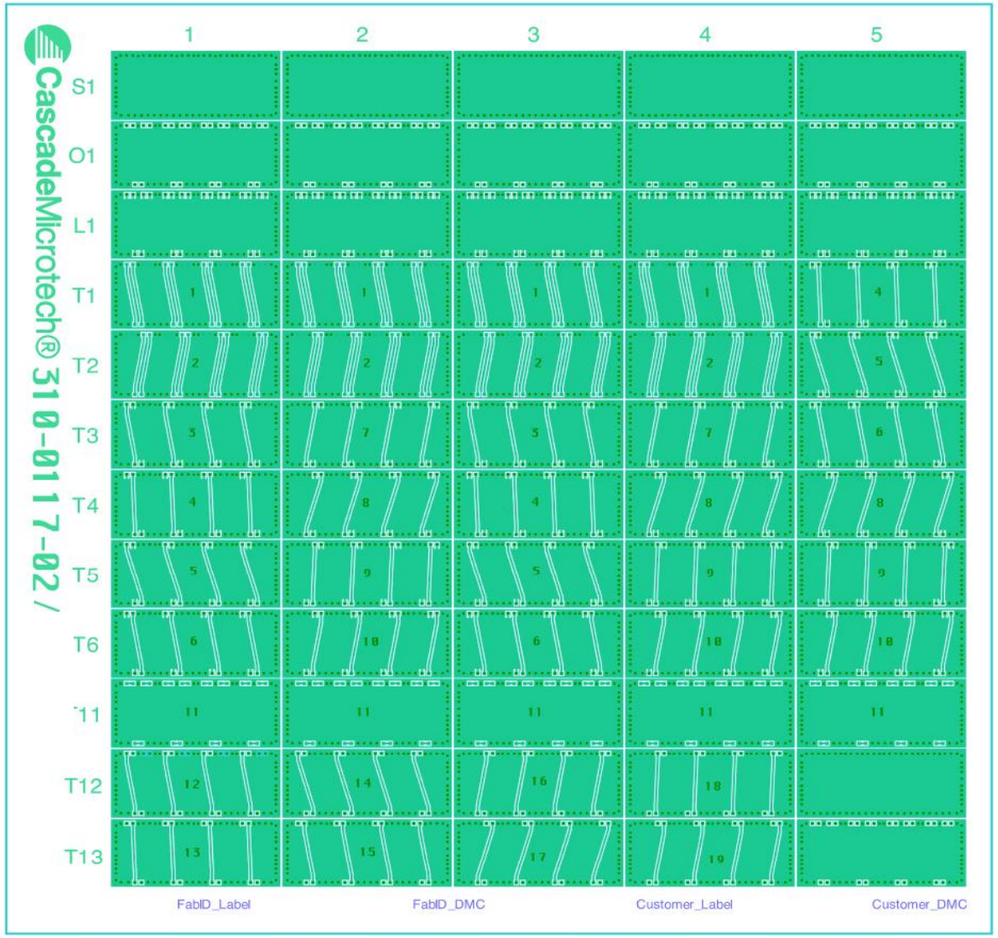




FFI Summit 12000 with eVue

ISS map

- The ISS map has a number overlaid on each different thru
  - L-short = 183 pH
  - L-load = 186 pH
  - C-open = 38.3 fF
  - Thru
    - 1-2 and 3-4 : 10.5 ps
    - 1-3 and 2-4 : 0.44 ps
    - 1-4 and 2-3 : 10.4 ps

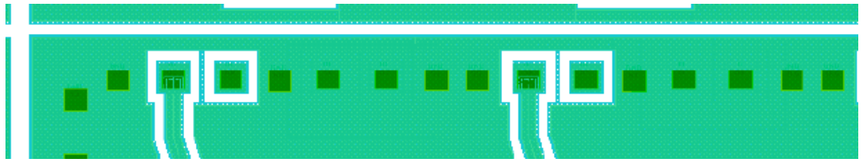


Test Variations

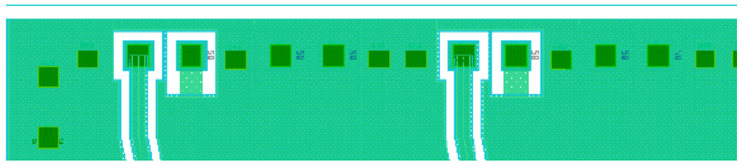
- ISS layout variations on the unmeasured standard:
  - GSLG vs. GSOG
    - Is it better to terminate the signal line adjacent to the measured thru or to leave it open?
- SOLT vs SOLR
  - SOLT uses a well-defined thru in the calibration
  - SOLR uses undefined thru, and tries to calculate the thru performance
    - Typically has better performance at higher frequencies

First comparison: GSLG vs. GSOG

- First evaluation was done by looking at the differences between measurements using the open on the unused line in the thrus vs using a load



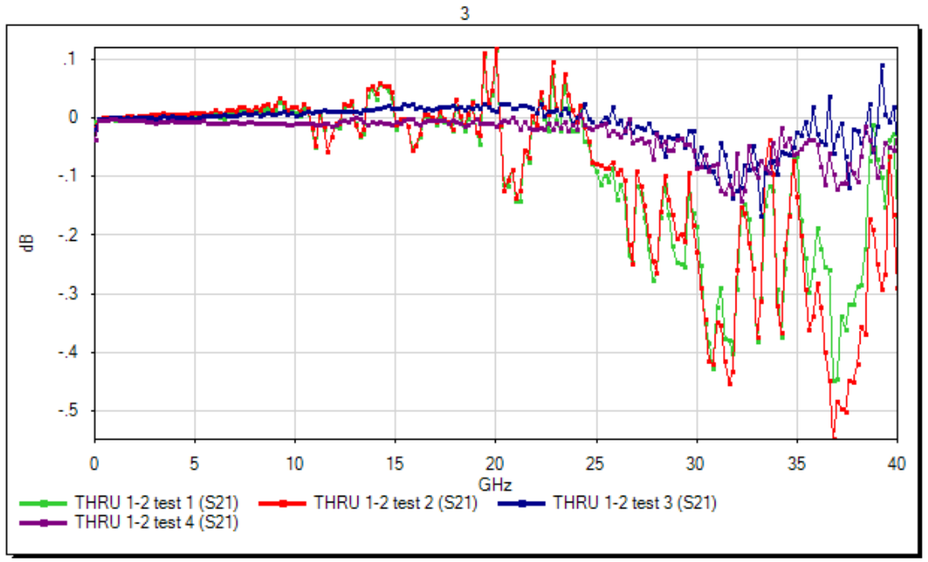
GSOG



GSLG

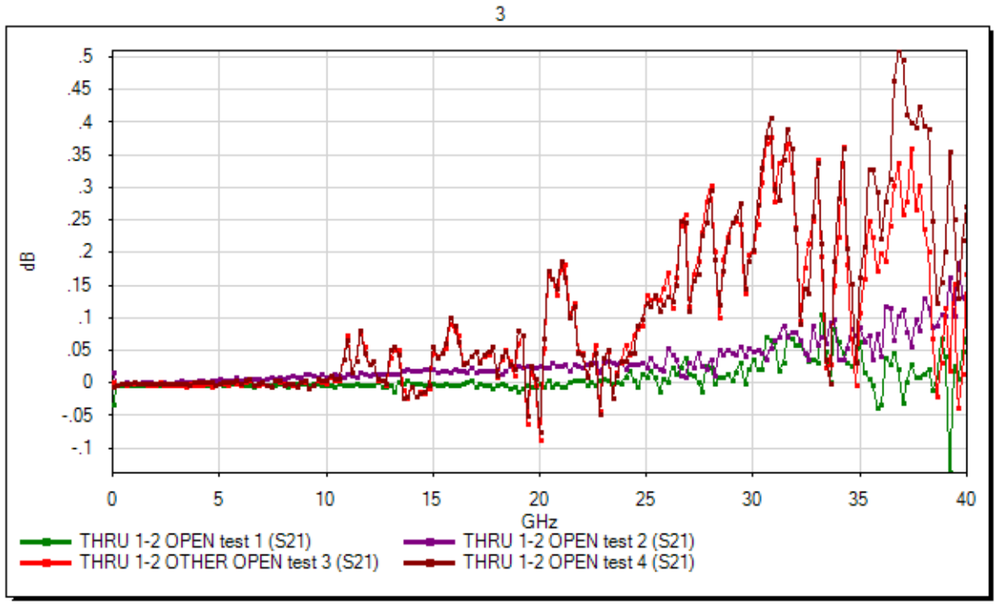
GSOG vs GSLG : Measuring GSLG thrus

- Thru
  - This is a comparison of the GSLG structures with the different calibration routines.
    - When the GSLG is measured after calibration using GSLG thrus, the performance is well behaved (purple and blue)
    - When the GSLG is measured after calibration using GSOG thrus, the performance is not well behaved with a lot of ‘noise’ in the measurement (red and green)



GSOG vs GSLG : Measuring GSOG thrus

- Thru
  - This is a comparison of the GSOG structures with the different calibration routines.
    - When the GSOG is measured after calibration using GSLG thrus, the performance is not well behaved with ‘noise’, like we say in the previous slide when the GSOG is measured after GSLG calibration (dark and light red)
    - When the GSOG is measured after calibration using GSOG thrus, the performance is well behaved (purple and green)



Summary for GSOG vs. GSLG

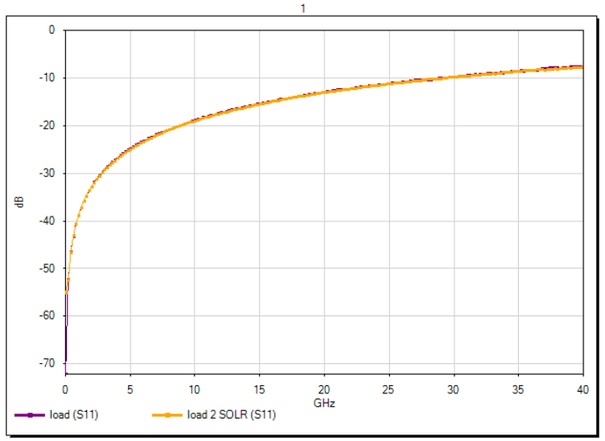
- The performance of the GSLG vs. GSOG in all of the thrus look similar in characteristic as the thru 1-2 comparison
  - Data being sent with the report
- The measurements of the opens with the GSOG show gain on the opens
  - This indicates that there is a failure in the calibration
  - Use only the GSLG structures for the thrus
- Accuracy when compared to the Infinity measurements looks the best when the GSLG standards are used

SOLT vs SOLR measurements

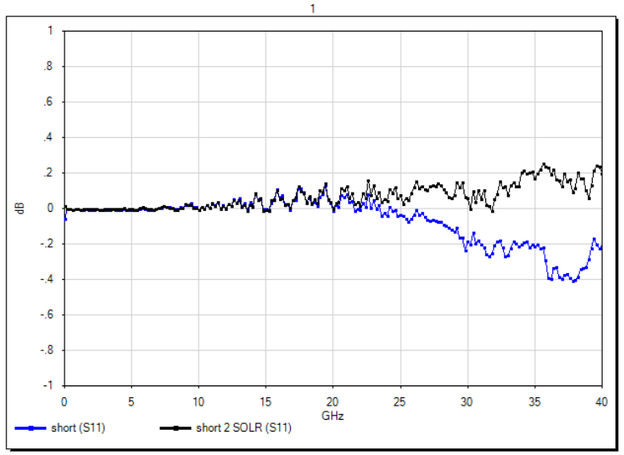
- Typically, SOLR is better because it will calculate the thru length
- At higher frequencies, dielectric material variation, fabrication variation, temperature, and other factors will affect the propagation velocity
  - Using a fixed length for the thru is therefore not as accurate as allowing the algorithm to calculate it at high frequency

4-port SOLT and SOLR compare

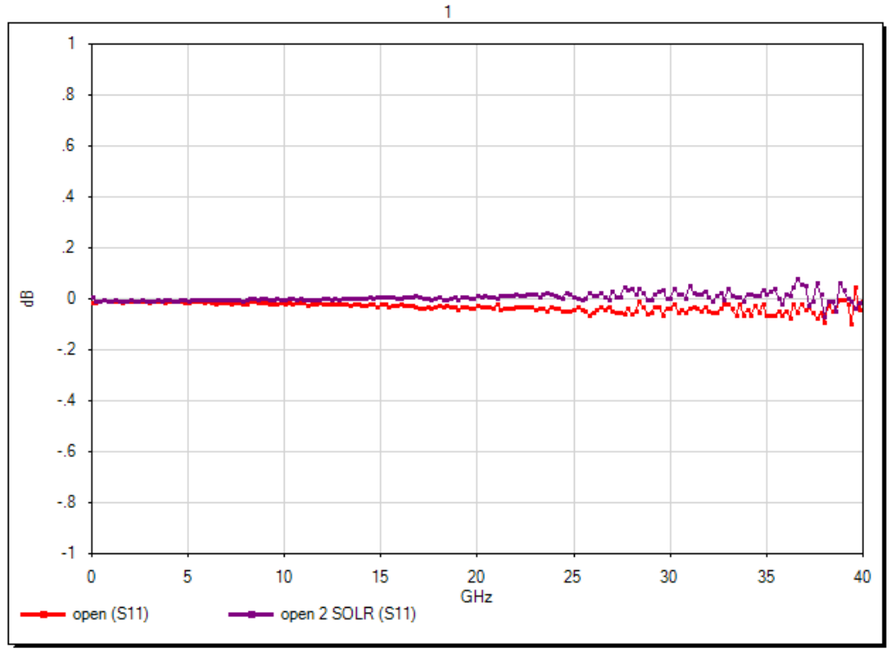
- Load – Looks normal for both



- Short – SOLR looks a little better with the short, within 0.3 dB of 0 dB

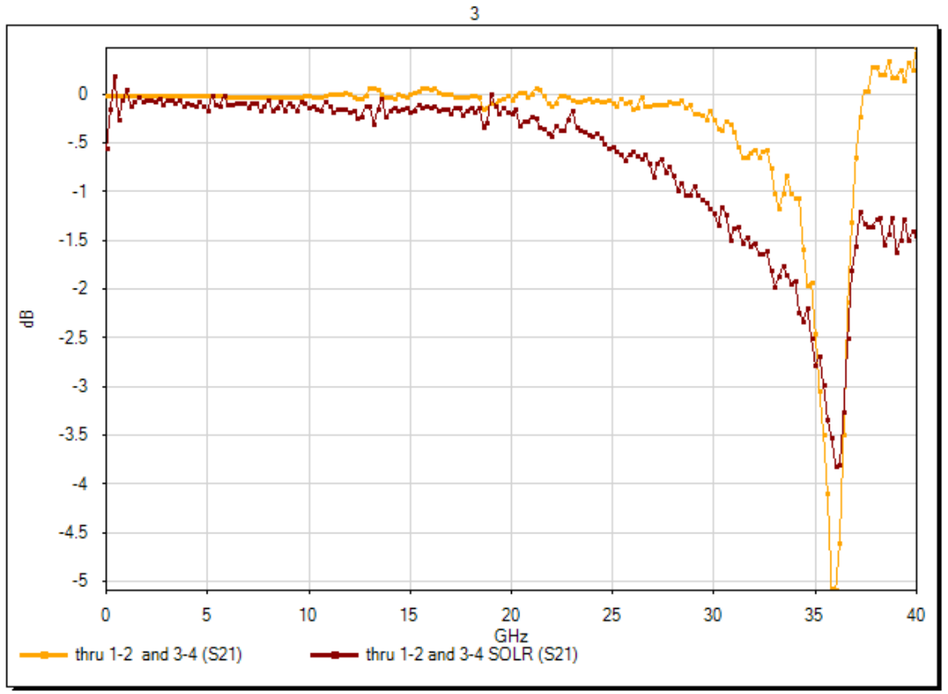


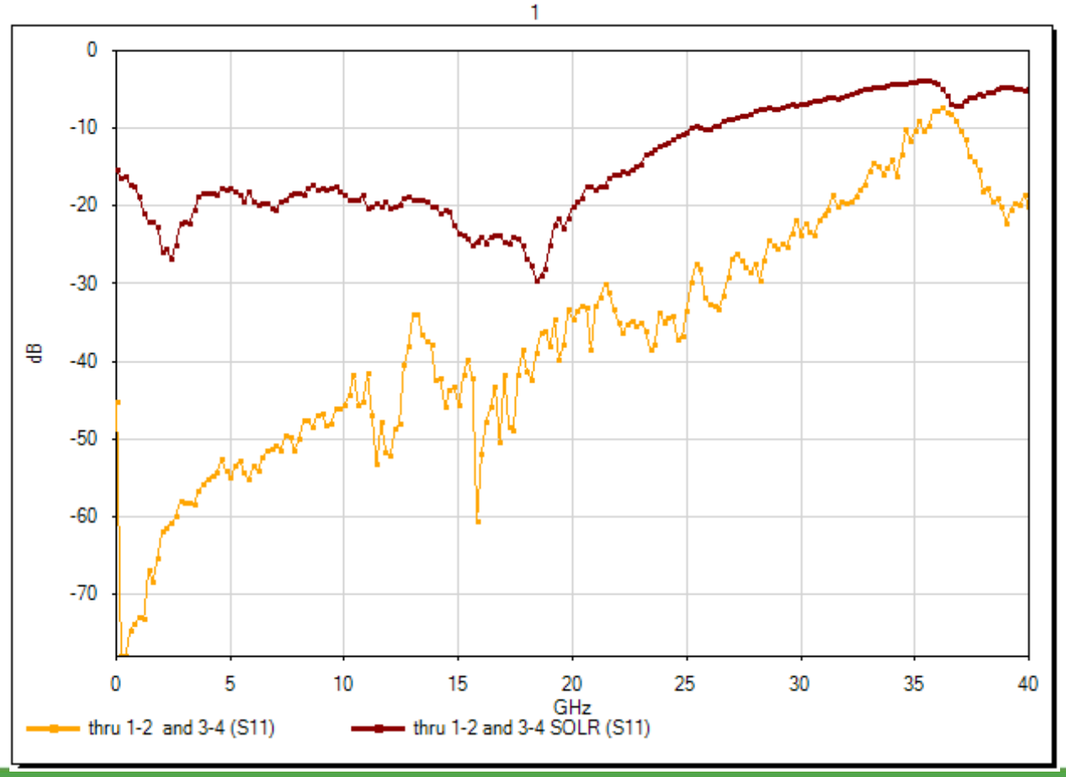
- Open – They both look really good



4-port SOLT and SOLR compare

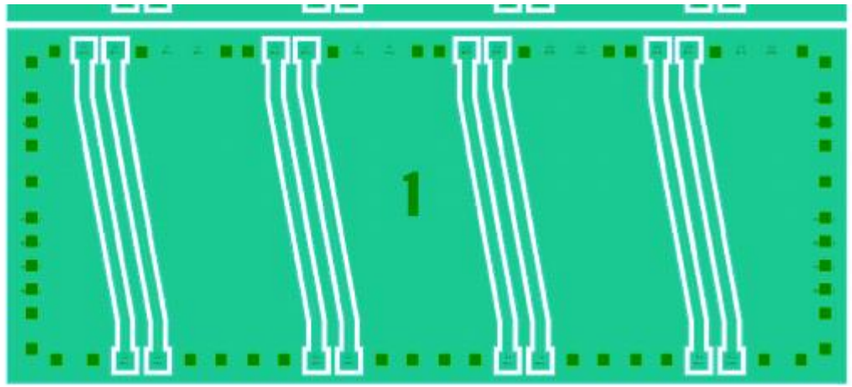
- Thru 1-2 and 3-4
  - SOLT has a sharper resonance

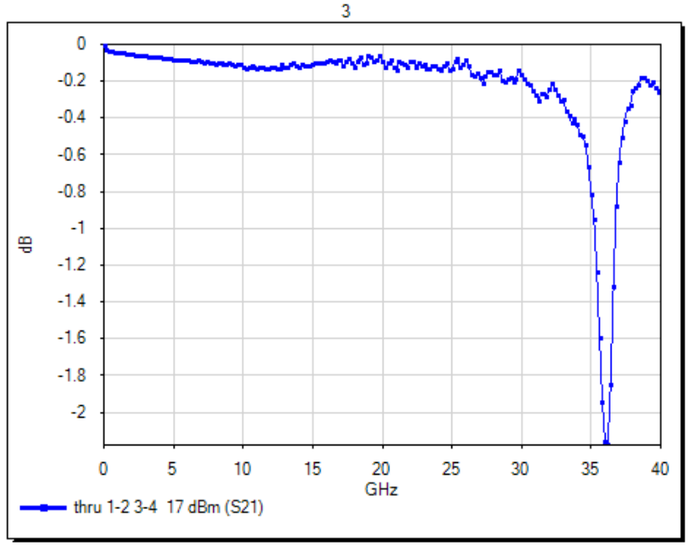


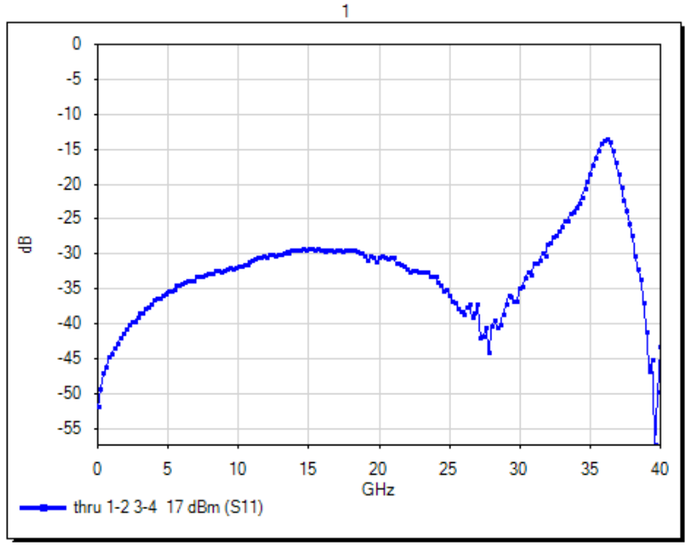


Resonance at 36 GHz

T1



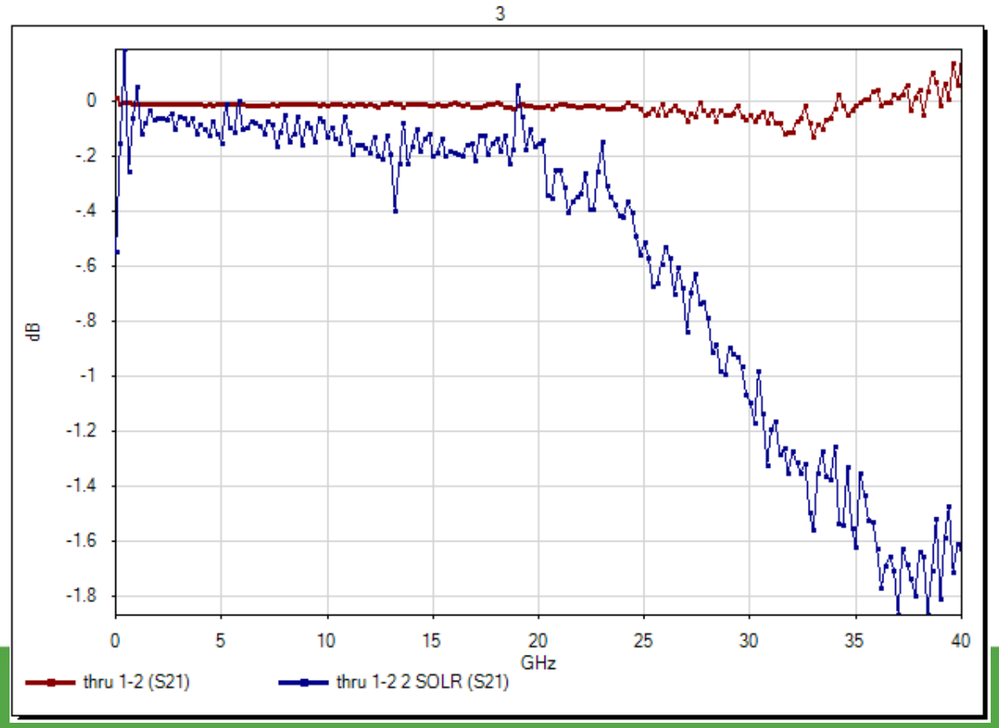


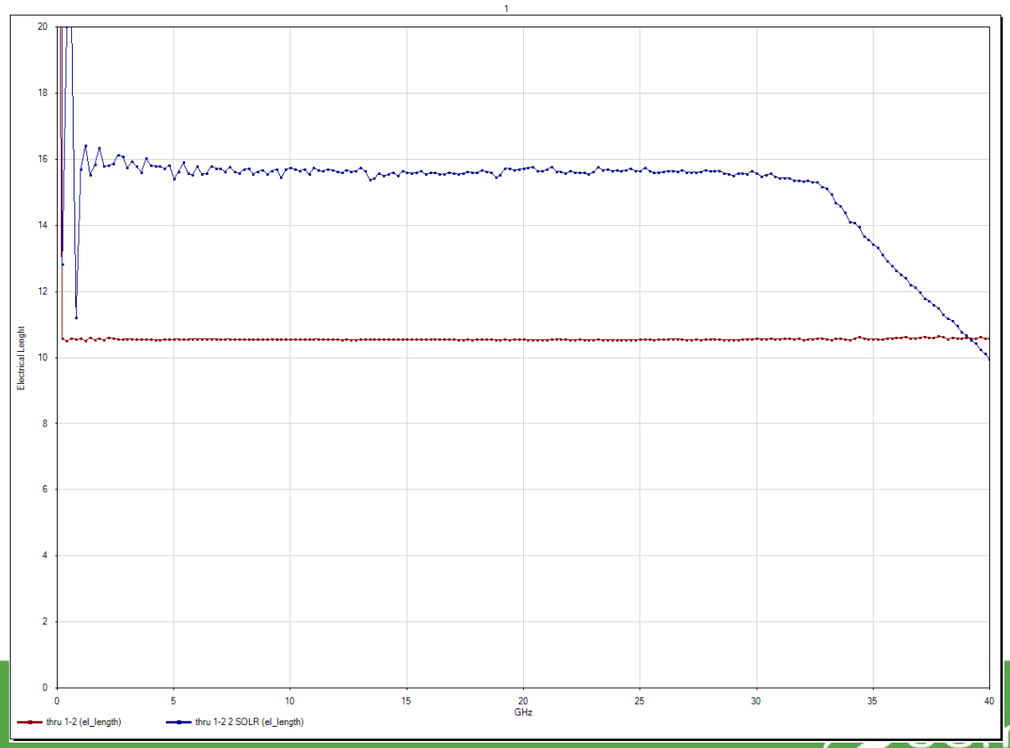


The resonance is occurring withing the pair.
Ground in between the pair is not a good ground
Not a calibration structure. Good structure to test out

4-port SOLT and SOLR compare

- Thru
  - The SOLT performance looks more like what we would expect with flat response
  - The electrical length also looks correct while SOLR doesn't make sense





Summary of SOLT vs SOLR

- It appears that SOLT handles the thrus better than SOLR
  - Most likely due to the crosstalk in the probe still causing some amount of issues with finding the thru length when it is unknown
  - Recommend using SOLT (known thru)

Conclusion

- Best performance comes from:
  - Putting a load on the unmeasured ports to suppress any oscillations.
  - Using SOLT vs SOLR