TRL Calibration
Issues and Improvements

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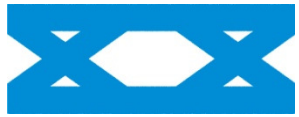
DesignCon 2010 TF-MA12 Tutorial
Feb. 1, 2010



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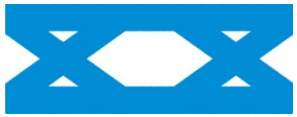
Typical Measurement Objective

- Measure S-parameters of a very specific structure, on a PCB, for creating a model of the device



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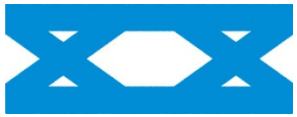
Want a Model Directly from Measurements

- After calibration we would like to be able to use measurements as a model
  - No post processing of data
    - No causality or passivity issues for passive structures
    - No fixes
    - No fuss, no bother



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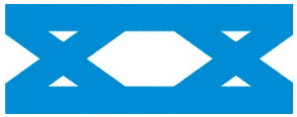
TRL Calibration for Dummies

- TRL does not require accurately modeled cal kit elements (relative to SOLT)
- TRL is a good solution for moving reference planes up to DUT on PCB's with no expensive calibration substrates or carefully modeled structures (SOLT)
- What is Required:
  - Launch must have superb S.I. (low S11, no resonance)
  - Connector repeatability from SMA to SMA – TDR confirm
  - Line lengths accurate – layout, etch
  - Impedance variation across board low – etch, fiber weave, etc.,



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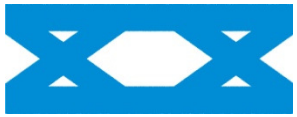
Ideal Measurement of THRU after Calibration

- Insertion loss should equal zero
- Should be passive
  - No gain from a passive structure
  - Cannot create energy
- Return loss should be very low
- Should be causal
  - Output should not occur before input



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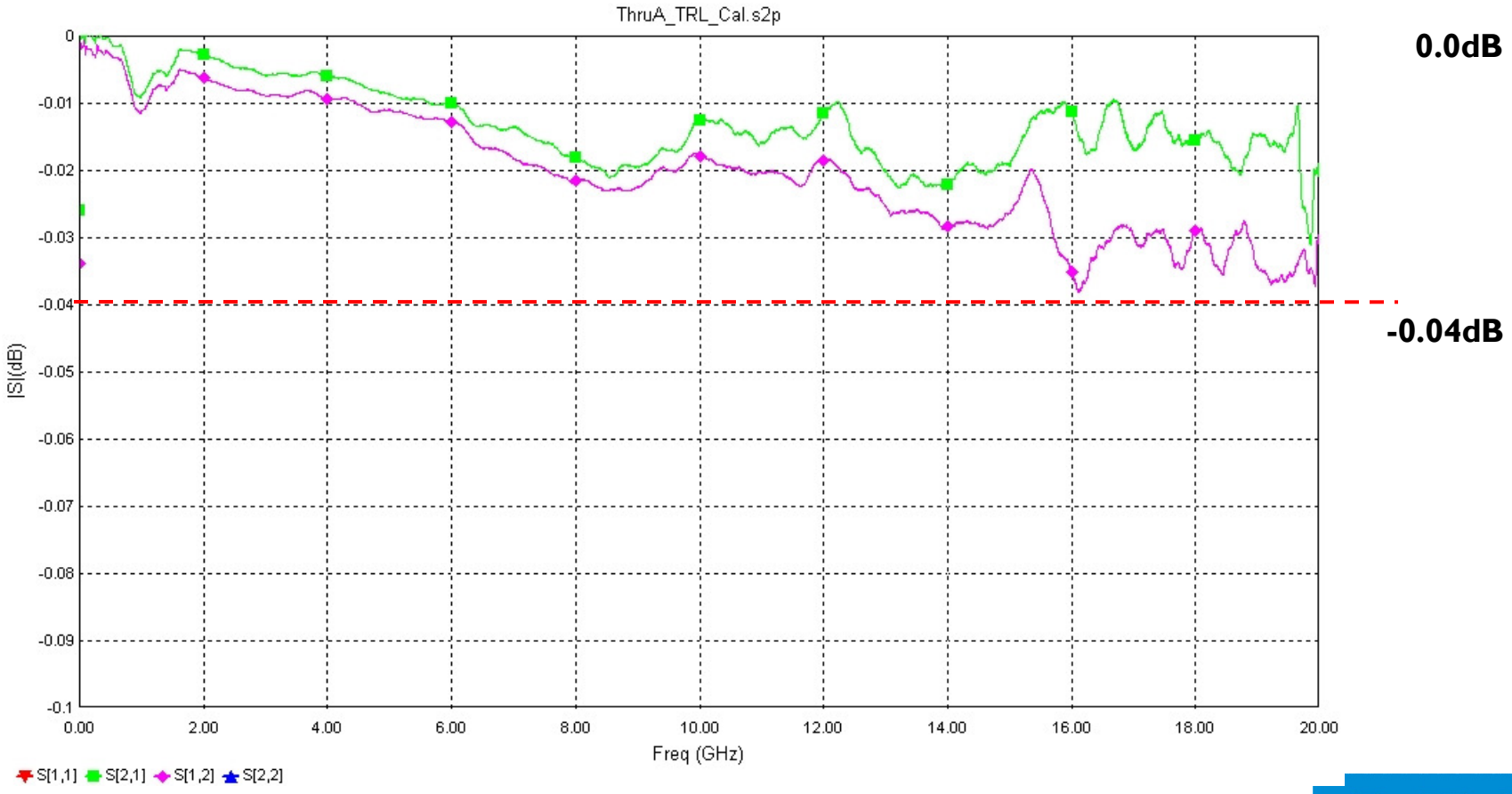
Thru A TRL S21 detail,

0.04dB error to 20GHz



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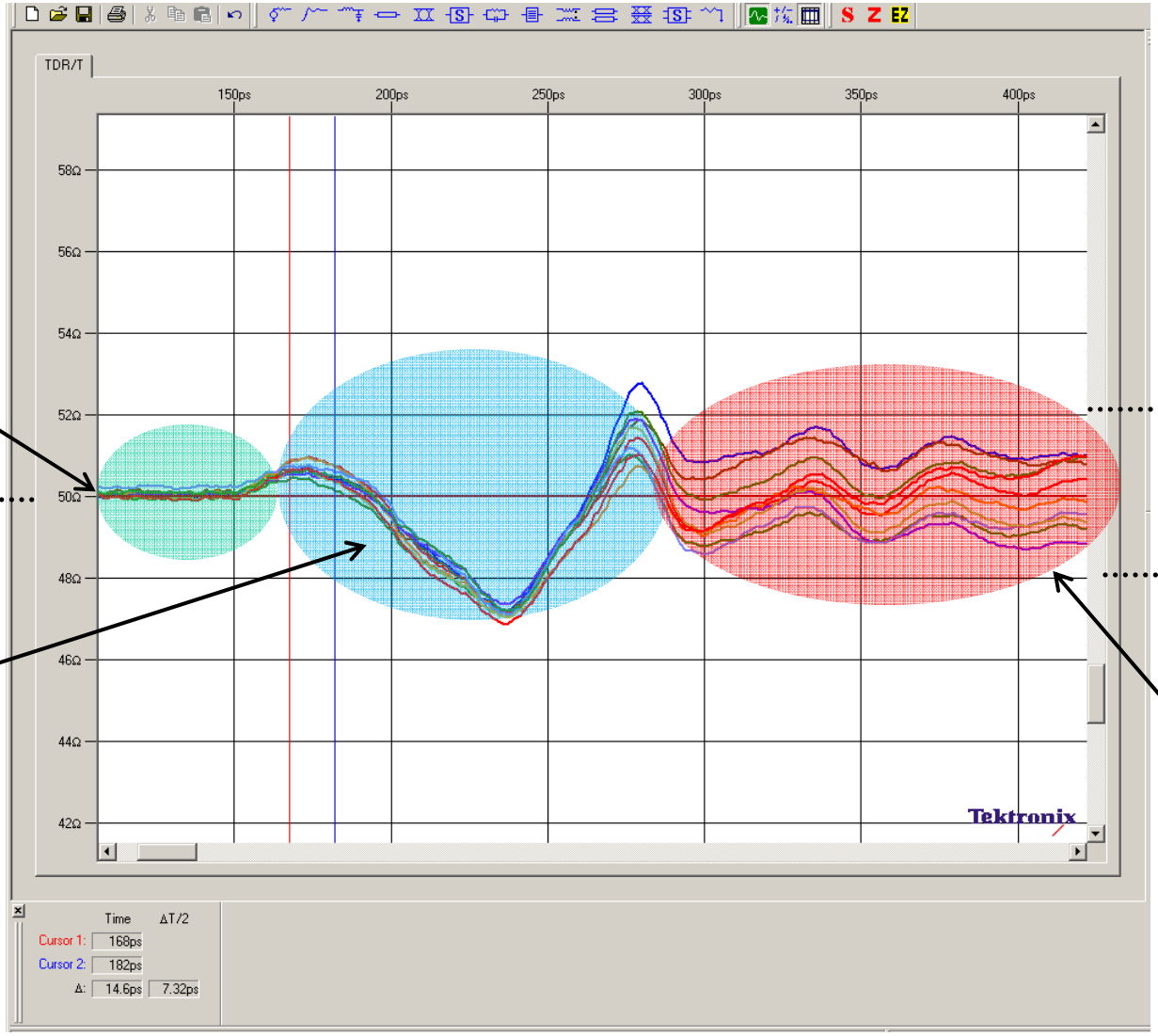
What makes a good TRL calibration kit design?

- Consistent RF Launches
- Consistent Line impedance

Goal is Consistent Zo through system



Cable

50 Ohms

Launch

52 Ohms

48 Ohms

Board Zo

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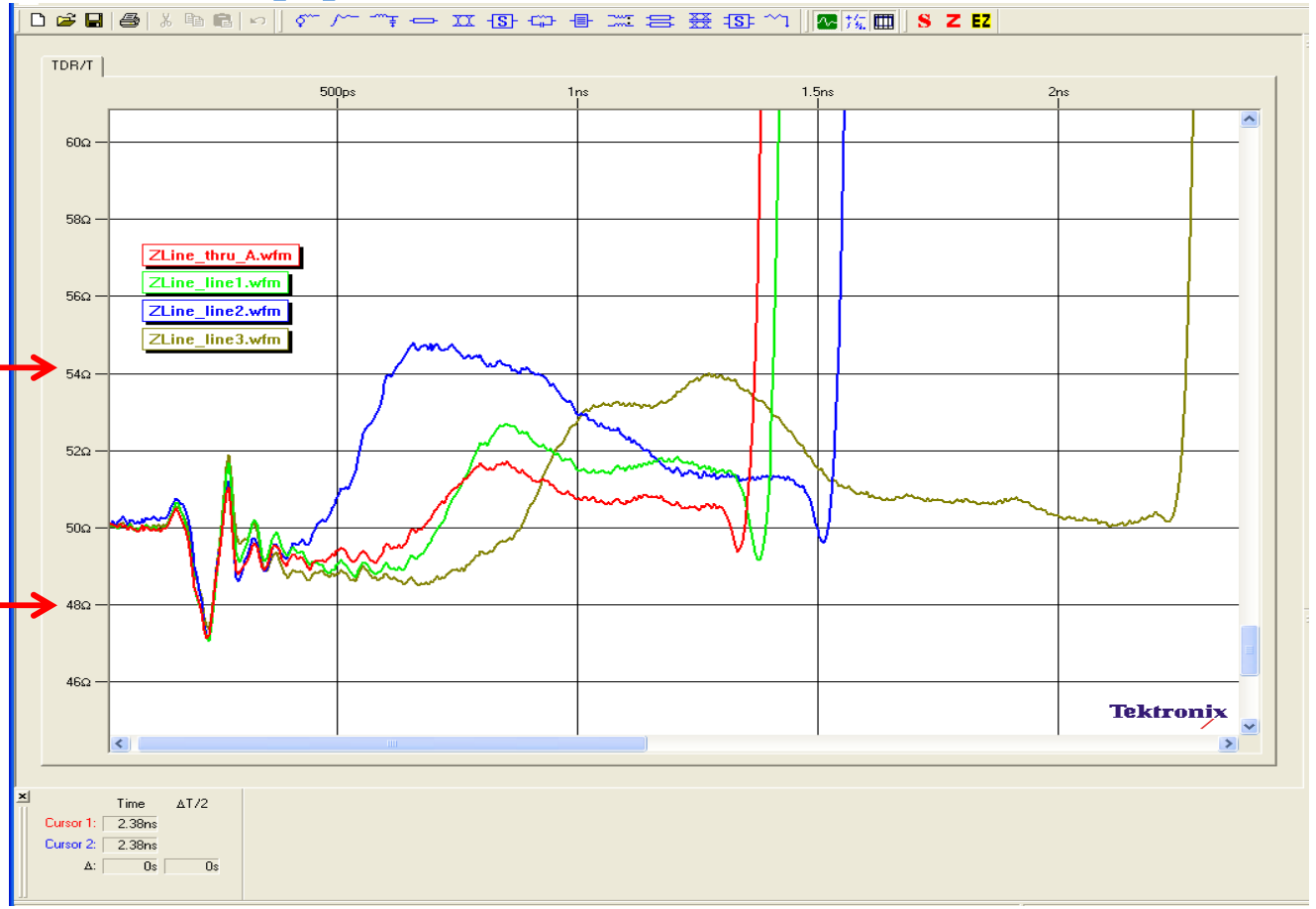
Impedance Profiles THRU, LINE1,2,3 variation approximately +10%/-5%



54 Ohms

48 Ohms

Impedance variation on Cal structures

Weave effect?

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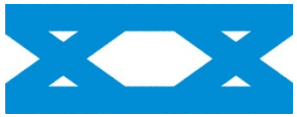
We Encountered Recurring Issues!

- Small passivity issues
  - <0.05dB in most cases
- Causality issues
  - Anywhere in the frequency band
  - Usually in small areas
  - Noise related
    - Most fixed with averaging or smoothing
    - Improved through decimation



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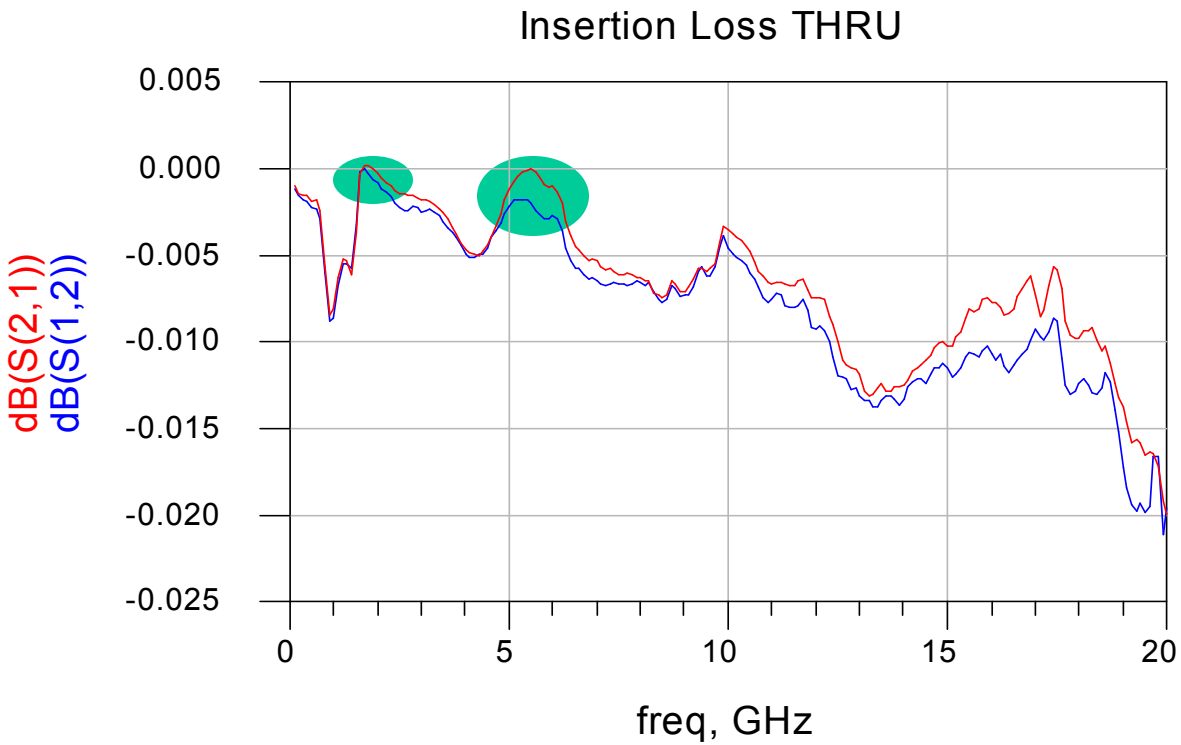
Small Passivity issues



THRU should have 0dB of magnitude loss, 0dB of phase, 0psec of Group Delay

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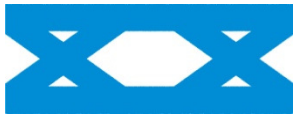
What are some of the variables

- VNA setup
  - Number of averages
  - IF bandwidth
- Cables
- Connection repeatability
- Standard's quality

Averaging

- Averaging improves SNR by SQRT N
  - 100 averages ➡ 20dB improvement



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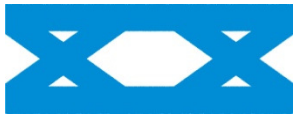
IF bandwidth

- Reduces noise at expense of measurement time
- Original work at 100 KHz
- Experiment at 1 KHz



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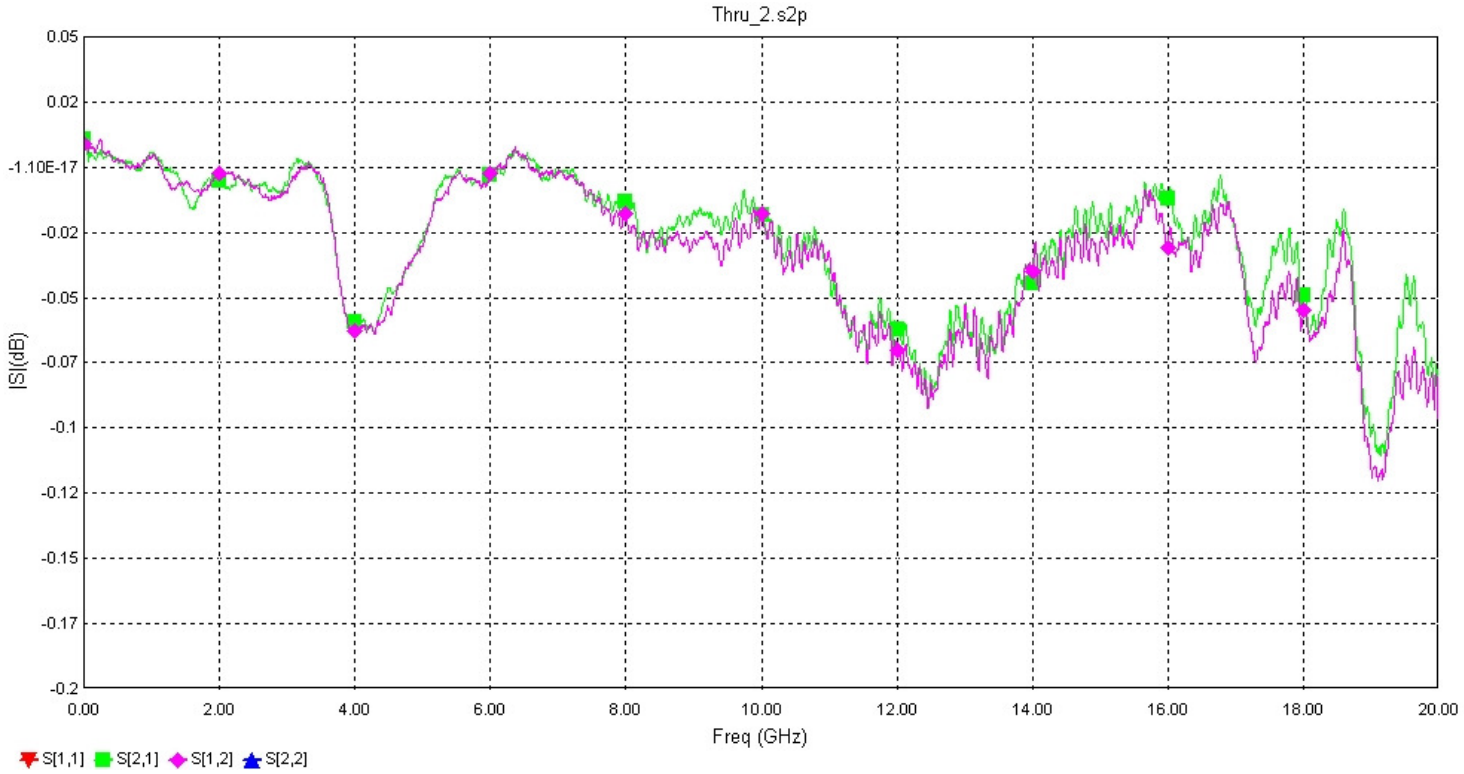
THRU no AVG 100KHz



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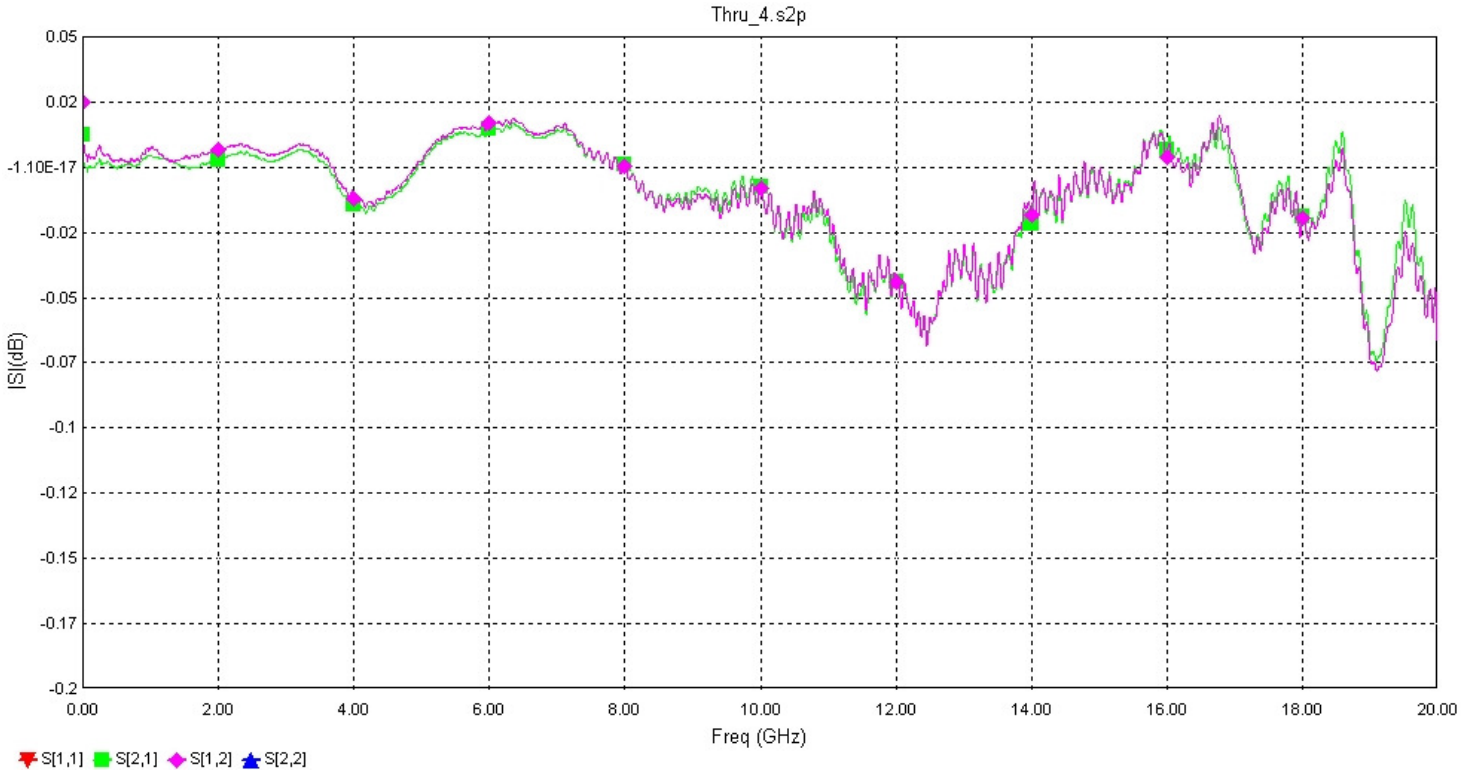
THRU 8AVG 1KHz



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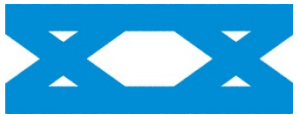
Cables

- Cables vary in phase and loss with flexure
  - Did notice we could tune the response
  - Questions about connector to board contact resistance vs stress on connector



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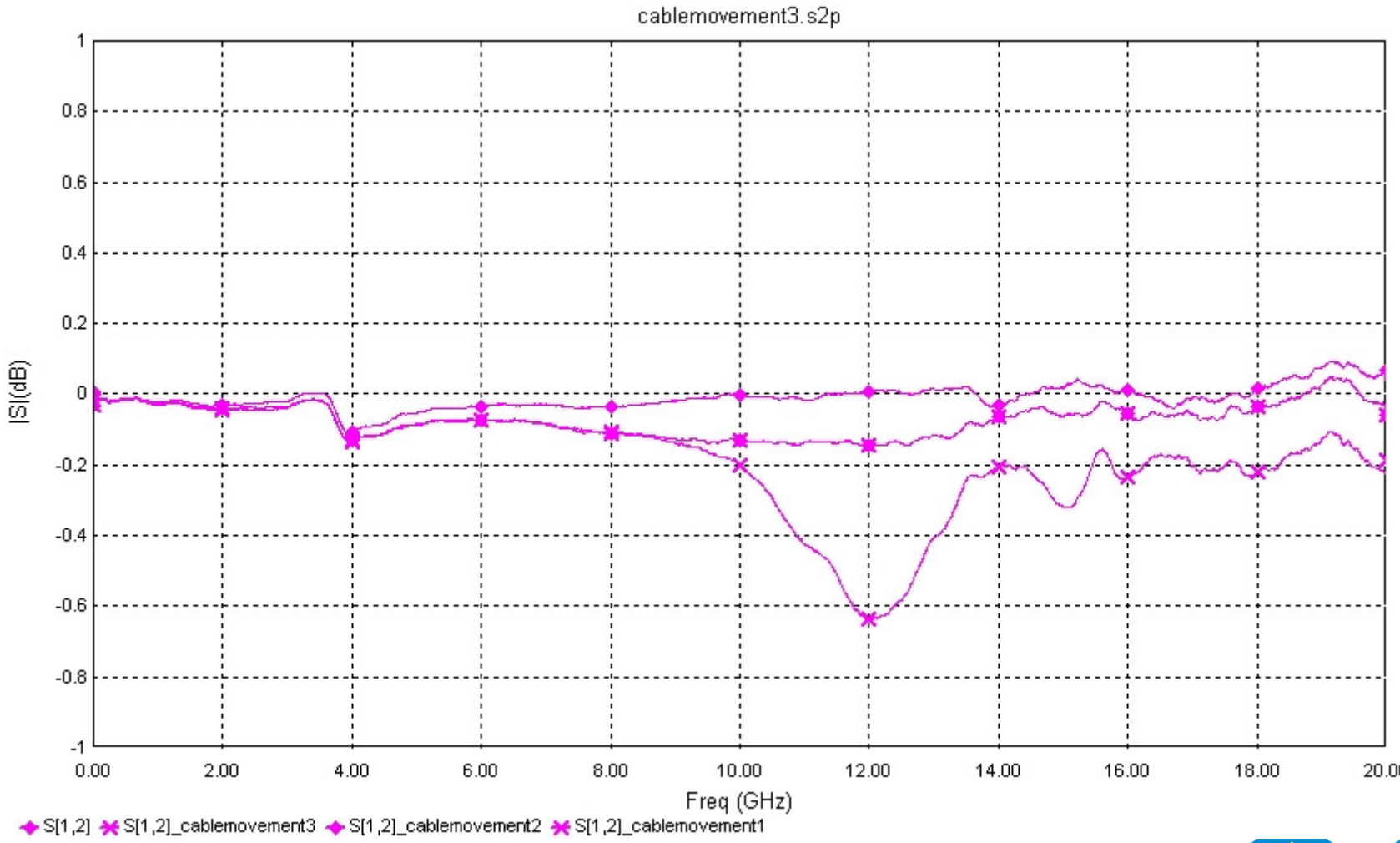
Cable Movement



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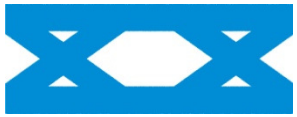
Connector Repeatability

- A requirement for any VNA calibration is consistent measurements
- Connection repeatability is important



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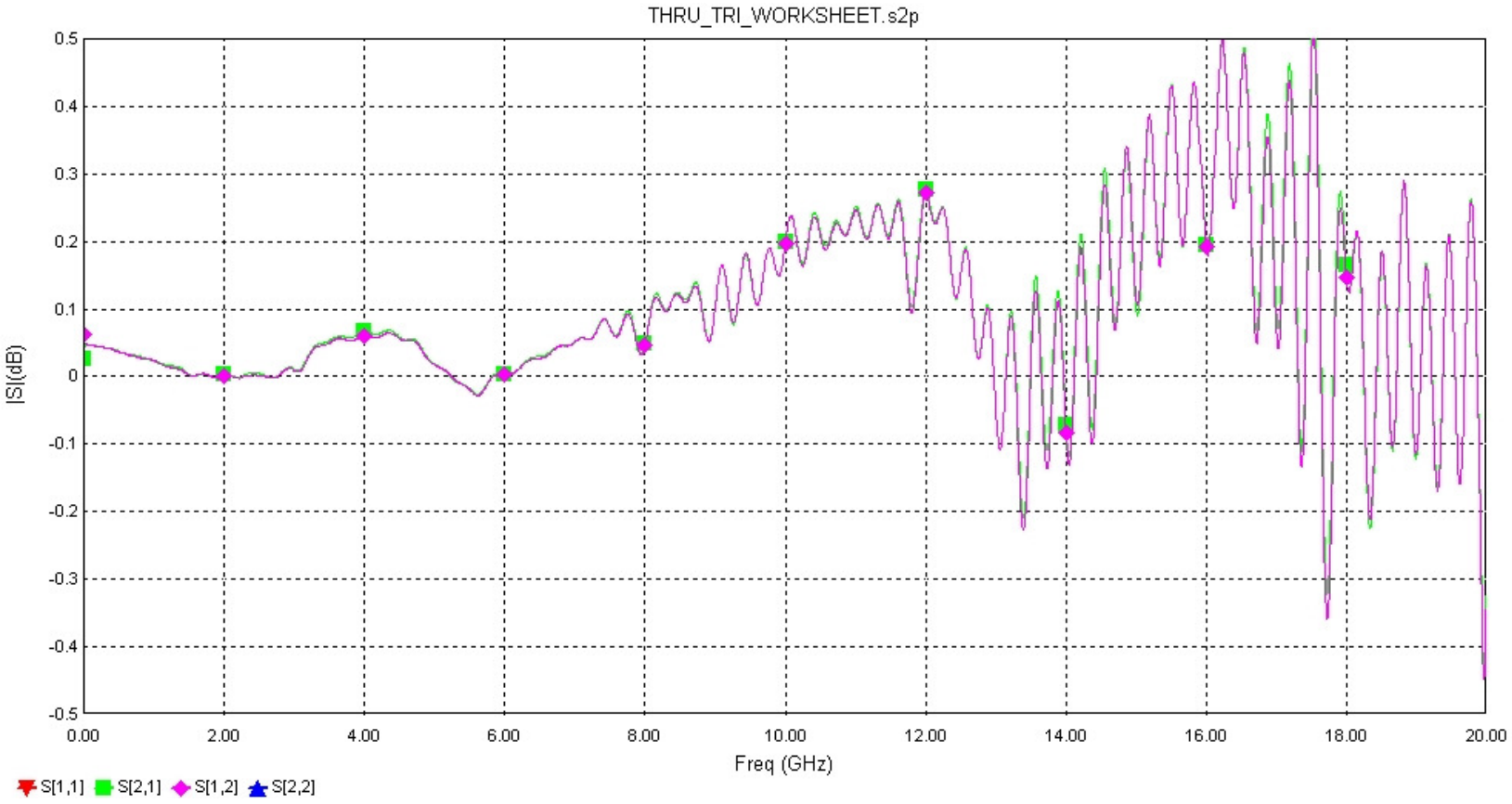
Effects of a bad connector - S21



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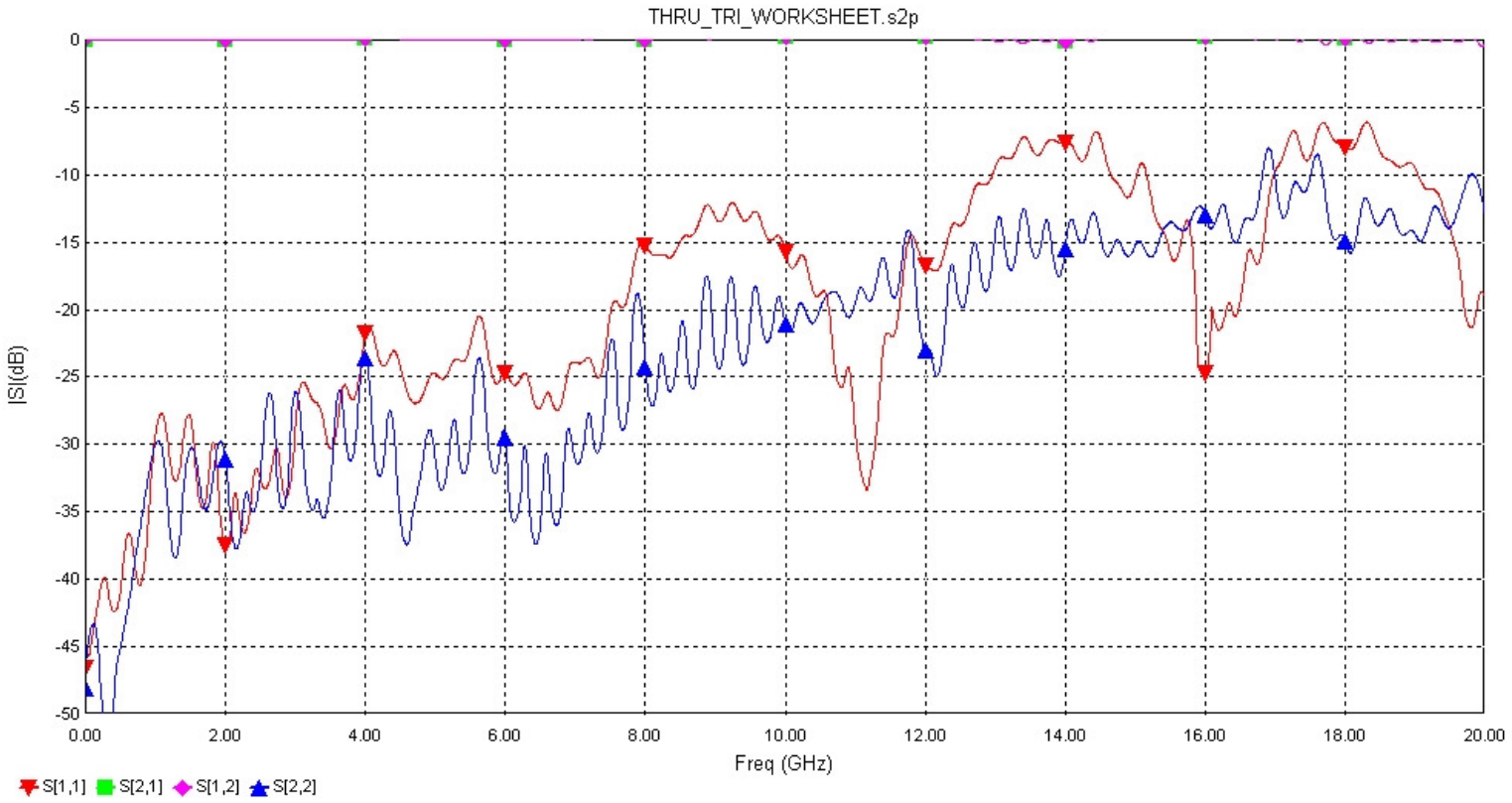
Effects of a bad connector - S11



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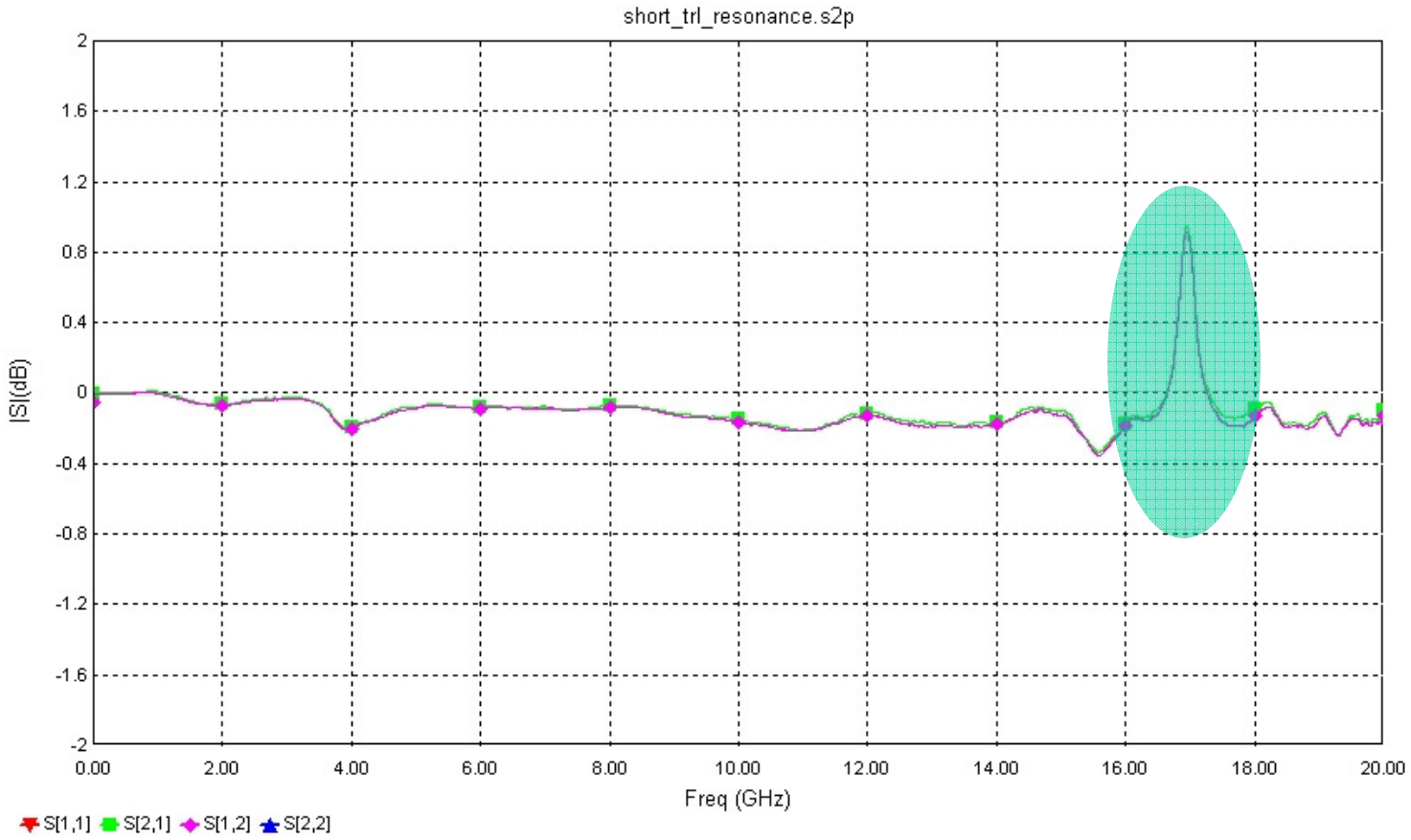
Standard's Quality

- TRL
  - Transmission or THRU
  - Reflect
    - Open
    - Short
  - Line/Load
- We had an issue with a short

THRU Response After Cal



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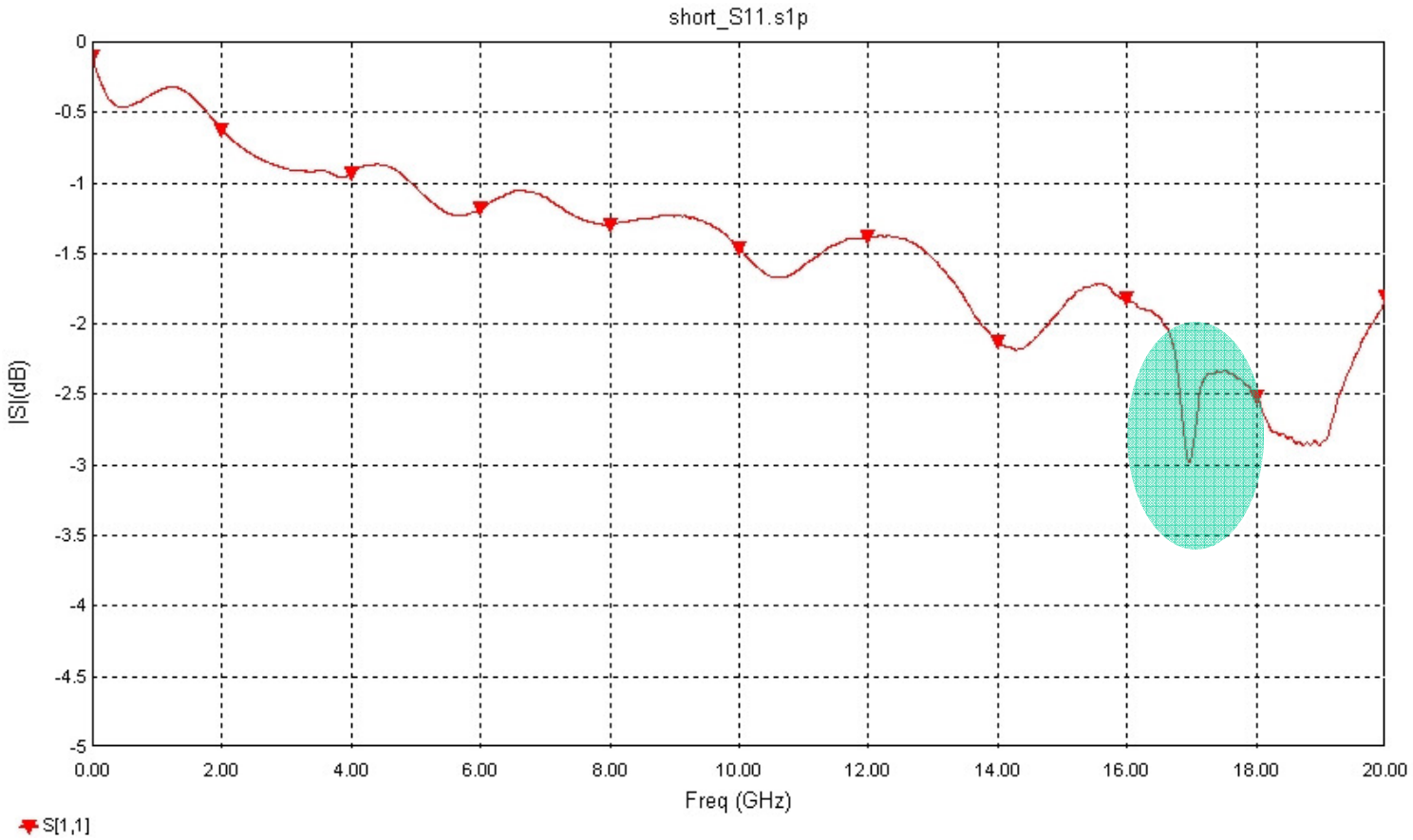
S11 Issue



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Conclusions

"After calibration we would like to be able to use measurements as a model"

However, in the "Real World" :

- Calibration does not guarantee causality or passivity for passive structures
- Analysis of data quality is required to improve the accuracy of test fixture removal
- This is not easy stuff – broad band measurements are tough

Thank You

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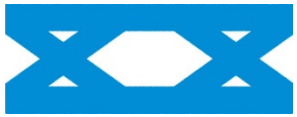

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