

Advances in VNA-based Signal Integrity Tools and Techniques

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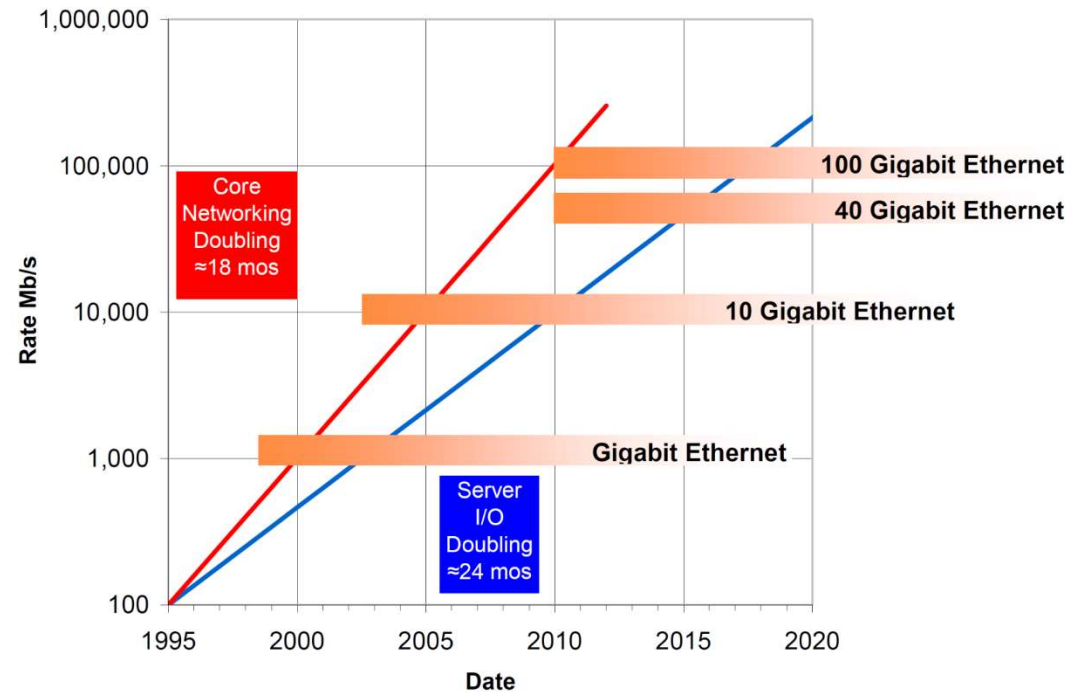
Outline

- Technology Driver: Data Rates
- Improving measurement technology for SI applications
 - De-embedding methods
 - De-embedding tools



Data Rate Trajectory

- LTE success driving wired communicating networks
- Amount of data generated has exploded
- Core network capacity doubles every 18 months
- Server I/O doubles every 24 months
- 100 GE is currently deployed



Double Data Rate with PAM4

PAM4 example

- 4 discrete levels (symbols)
- 2 bits per symbol

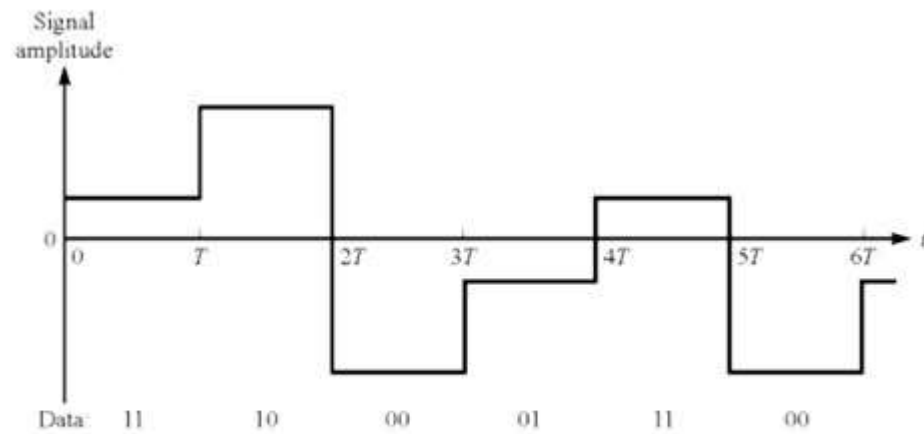


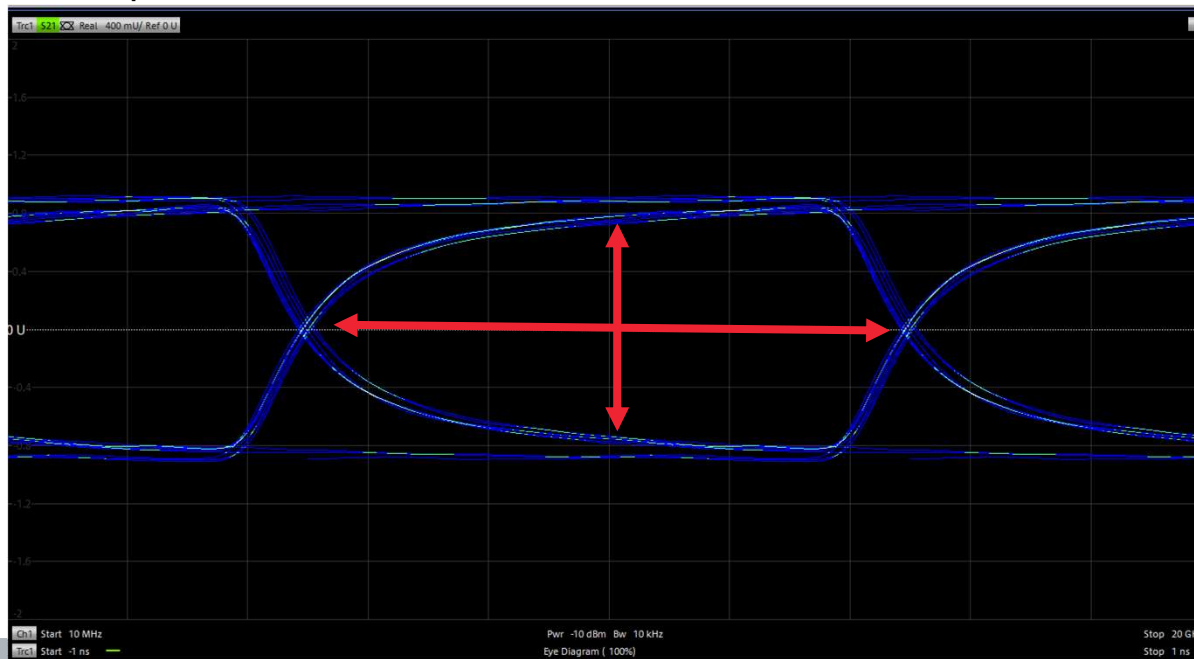
Fig.1 A PAM-4 signal in time domain, $T =$ symbol period.



What is an Eye Diagram?

- Overlay of a bit sequence of a digital signal
- Look at 21-bit sequence "010101101001110010111"

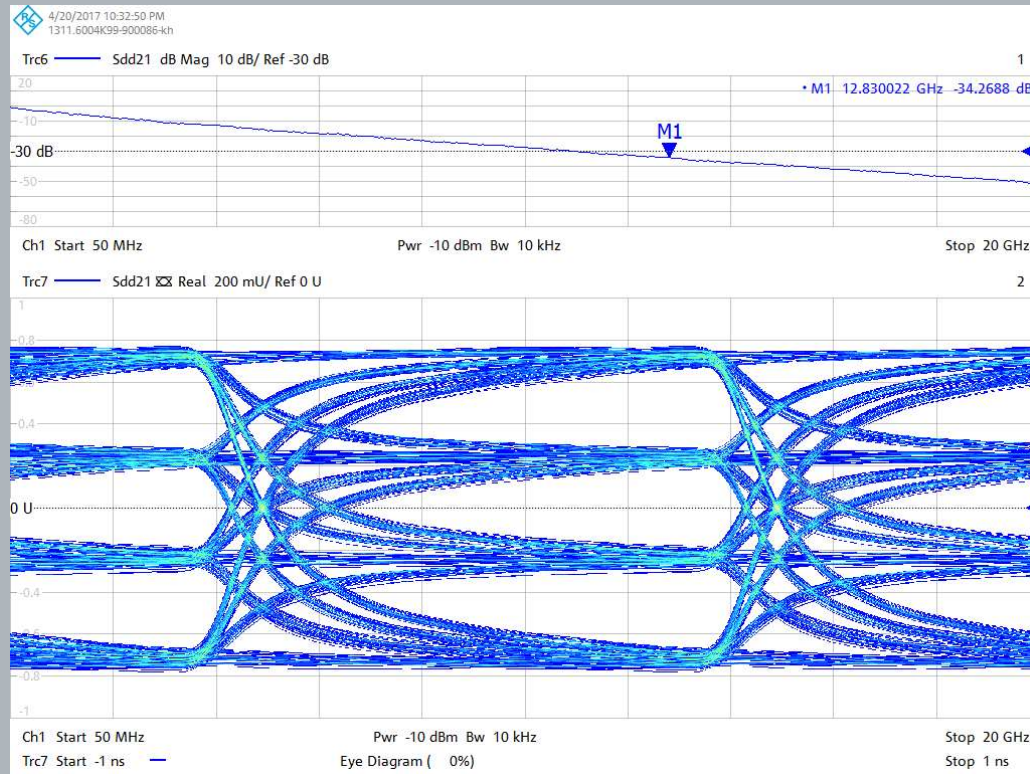
Bit 1
Bit 2
Bit 3
Bit 4
Bit 7
Bit 21



Eye Height

Eye Width

PAM4 Measurement



Comparison of PAM4 vs. NRZ

■ Advantages:

- Requires 1/2 bandwidth of NRZ

■ Challenges:

- 1/3 eye height of NRZ
- 1/2 to 1/3 eye width of NRZ
- Eye levels are asymmetric
- More sensitive to ISI than NRZ
- More sensitive to reflection than NRZ
- More sensitive to crosstalk than NRZ
- Much more sensitive to intra-pair skew than NRZ
- More sensitive to nonlinearities than NRZ

Accurate Channel characterization is crucial for PAM4 signaling



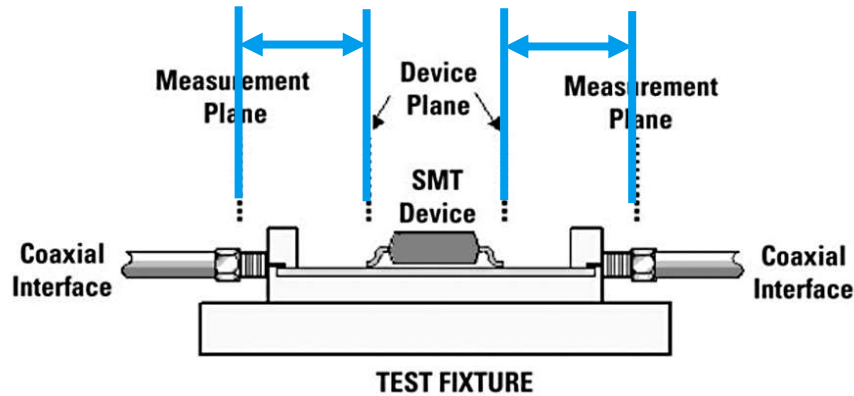
Improving measurement technology for SI applications

- SI Measurement Objective is similar to ANY VNA Measurement Objective:
 - Measure ONLY the DUT
 - Remove reflections
 - Remove extraneous loss
 - Remove extraneous phase shift/rotations
 - Focus on Ease of Use...

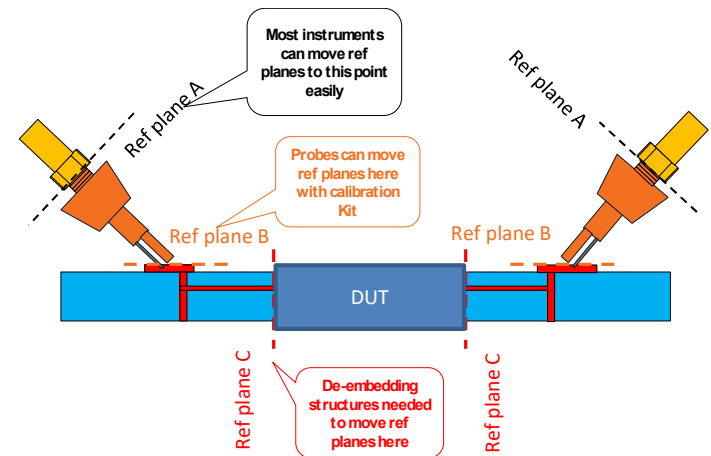


Problem Description: Device Performance

How do you measure this?



- Is the left side = right side?
 - Different length
 - Skew (glass weave skew)?
 - Manufacturing tolerances?
- Is the material the same over the whole PCB
 - Glass/fiber weave effect



Concept of test coupon

- Add test coupon to characterize trace
 - Either on the same board
 - External board but same material
 - External board and different material
- Typical calibration standards
 - TRL calibration standards
 - 2x through
 - 1x through
 - Other reference traces
- Advanced de-embedding methods
 - Can handle coupon with (slightly) different material

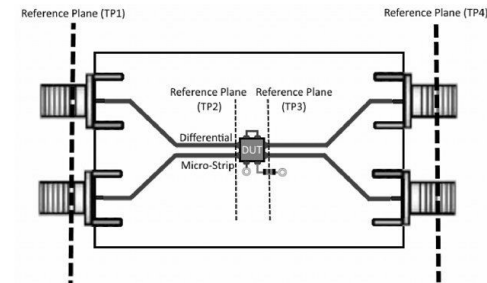
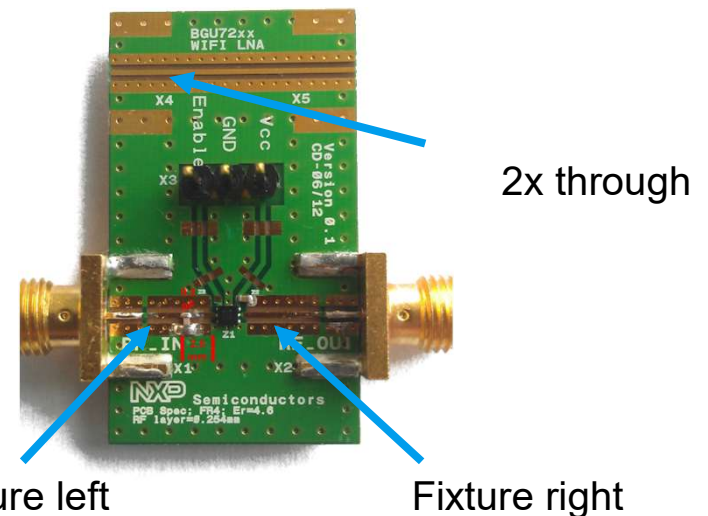


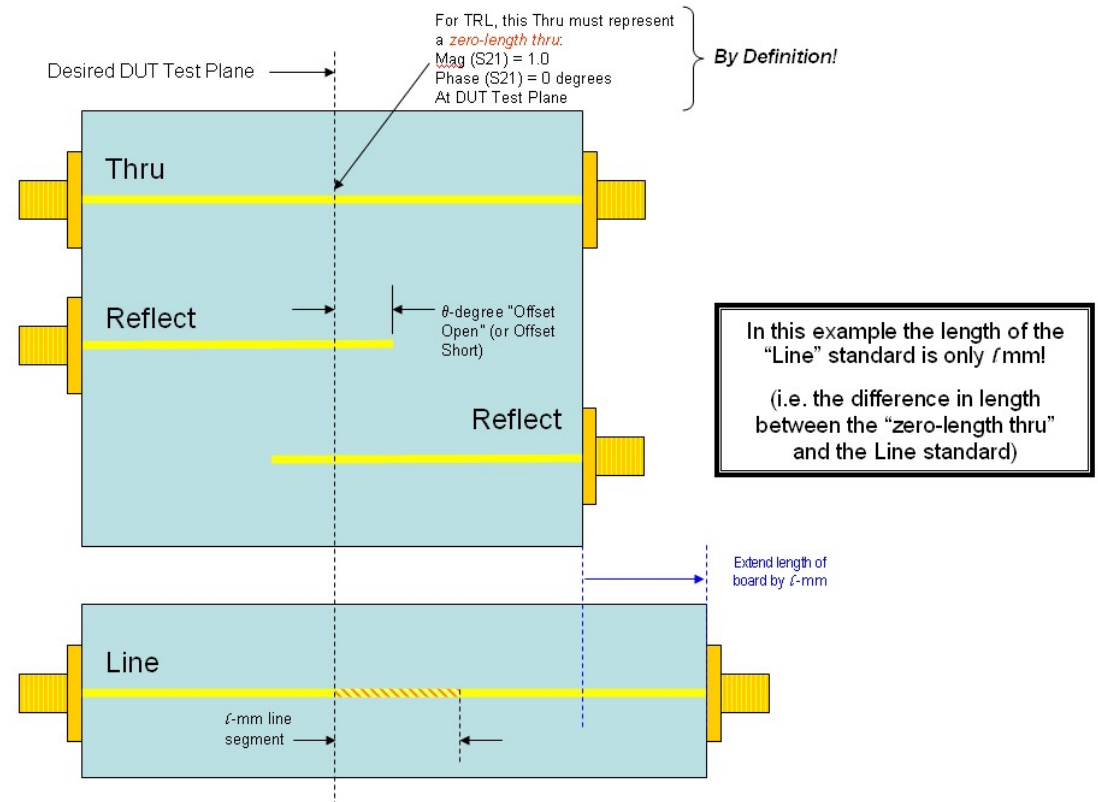
Figure GG-GG — Coaxial connectors on a PCB with differential micro-strip traces to a DUT



Classic approach

TRL Calibration

- Requires:
 - Reflect standard
 - Zero-length through standard
 - Line Standard:
 - 20 degrees at lowest freq
 - 160 degrees at highest freq



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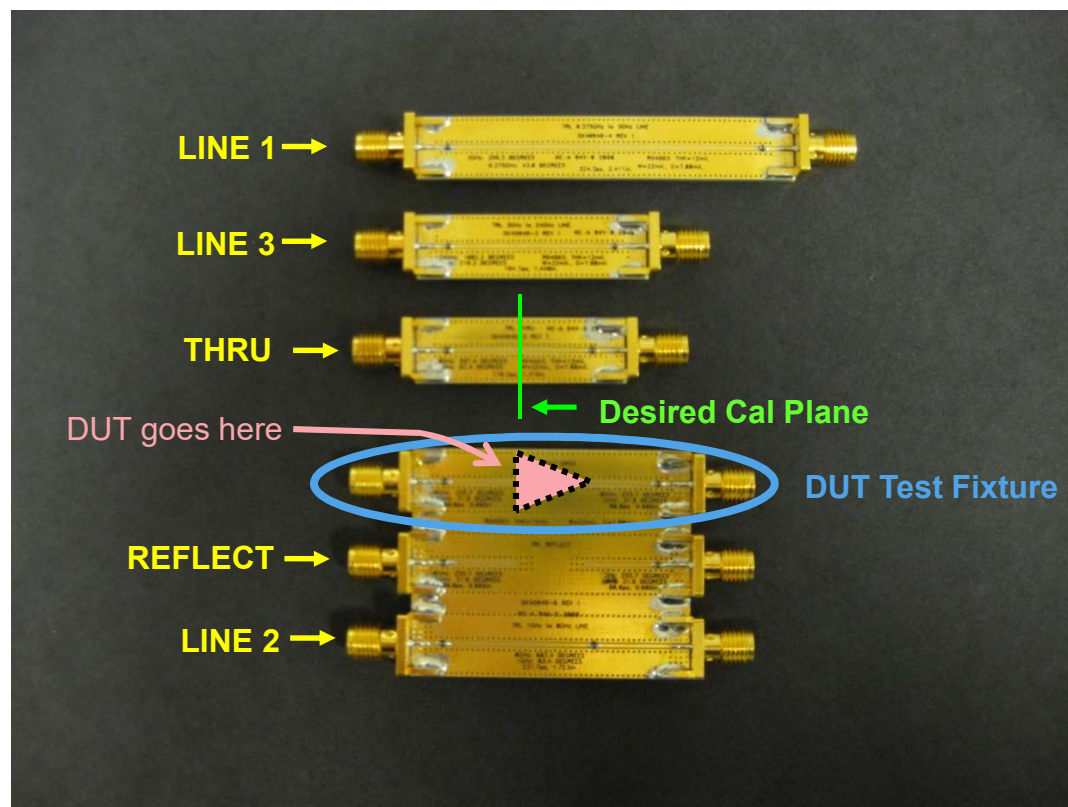
May 11, 2007



TRL Standards for Custom Kit (Three Line standards cover 375 MHz to 24 GHz)

TRL Challenges

- Multiple lines required to cover higher frequencies
- Still requires Match standard for lower frequencies
- Cal Plane established in center of THRU standard
- Cal Plane established in center of THRU standard

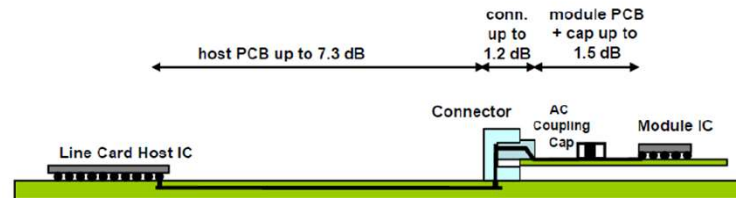


CEI56, VSR, MR, LR

Very Short Reach

- 10 cm
- Chip-to-Chip
- One Connector

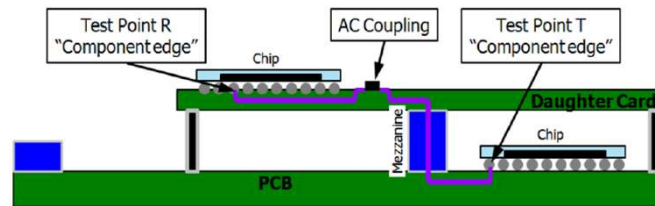
Figure 16-15. CEI-56G-VSR-PAM4 Channel Reference Model



Medium Reach

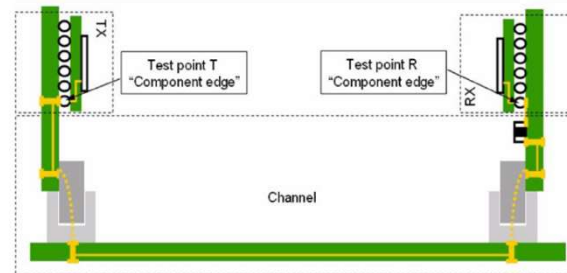
- 50 cm
- Chip-to-Chip
- One Connector

Figure 17-1. CEI-56G-MR Reference Model



Long Reach

- Chip-to-Chip
- Two Connector



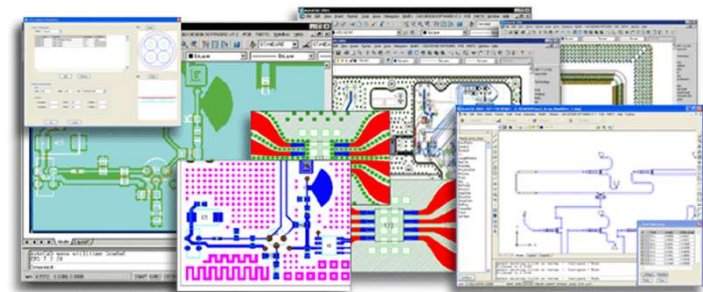
Common Features:

- Equalization
 - CTLE/FFE/DFE
- Error correction
 - FEC



Alternative (simpler) solutions

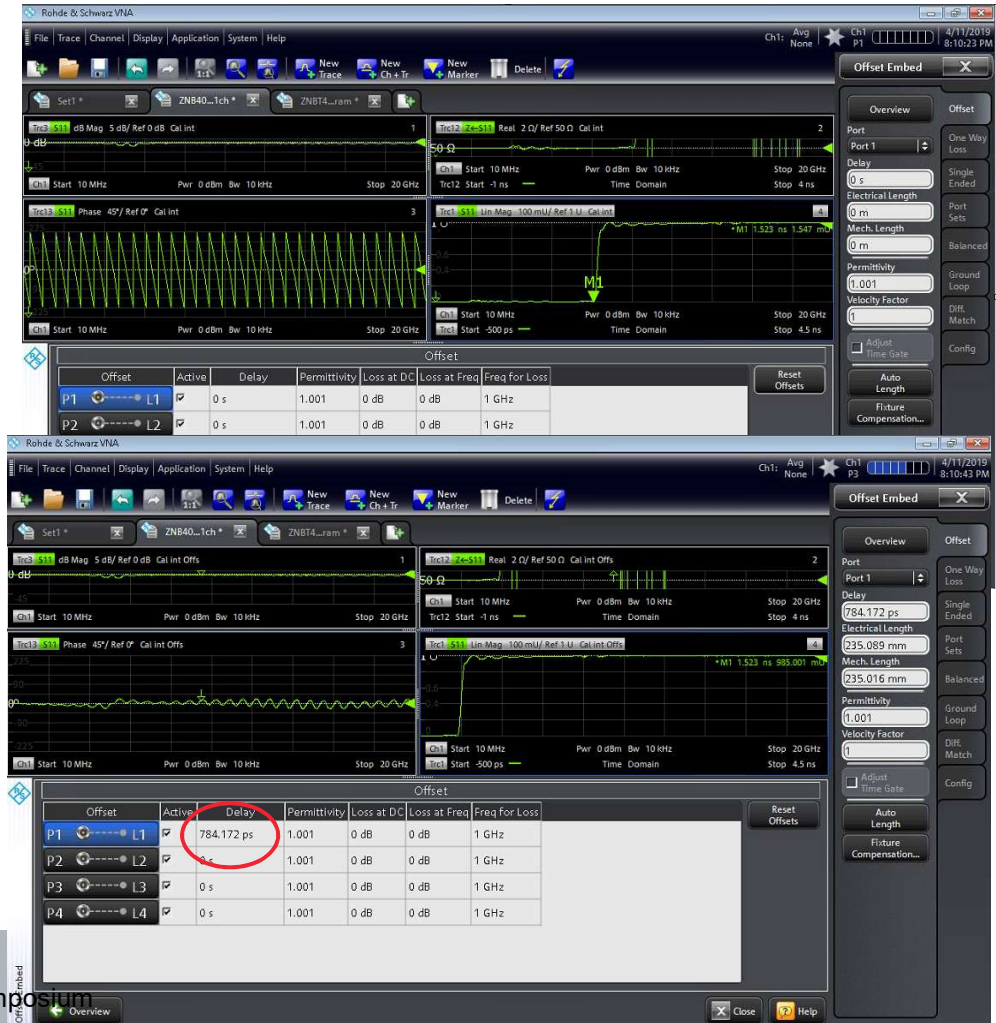
- Use Offset De-embed
- One Way Loss/Auto Length/Loss
- Use S-parameters from board simulation
- Use advanced fixture de-embedding techniques



Alternative approaches

Auto Length

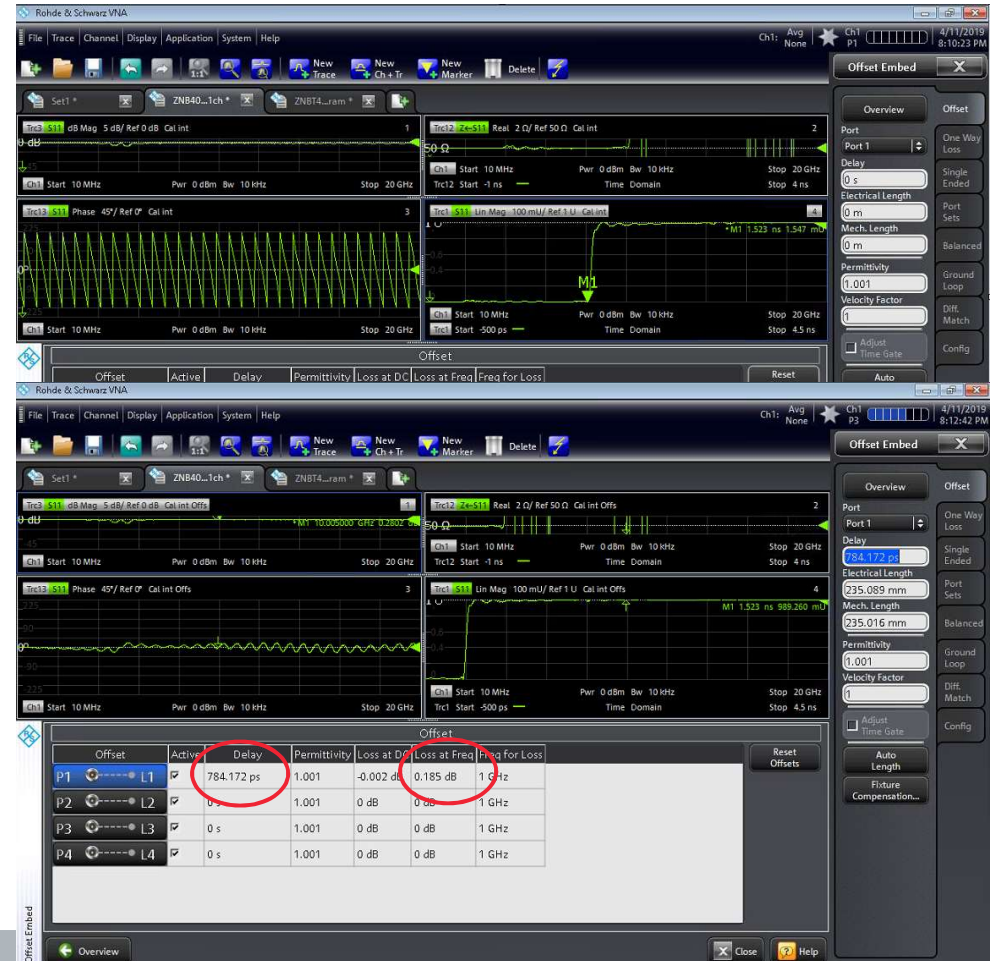
- Advantages:
 - Simple (requires only an OPEN)
 - Remove reflections
 - Remove extraneous loss
 - Remove extraneous phase shift/rotations
- Disadvantages:
 - Assumes line (to be removed) is Z_0



Alternative approaches

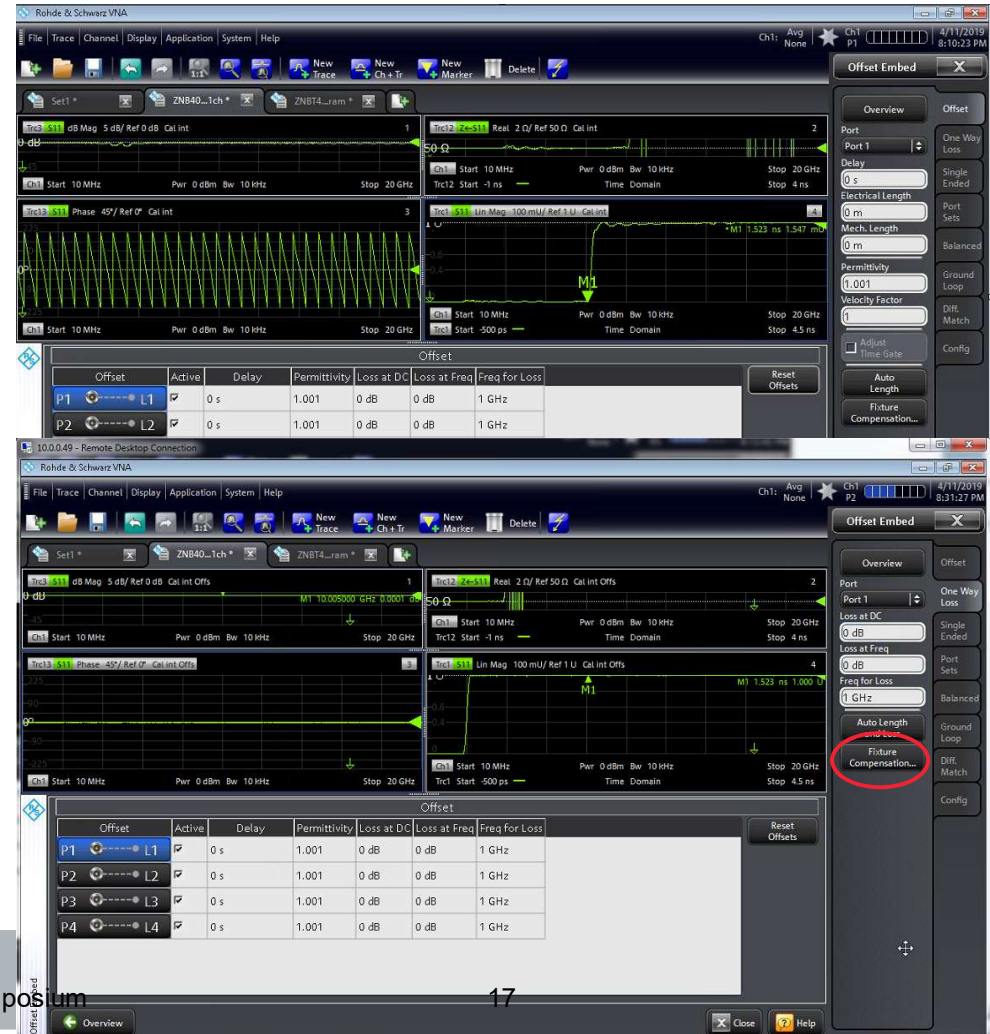
■ Auto Length & Loss

- Advantages:
 - Simple (requires only an OPEN)
 - Remove reflections
 - Remove extraneous loss
 - Remove extraneous phase shift/rotations
- Disadvantages:
 - Assumes line (to be removed) is Z_0



Alternative approaches

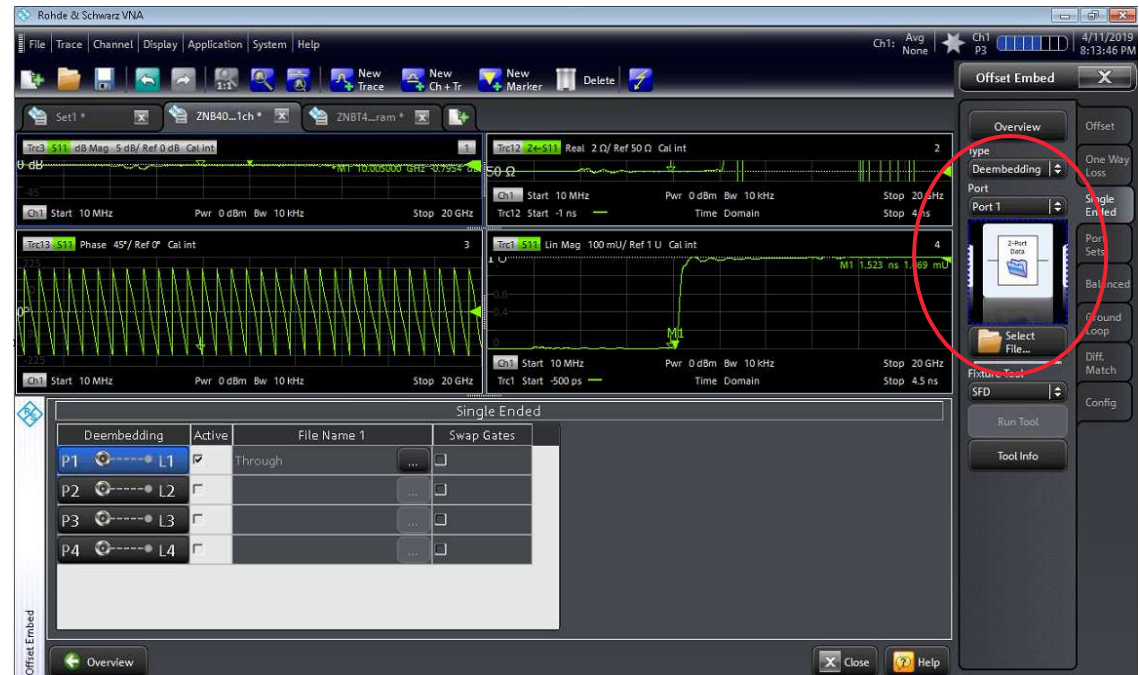
- Fixture Compensation
 - Advantages:
 - Simple (requires only an OPEN)
 - Remove reflections
 - Remove extraneous **loss**
 - Remove extraneous phase shift/rotations
 - Disadvantages:
 - Assumes line (to be removed) is Z_0
 - Can provide “overly optimistic” results



Alternative approaches

■ Fixture De-Embedding

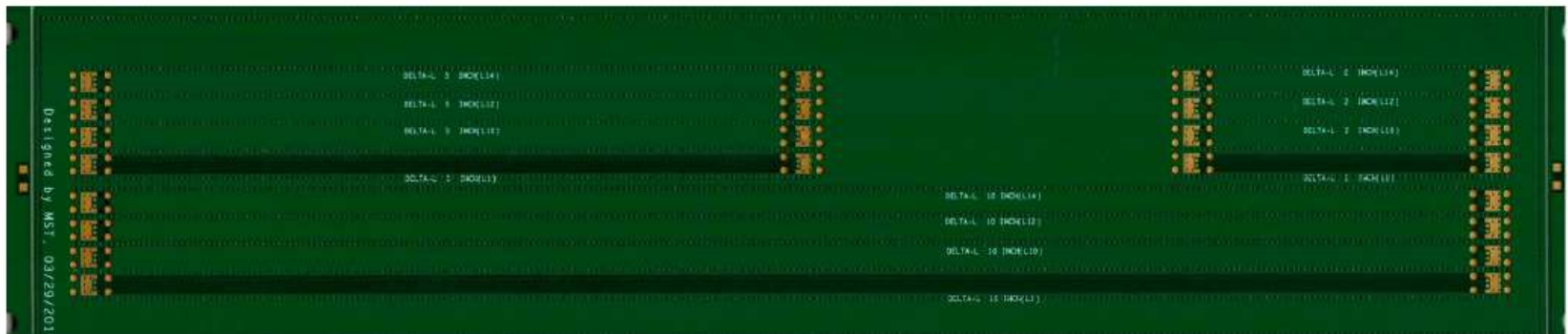
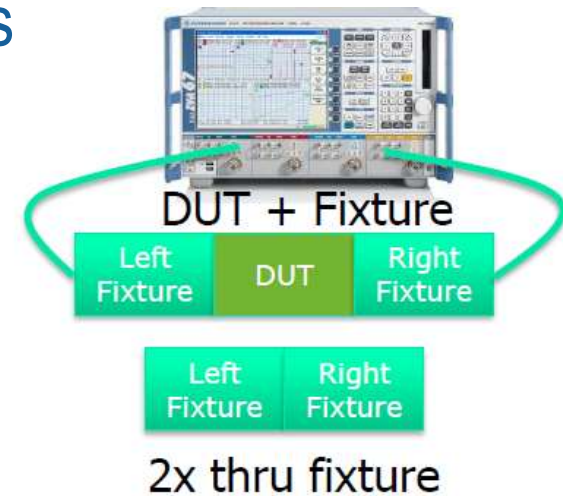
- Advantages:
 - Remove reflections
 - Remove extraneous loss
 - Remove extraneous phase shift/rotations
- Disadvantages:
 - Requires 2-port s-parameters
 - (measured or modelled)



Advanced Fixture De-embedding Techniques

2-X Thru Tools:

- Keysight: AFR (Automatic Fixture Removal)
- Packet Micro: SFD (Smart Fixture De-embedding)
- Ataitec: ISD (In-Situ De-embedding)
- Disadvantages:
 - May produce non-casual response



What is causality?

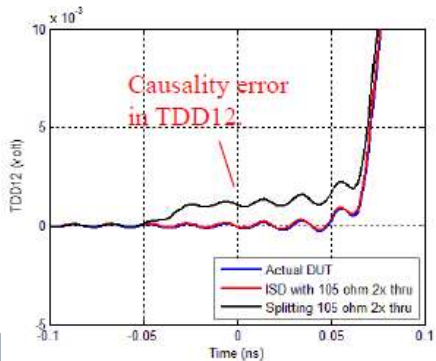
cau·sal·i·ty

noun

1. the relationship between cause and effect.
2. the principle that everything has a cause.

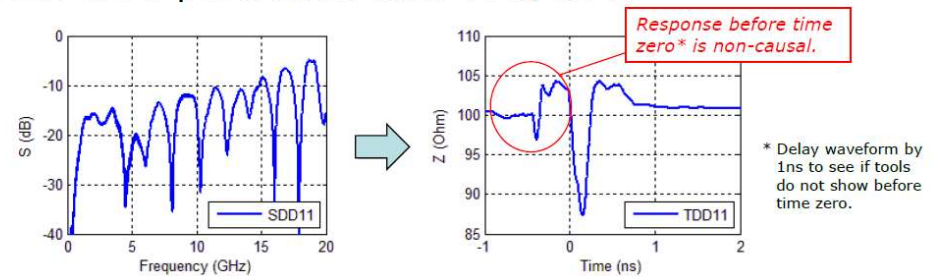
In other words:

Can not get something from nothing.

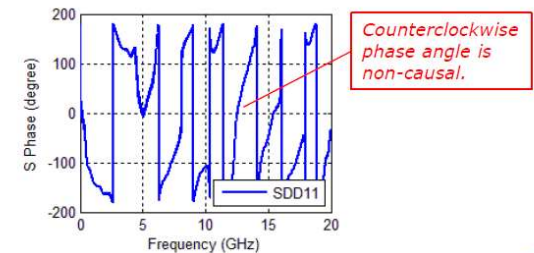


How to identify non-causal S parameter

- Convert S parameter into TDR/TDT.



- Check phase angle.

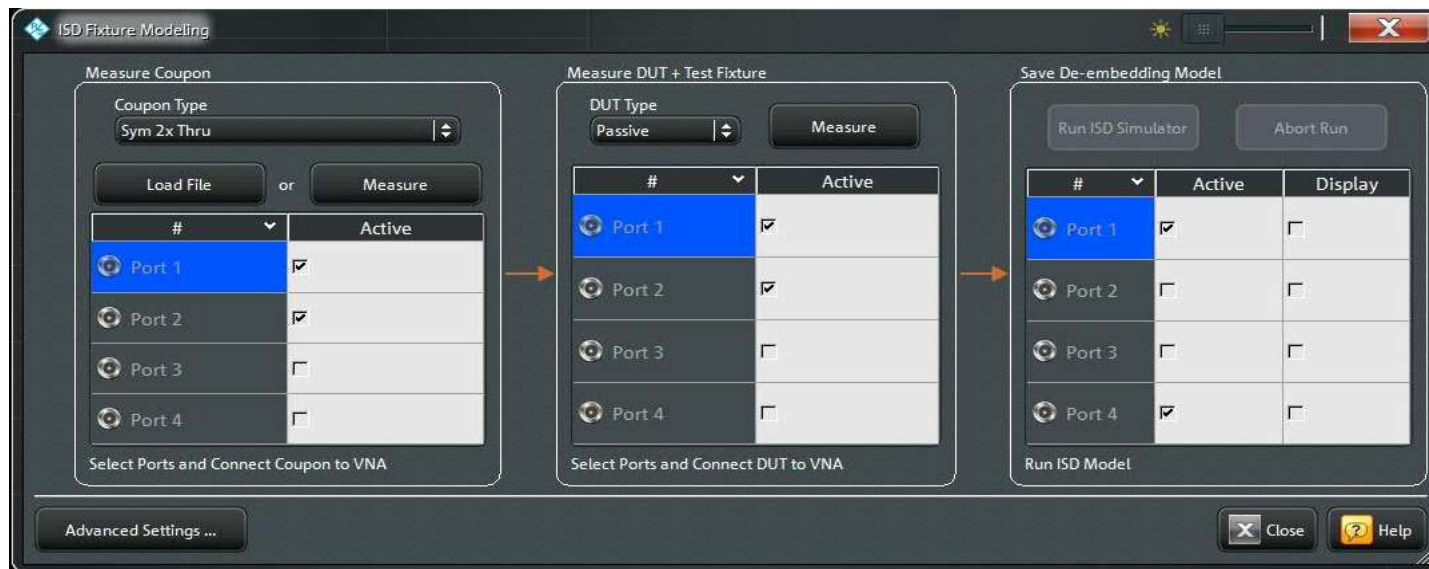


ISD and SFD Dialog in ZNB, ZNBT Vector Network Analyzers

3 steps: 1) Measure Coupon

2) Measure DUT

3) Run De-embedding



ISD provided by Ataitec, SFD provided by PacketMicro

