# Do Something Really Useful with Time Domain Processing for VNAs

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Constant Wave

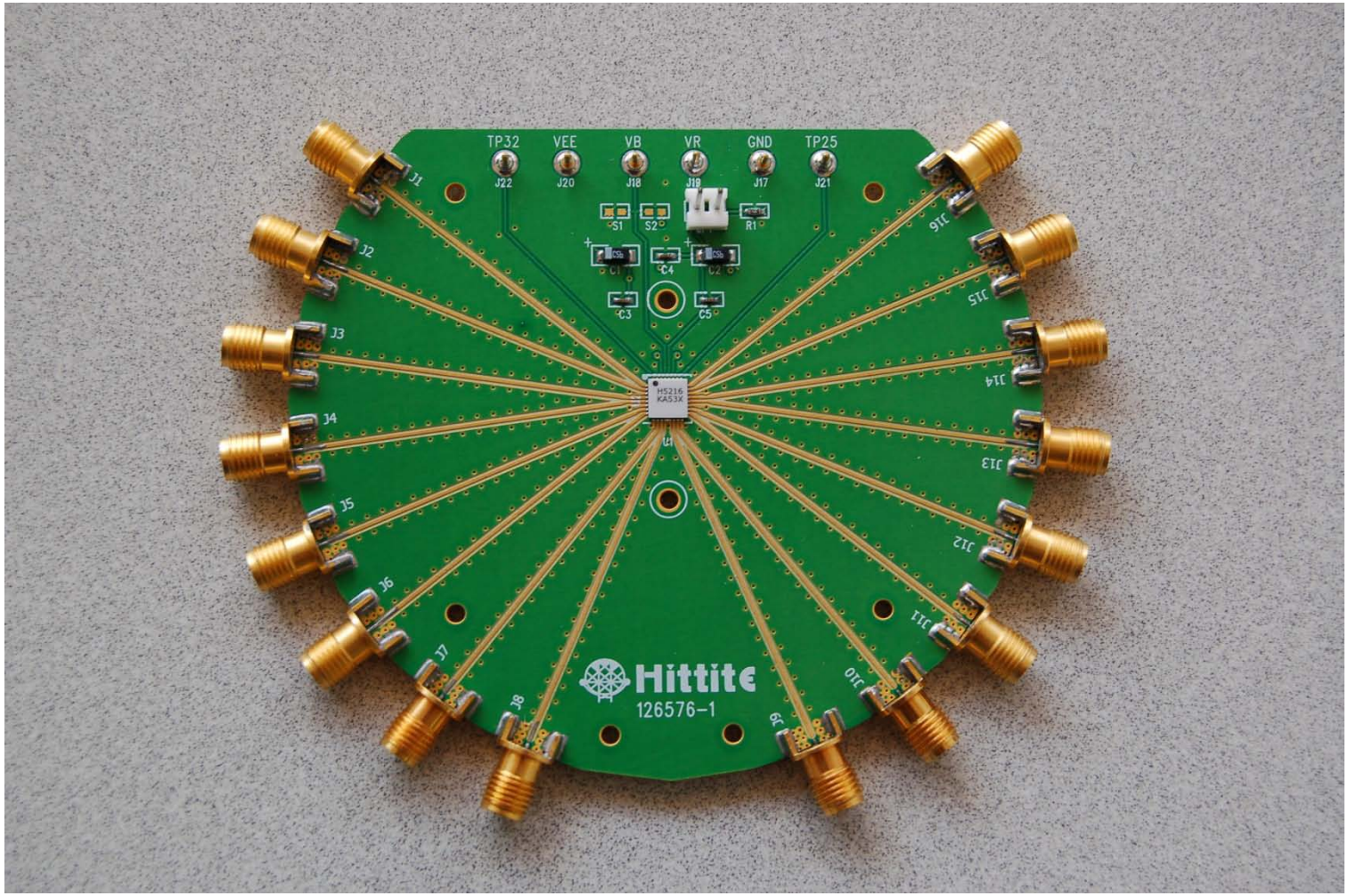
Time is nature's way of keeping everything from happening at once.

– Woody Allen or Albert Einstein

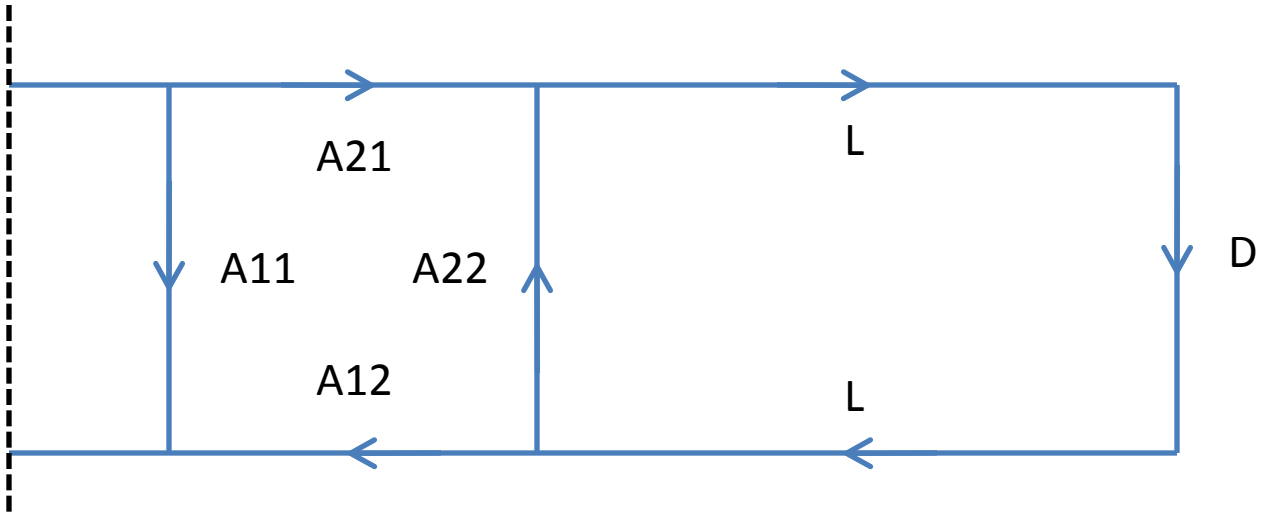
# VNA Measurement Problem

- Easy to calibrate a VNA at cable ends
- Harder to calibrate at DUT locations on a PC board
- Propose a simple solution to de-embedding the measurement of a DUT on a PC board
- Call this method “Time Domain Substitution”

# Example: Eval Board De-embedding



# A Mathematical View




- General model of a launch (A11, A12, A21, A22), a transmission line (L) and a DUT (D)
- Want to extract DUT from a measurement of the entire system

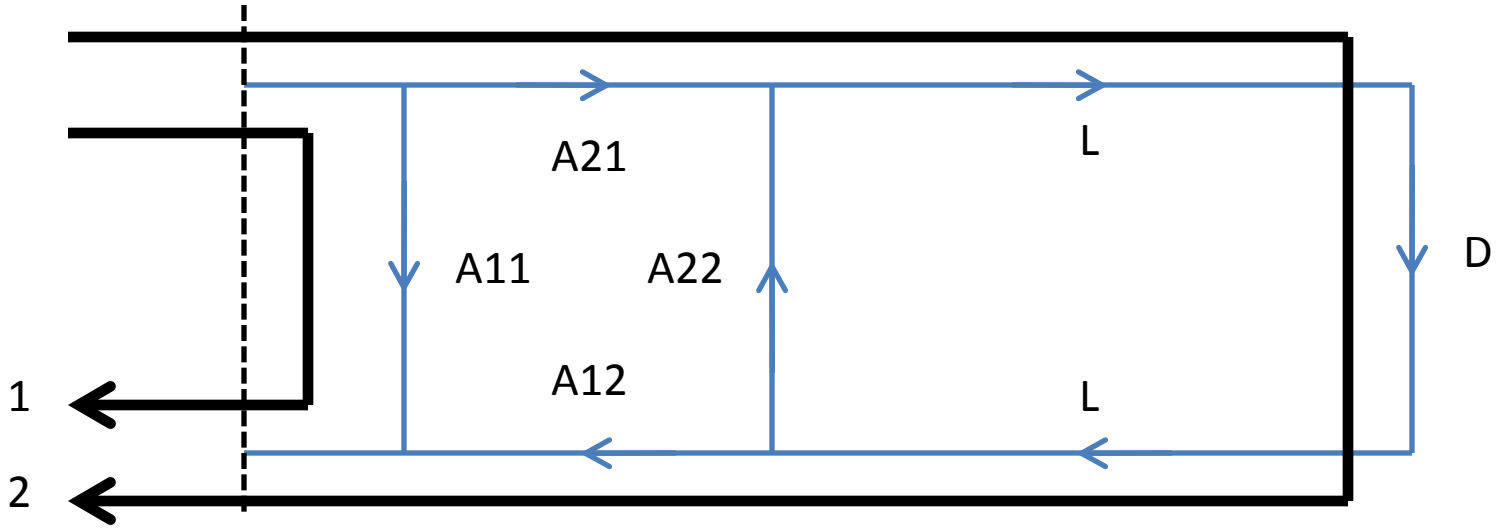
# In the Frequency Domain

- S11 measured is

$$S11 = A11 + \frac{L^2 D\, A12\, A21}{1 - L^2 D\, A22}$$

- Solving for D requires knowing A11, A12, A21, A22 and L
- Resort to re-calibration to move the reference plane down to the DUT

# In the Time Domain




- First reflection in time is S11 = A11
- Second reflection in time is S11 = A21 A12 $L^2$ D
- Note the simplicity of the second equation

# Time Domain Substitution

- Considering the second reflection in time
- Measure S11 with the DUT in place, call it M1

$$M1 = L^2\ A12\ A21\ D$$

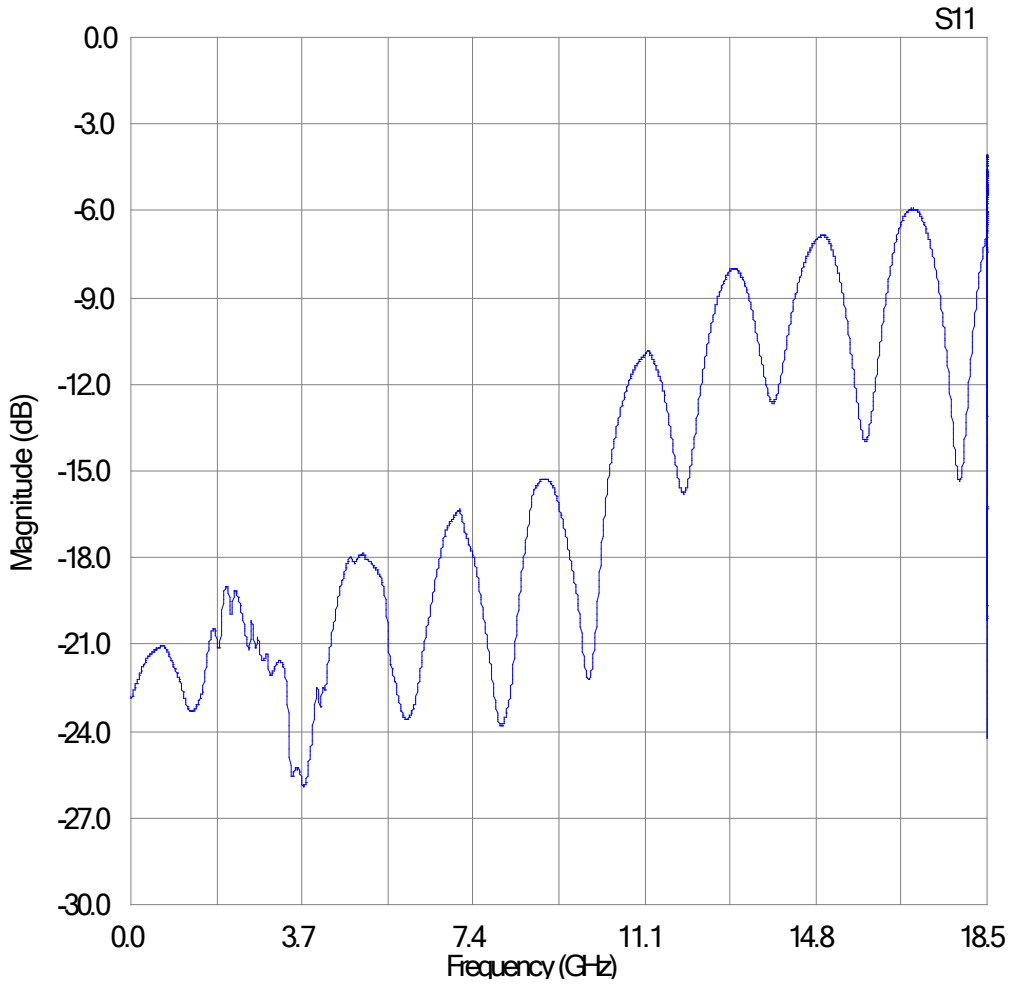
- Measure S11 with something known in place (short or an open), call it M2

$$M2 = L^2\ A12\ A21\ K$$

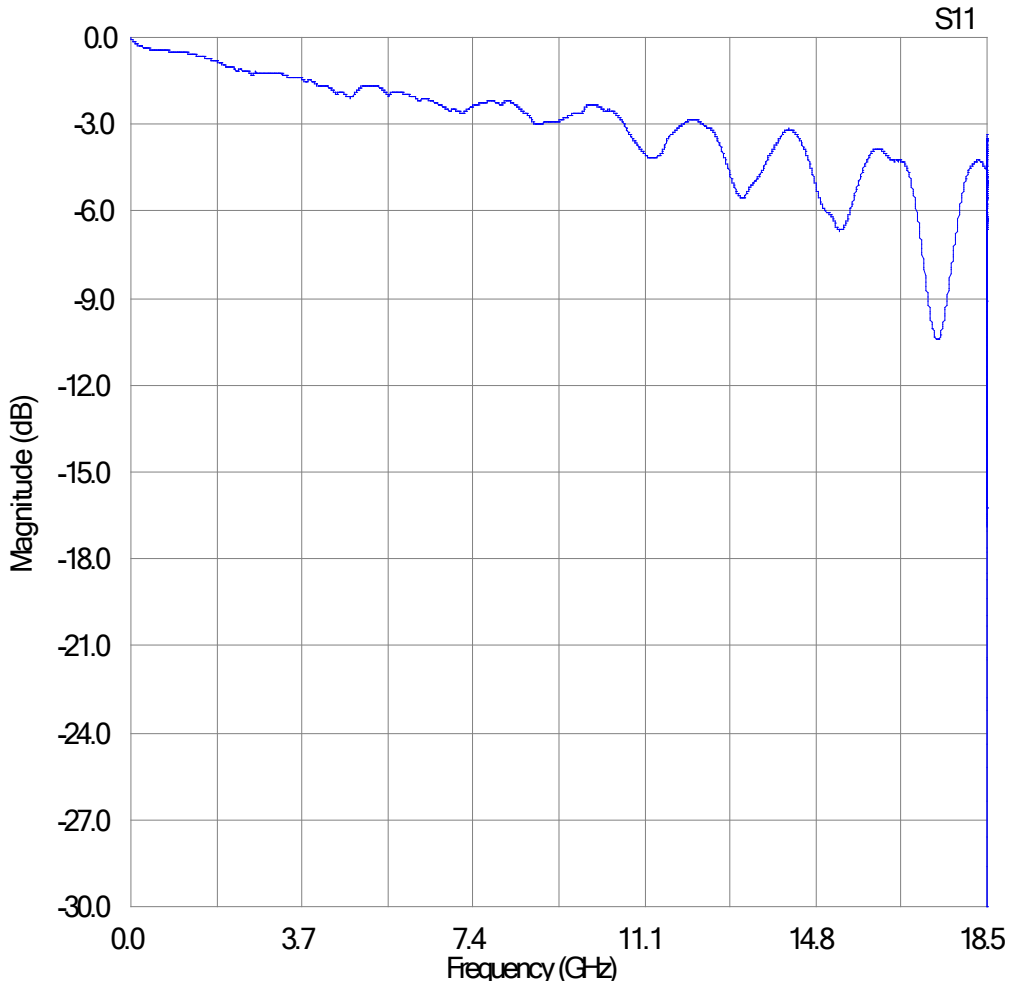
- Solve for the DUT

$$D = K\frac{M1}{M2}$$

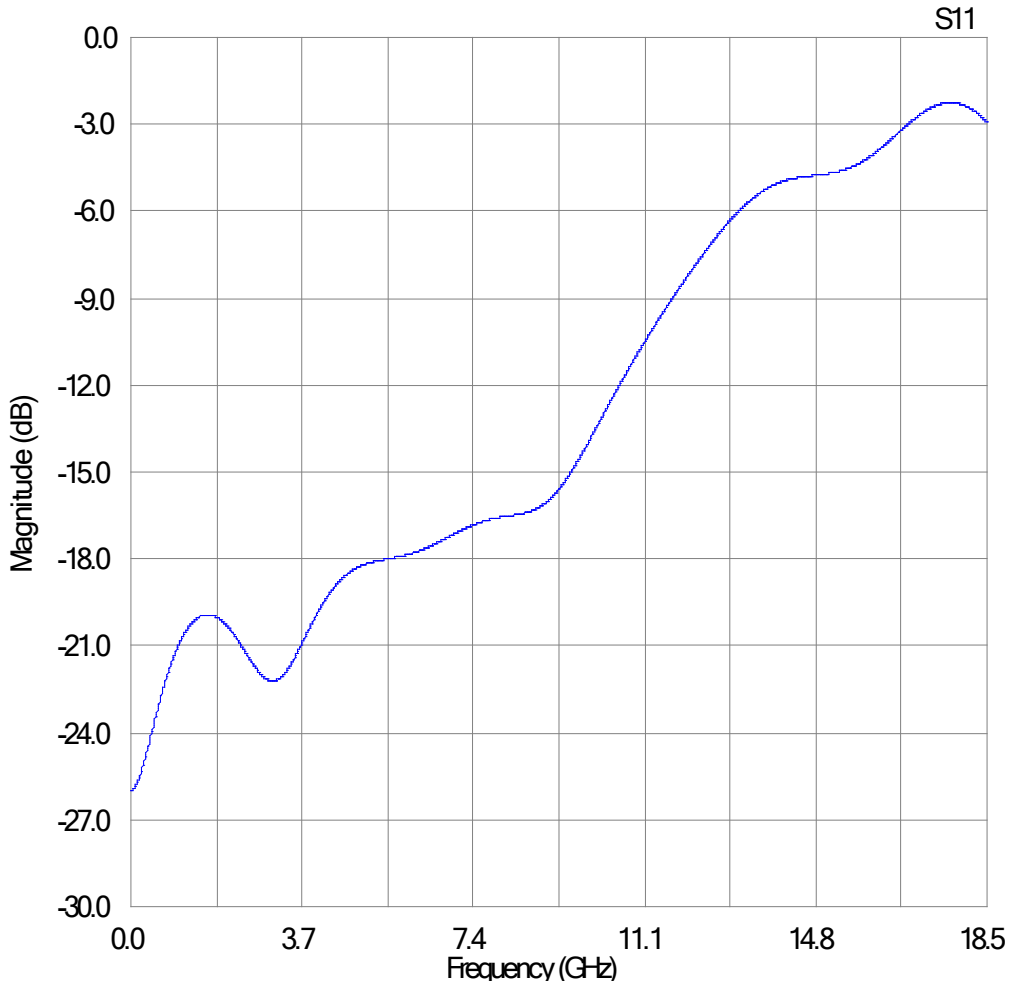
# Example: S11 of an Eval Board with DUT



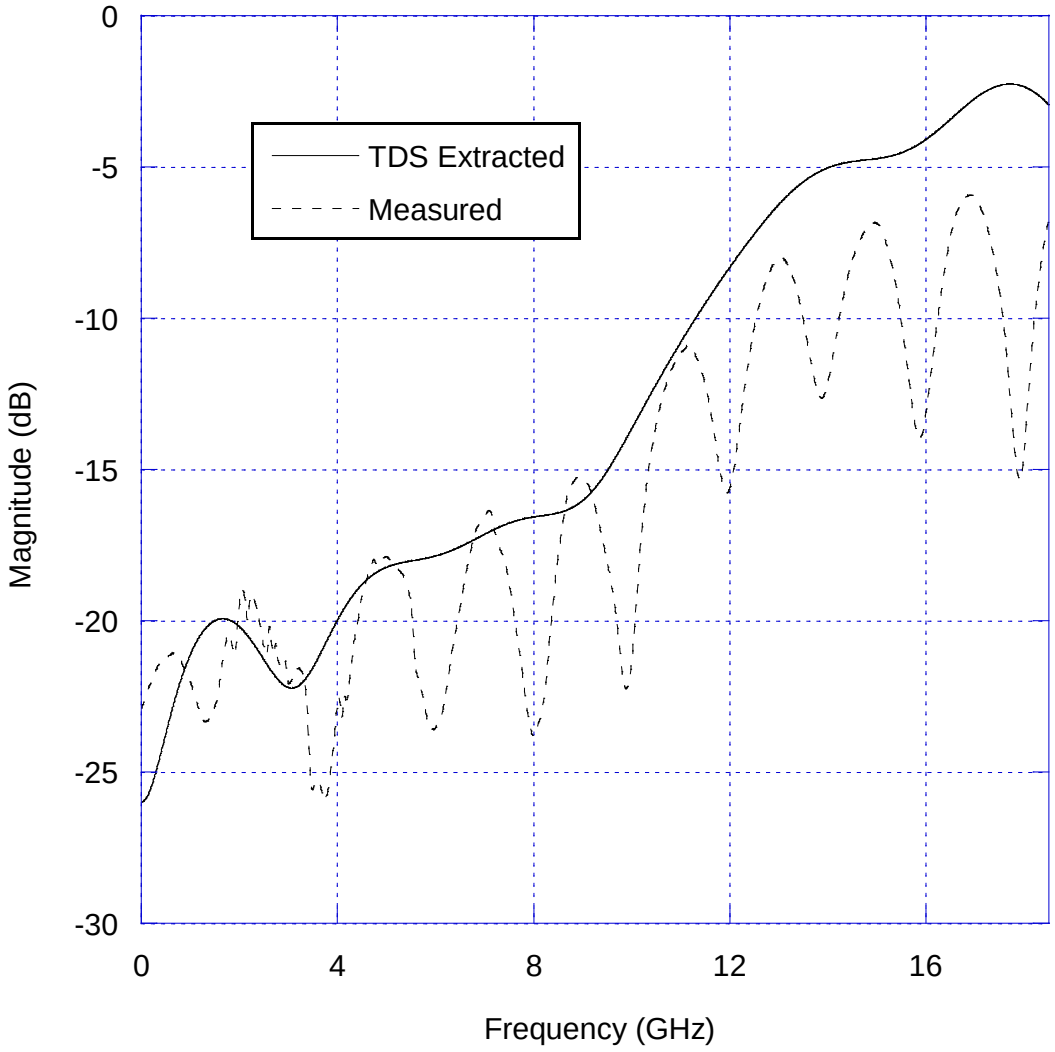
# Example: S11 of an Eval Board with Short at DUT



# Example: S11 of the DUT after Time Domain Substitution



# Example: Overlay Plot



# Time Domain Substitution Advantages

**Time Domain Substitution**

- Cheap and simple calibration standards
- No socket needed
  - Cal done with DUT in place
- No port-to-port standards for 2-port de-embedding
- Extension to n-port requires only 1-port standards

**Frequency Domain**

- Expensive and complex calibration standards
- Need socket for DUT
  - DUT must be removable
- Need port-to-port standards for 2-port de-embedding
- Extension to n-port requires 1-port and port-to-port standards

# 1-port De-embedding Process

**Time Domain Substitution**

1) Cal at cable ends
2) Measure the board with DUT
3) Measure the board with short at DUT input
4) De-embed DUT response

**Frequency Domain**

1) Cal at cable ends
2) Create Short-Open-Load standards at location of DUT
3) Measure Short at location of DUT
4) Measure Open at location of DUT
5) Measure Load at location of DUT
6) Characterize adapter between cable and DUT
7) Measure the board with DUT
8) De-embed DUT using characterization of adapter

# Further Discussion

- For the sake of time, some of the details of how Time Domain Substitution is implemented have been omitted in this discussion
- Time Domain Substitution is part of Spectro VNA, Constant Wave's time domain software tools for VNAs
- For more details, come visit Constant Wave at booth 2937
- Many thanks to Hittite Microwave in Colorado Springs for their help with this work