IEEE SW Test Workshop
Semiconductor Wafer Test Workshop

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# Probe Card Characterization in Time and Frequency Domain


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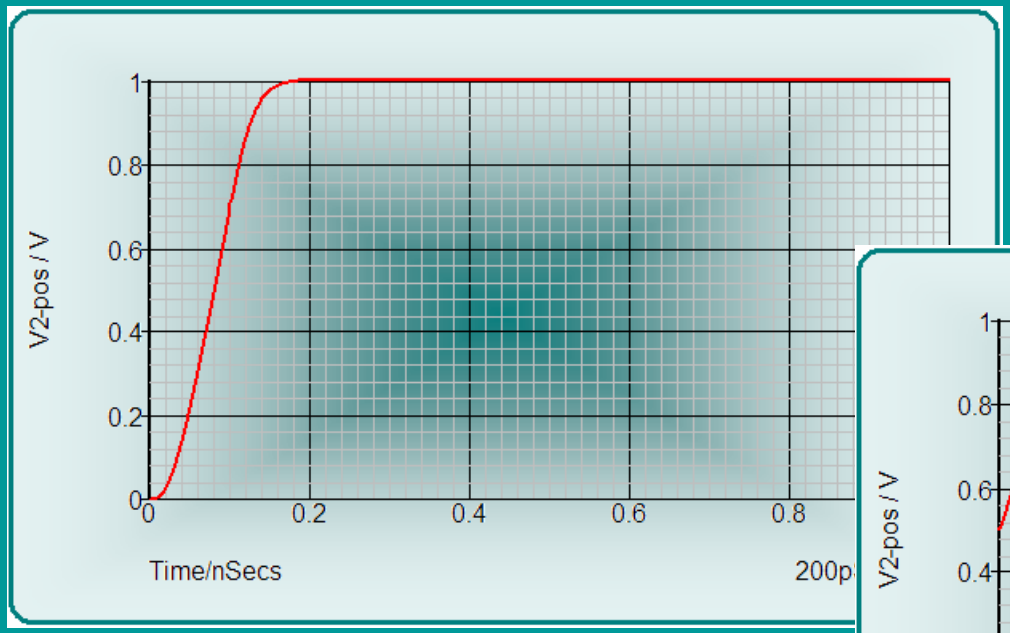
# Objectives

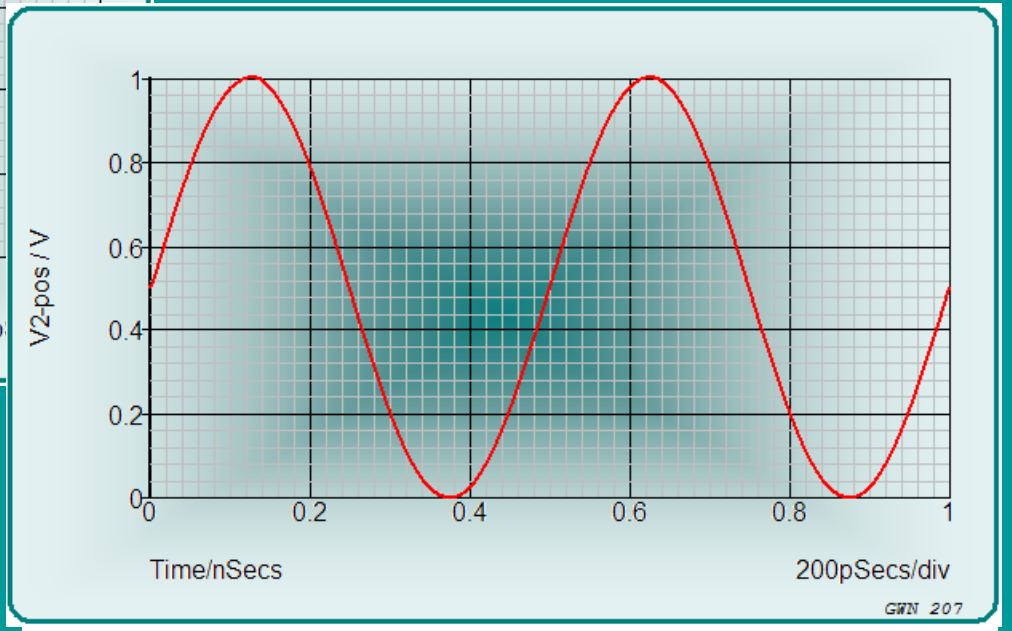
- Illuminate differences between Time Domain (TD) and Frequency Domain (FD) probe card measurements
- Explore thru and reflection measurements
- Identify measurement limitations due to terminations

# Time vs. Frequency Domain

- Time domain (TD) instrument records response of the circuit to a step excitation
- Frequency domain (FD) records response of the circuit to a sine wave of changing (swept) frequency
- Time and Frequency domain linked by Fourier transform - many test instruments are capable of operating in both domains

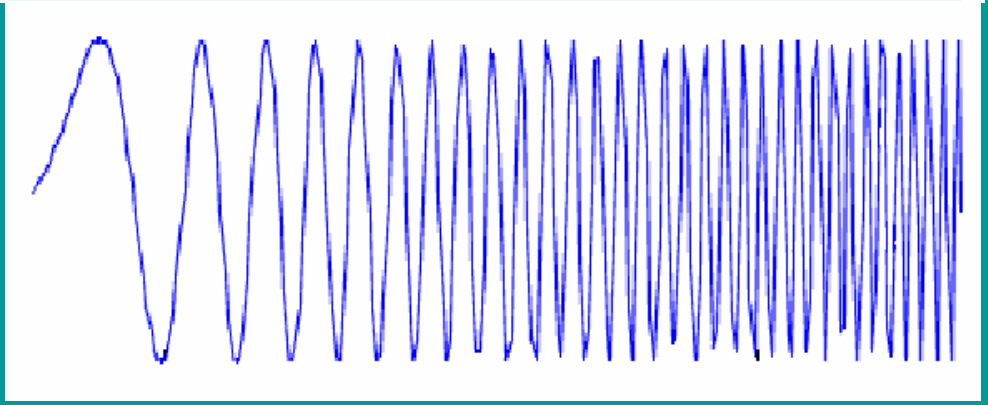
# TD vs. FD



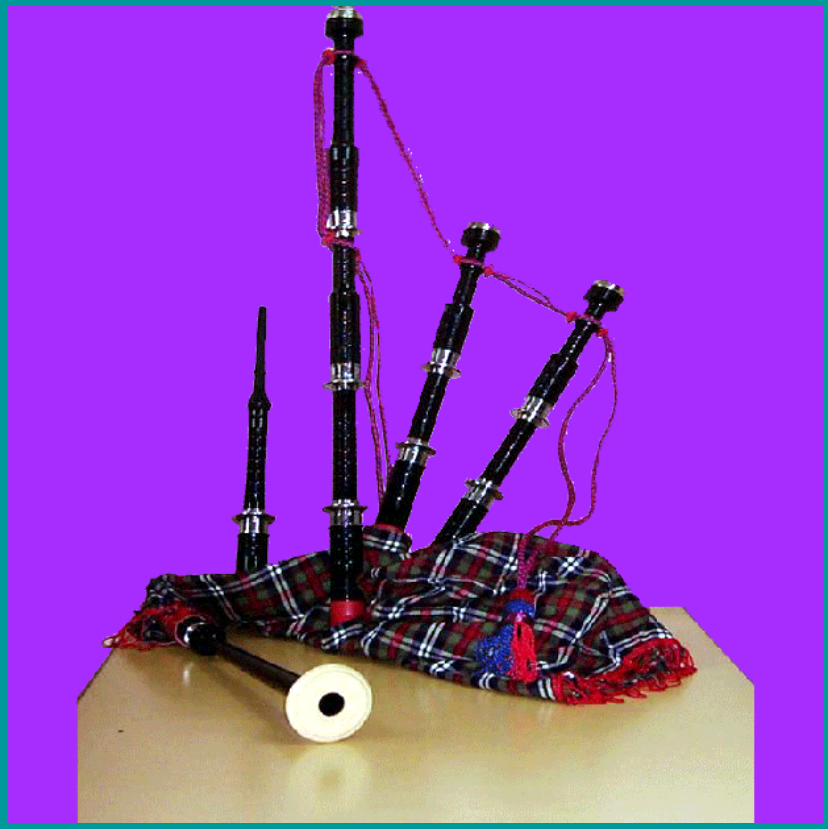

- Time domain:
  One step

- Frequency domain:
  Sine wave with
  swept frequency



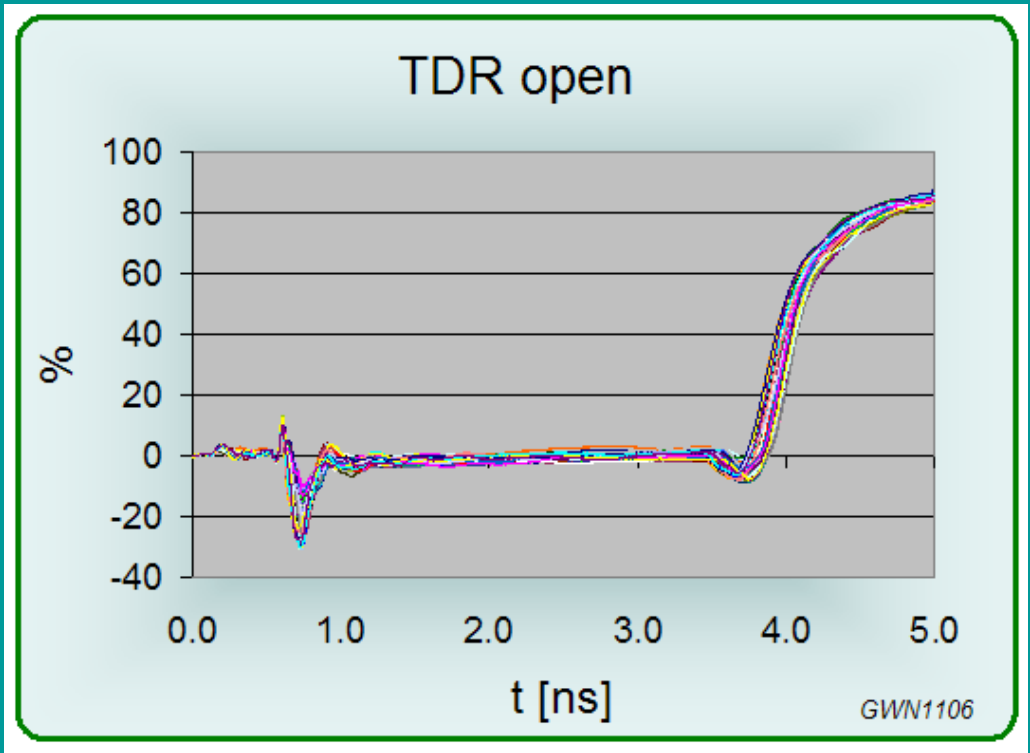
# TD vs. FD

- TD explores obstacles



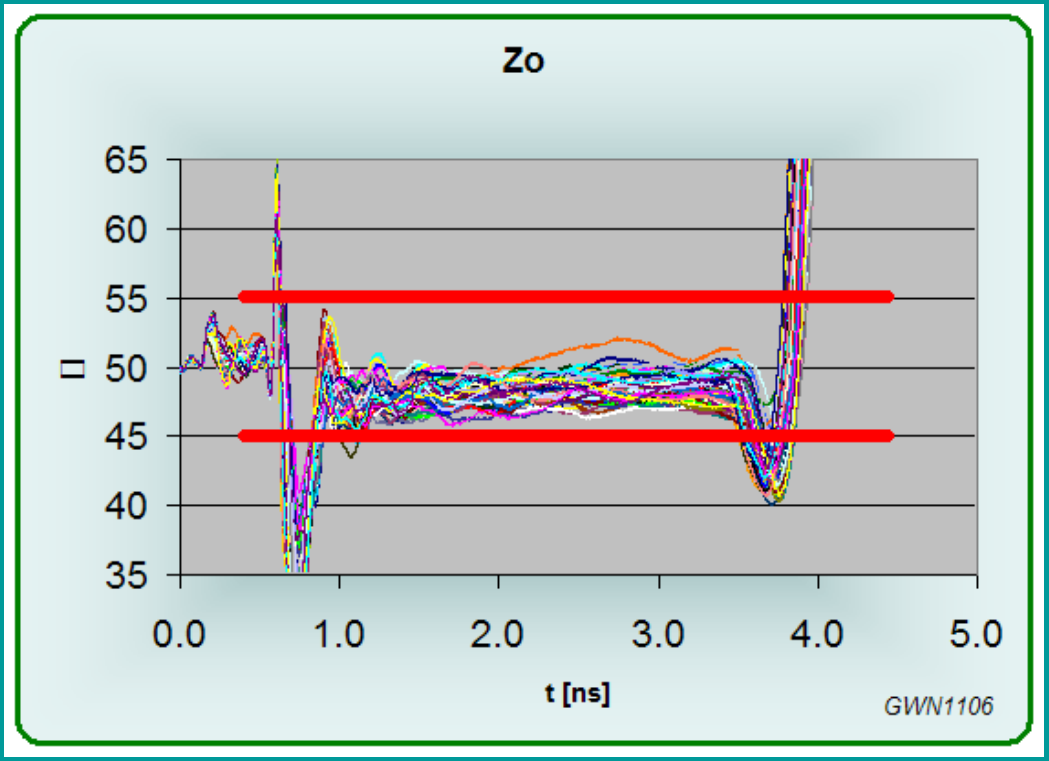
- FD explores individual response ‘components’

# Example: Probe Card TDR



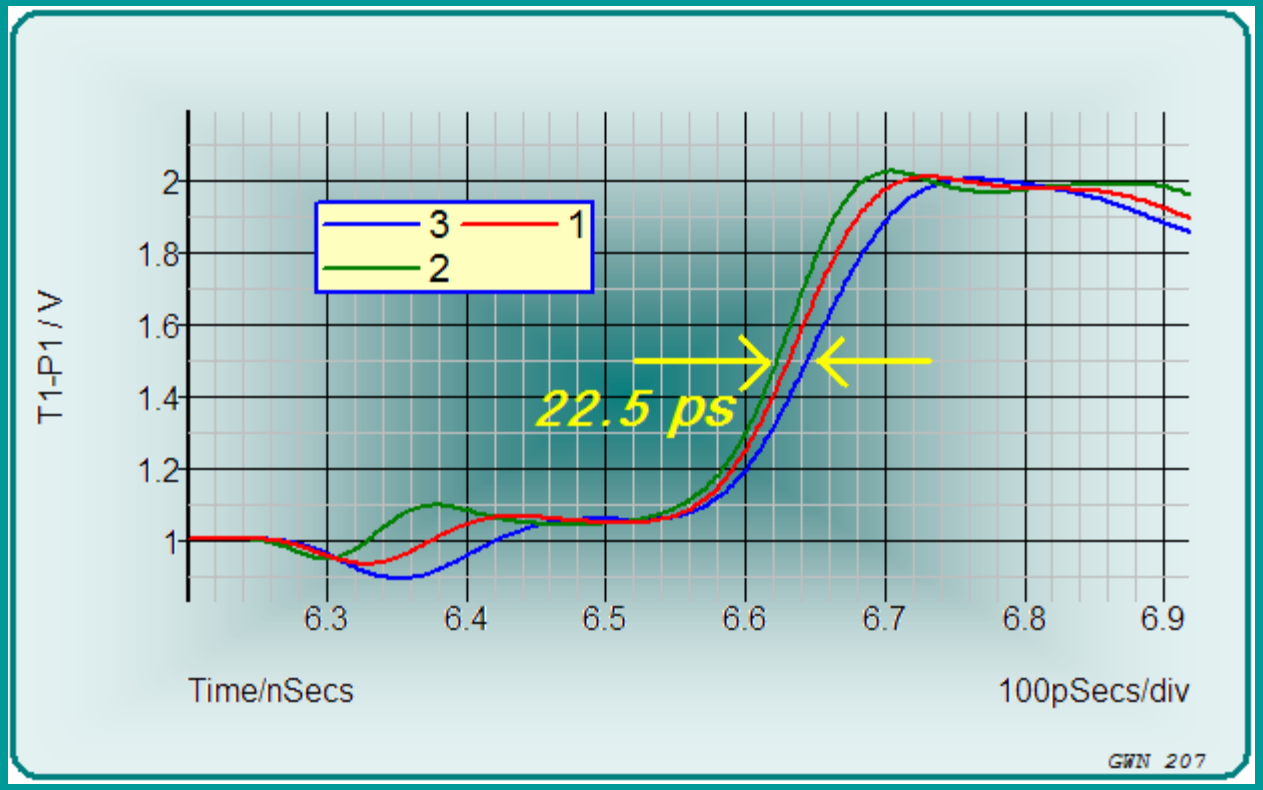

- Performed with an open circuit at the probes- examines impedance levels, discontinuities and timing differences (skew)

# Probe Card TDR



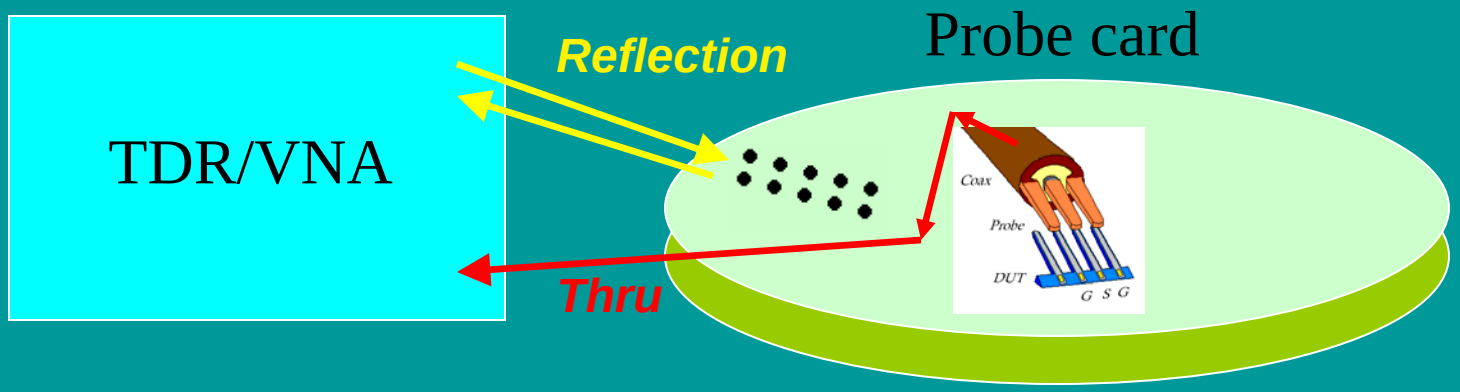

- Impedance graph gives info about the properties of PCB transmission lines

# Model results: Skew




- Despite perfectly matched line lengths, different parasitics (1-3) cause different delay times

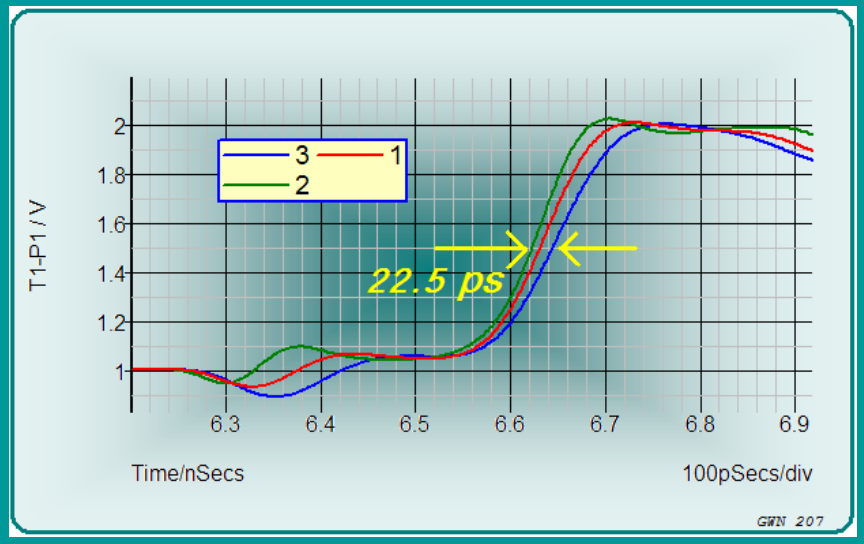
# Thru vs. reflection measurement




***The complexity of a 'thru' setup far exceeds that for 'reflection'***

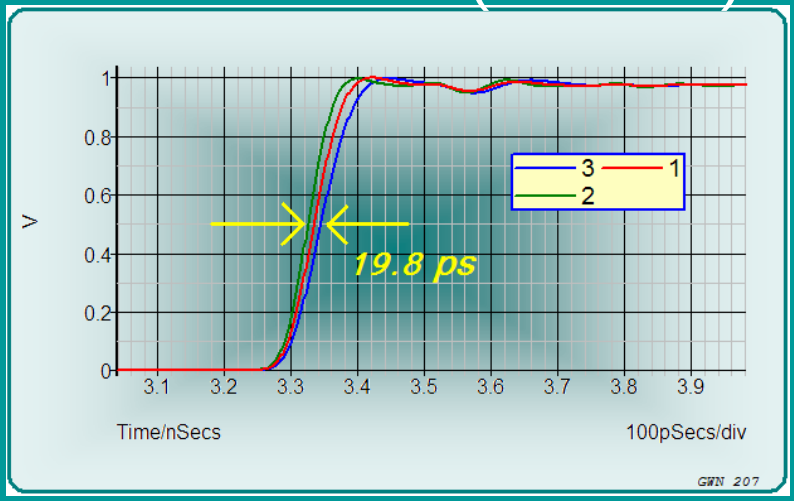
- Thru measurement gives response of signal path from source to load.
- Reflection measurement contains the effects of two signal passes through the signal path.
- Thru measurement is more representative of the effects the signal path will have on the signal.

# Compare: Reflection vs. transmission measurement



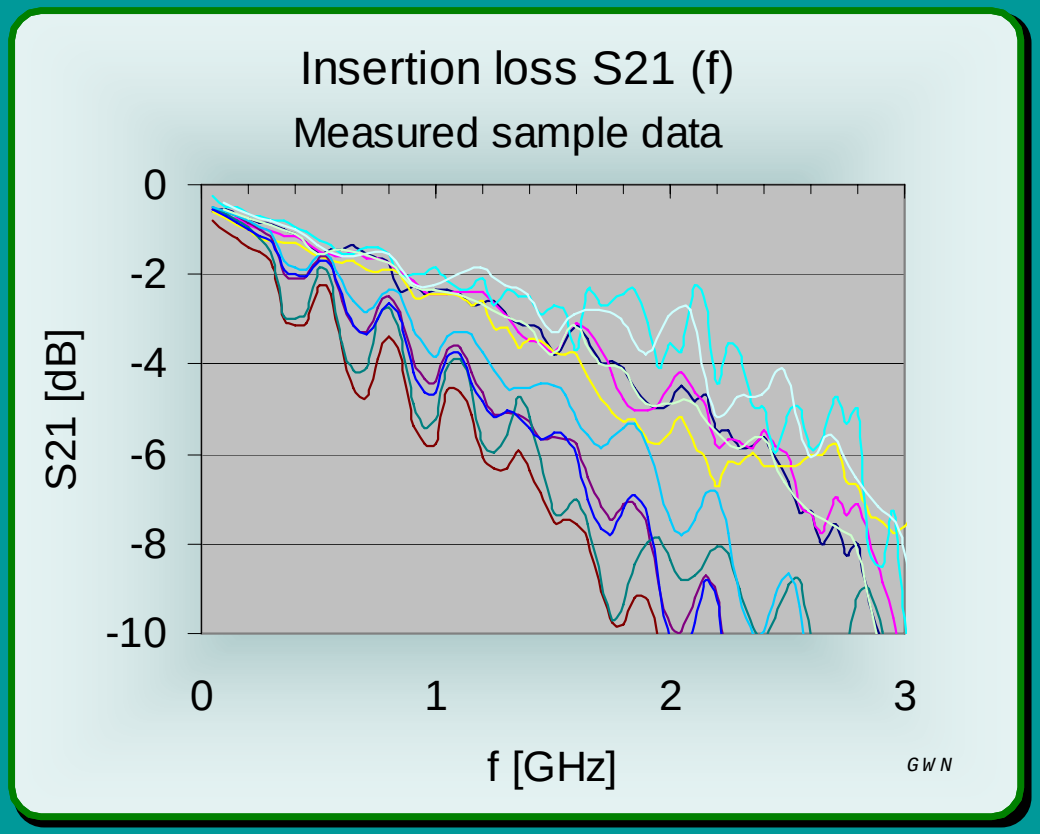

Reflection (skew = 2x actual because of round trip, i.e. skew = 11.25 ps)

Transmission (skew x1)



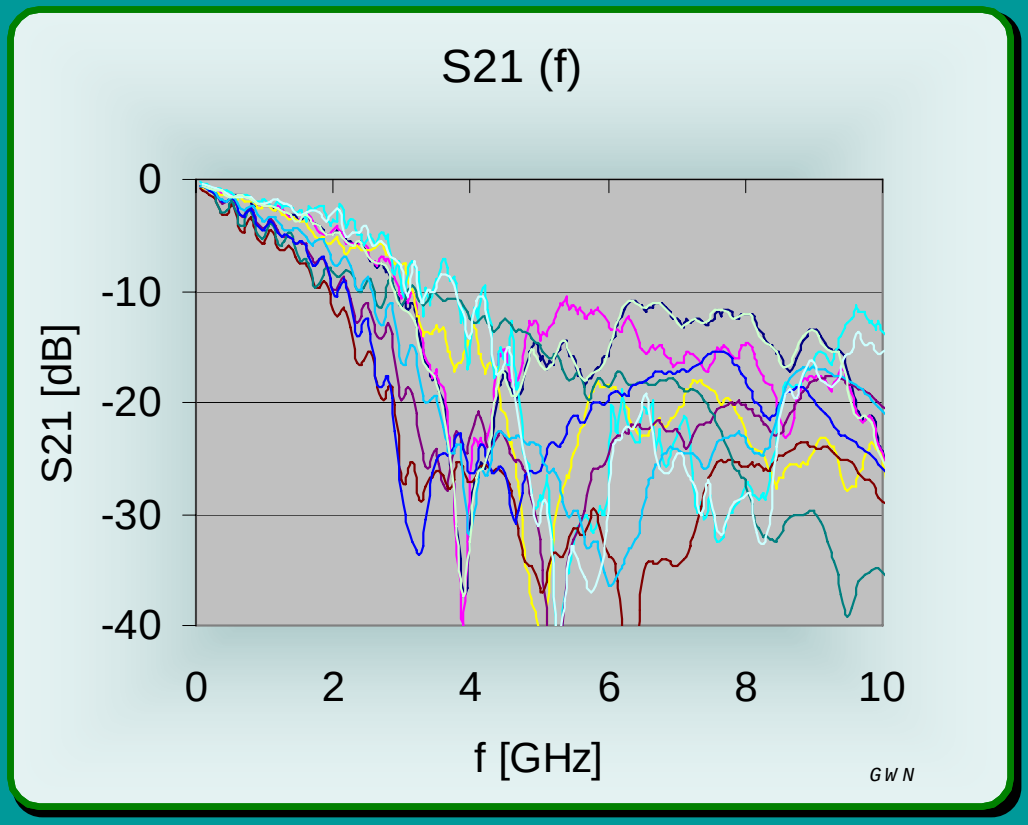

- Parasitics at the probes increase the skew, this is not appropriately captured in a reflection measurement

# Measurement results: Insertion loss (S21)



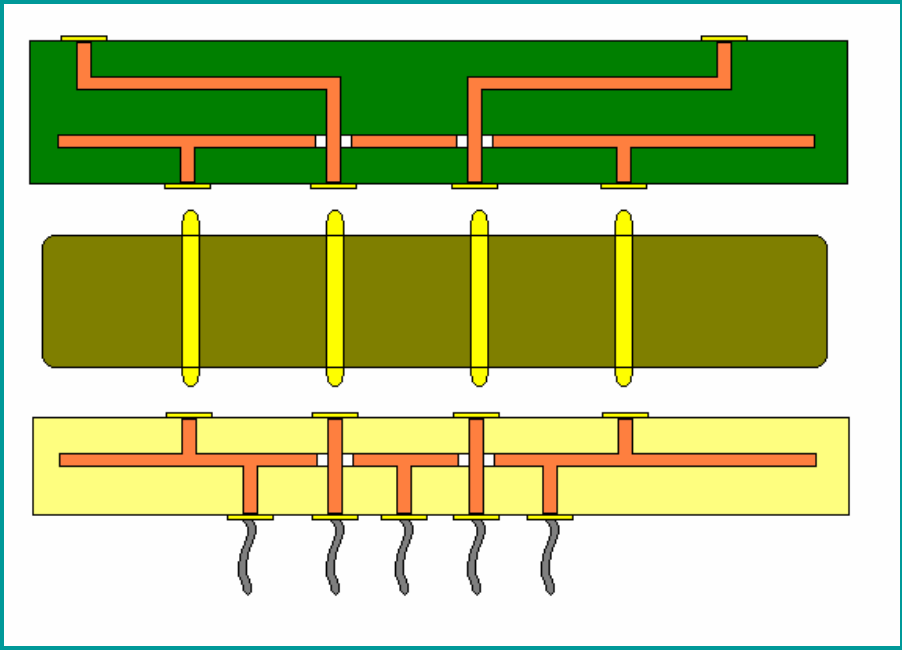

Thru measurement into a 50 Ohm load - apples and oranges selection, but all S21 increase more or less steadily toward 3 GHz

# Expanded frequency range



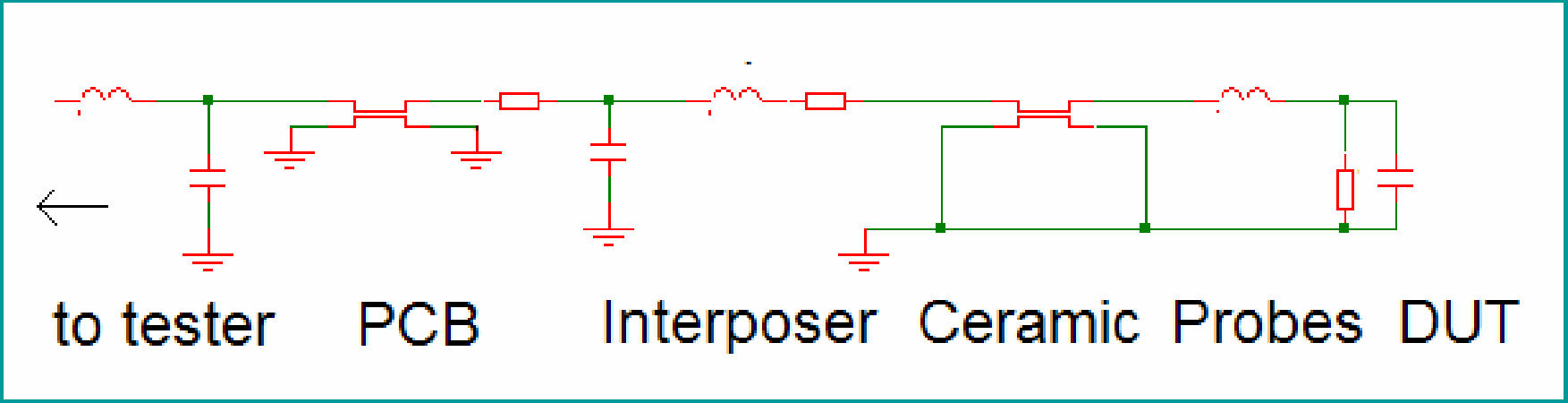

- Resonances become apparent; an examination of causes can be made via SPICE model

# Probe card components



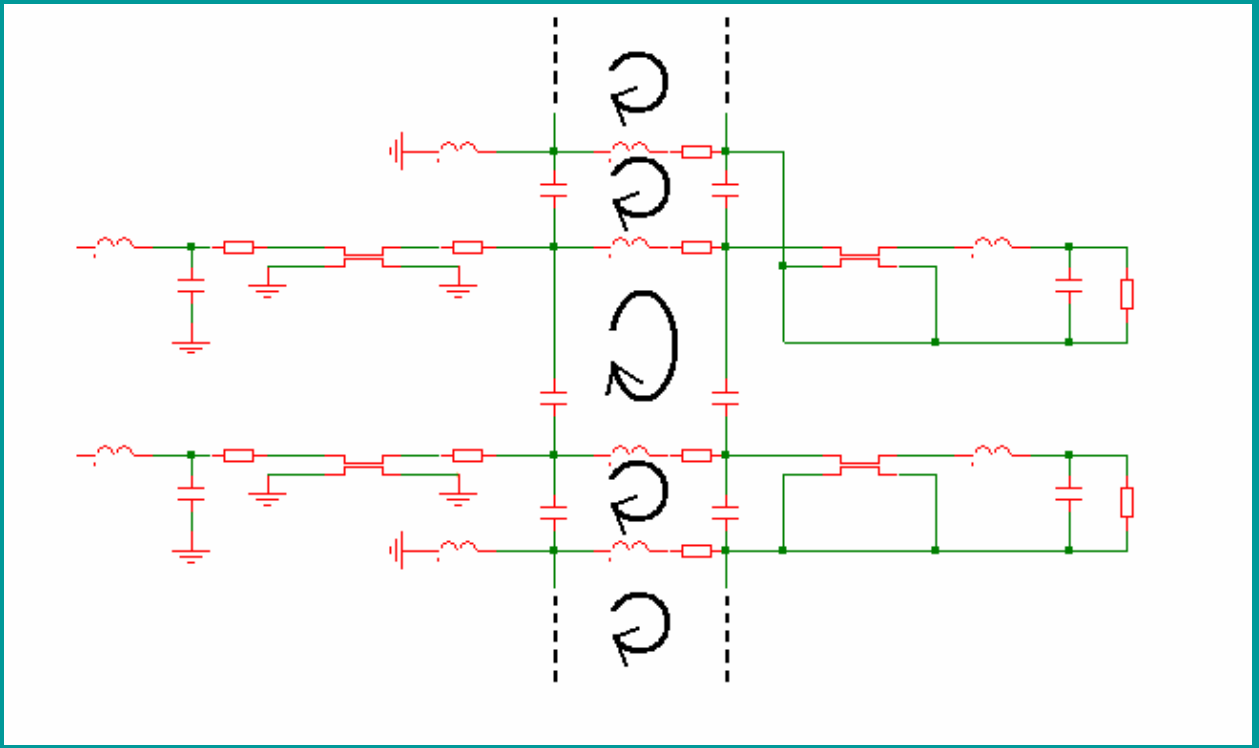
- PCB
- Interposer
- Ceramic
- Contactors

# A simple equivalent circuit



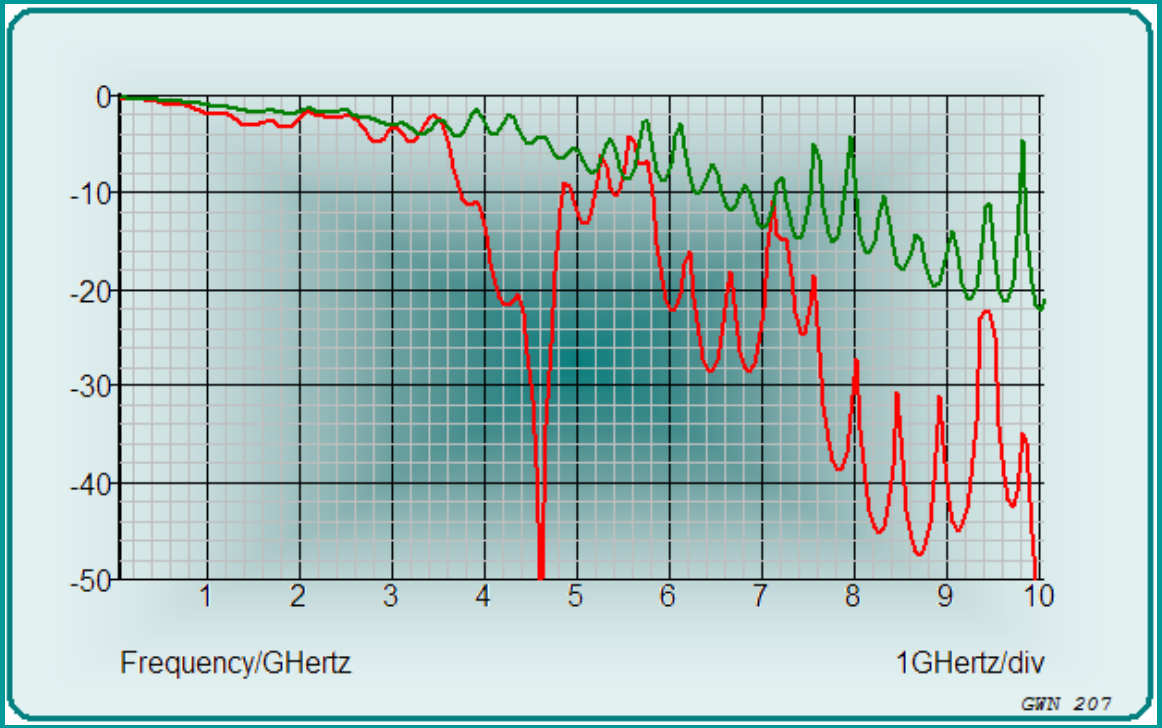

- Tester connector and PCB to ceramic interposer are modeled as lumped inductors
- Via parasitics are modeled as lumped capacitances
- PCB and ceramic are modeled as lossy transmission lines

# Expanded interposer model



The simple model of the interposer can be expanded to include interactions with adjacent connections. The interposer has many contacts that are electrically coupled with each other.

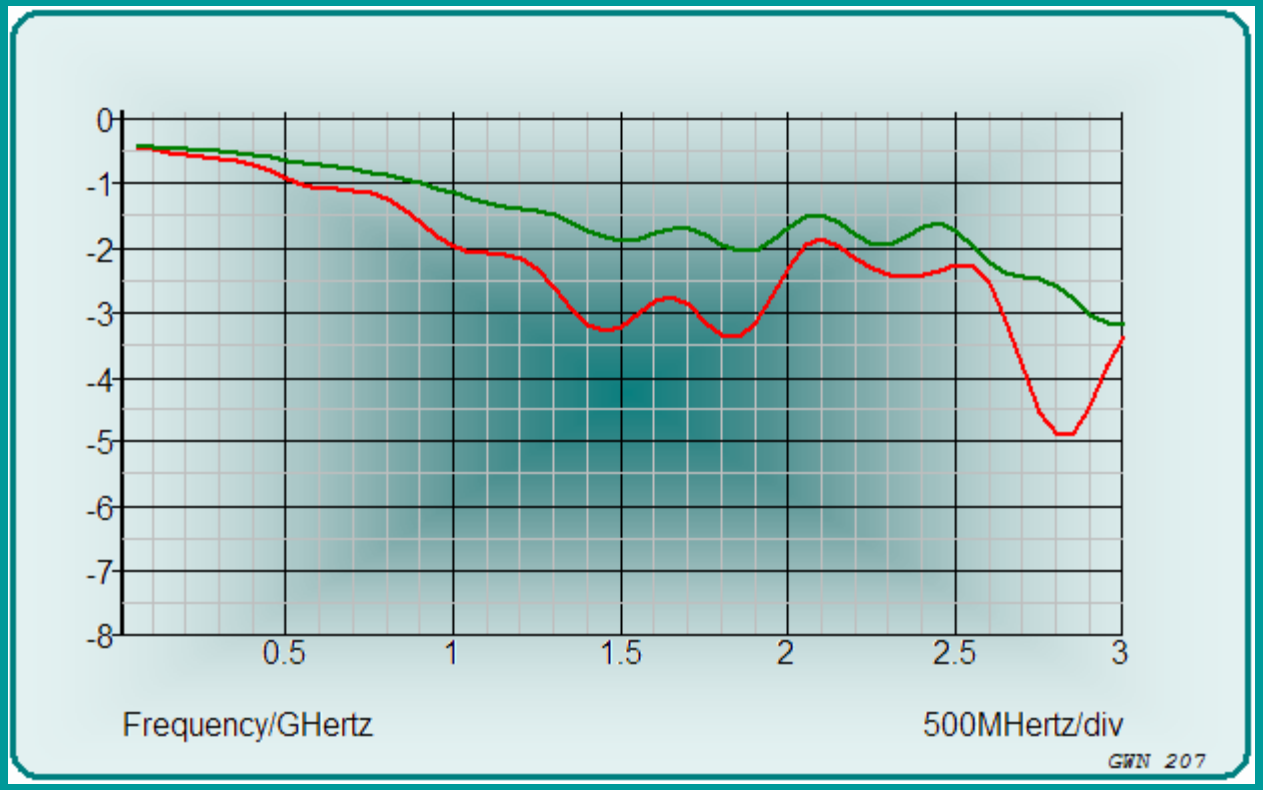
# Model results: S21




- Thru model: Simple (green), expanded (red)

  Strong resonance dips appear at elevated frequencies for the expanded interposer model

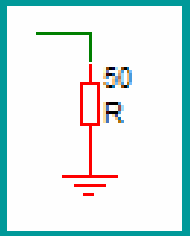
# Lower frequency detail




Components with resonances can adversely affect the performance at lower frequencies (red curve)

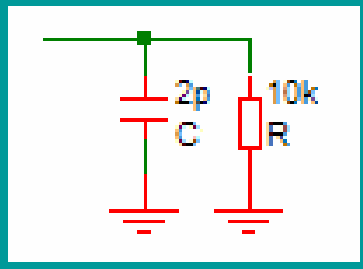
# Effect of terminations

- Thru measurements generally require a 50 Ohm termination at the receiver end.

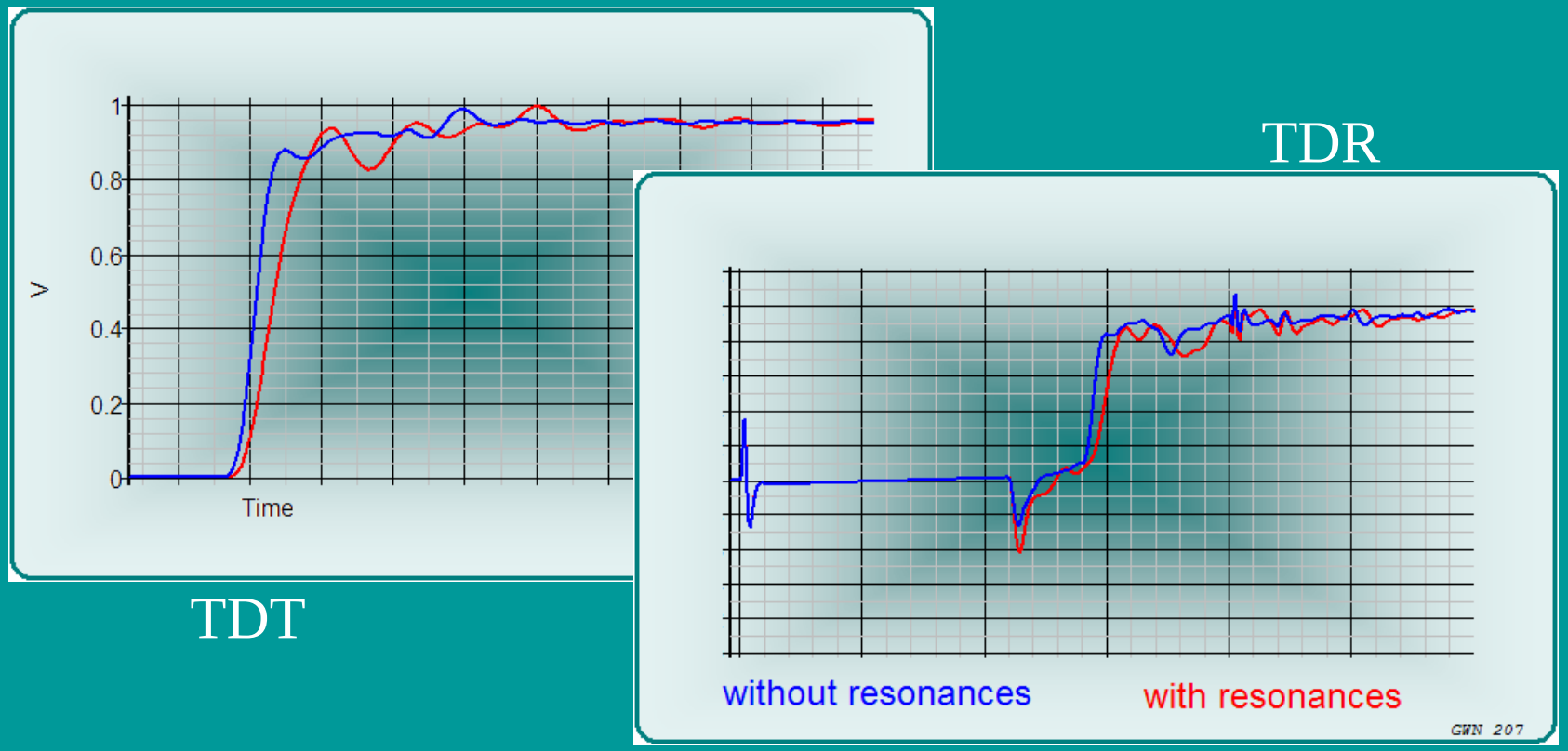



- The actual device being tested does not necessarily present a load of 50 Ohms.

*Example:*

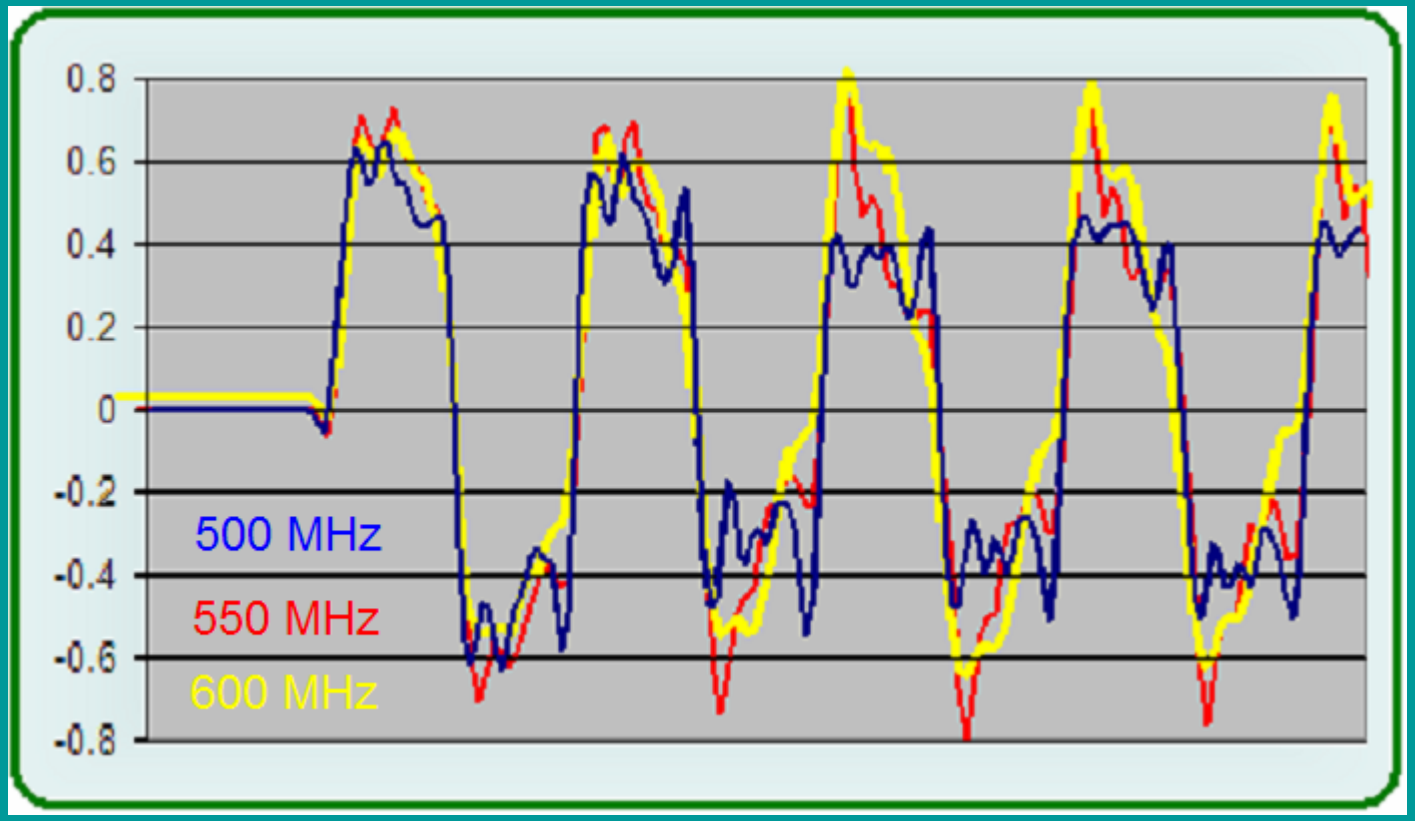


# Model results: Time domain




- Model for a single step excitation with and without resonances: Only a modest resonance signature is apparent

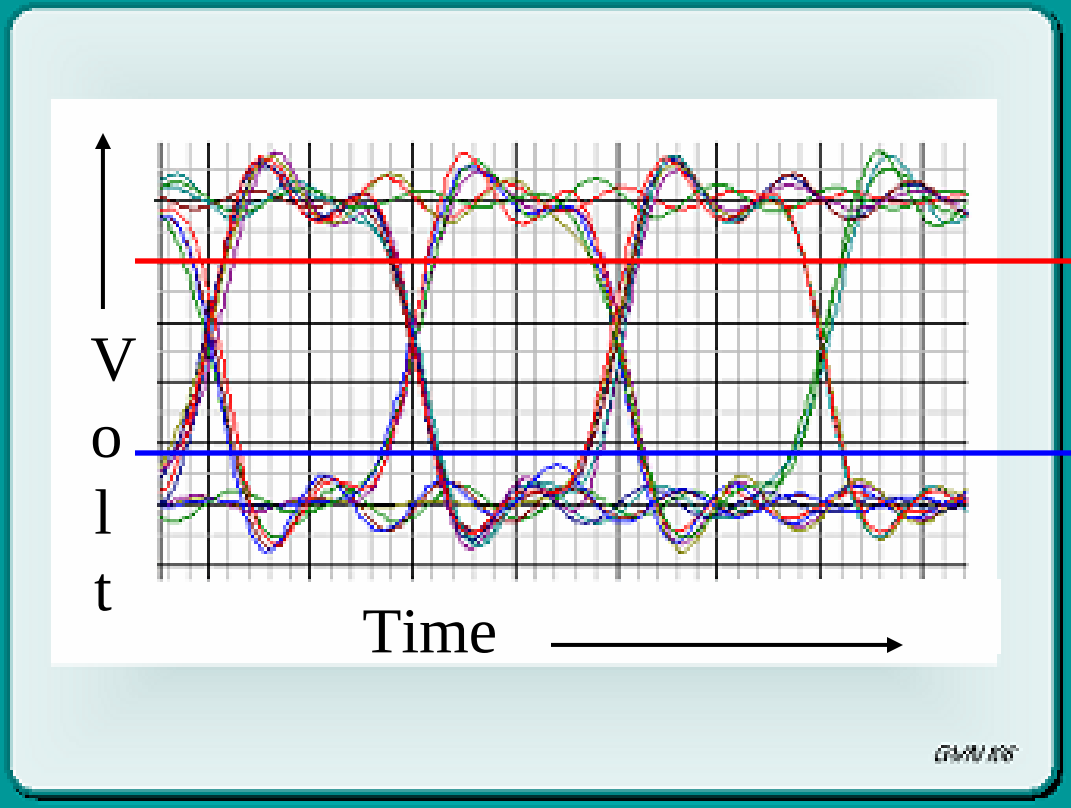
# Model results: Time domain




Thru response simulation for a 5 kOhm/1pF load at different clock frequencies of 500, 550, 600 MHz

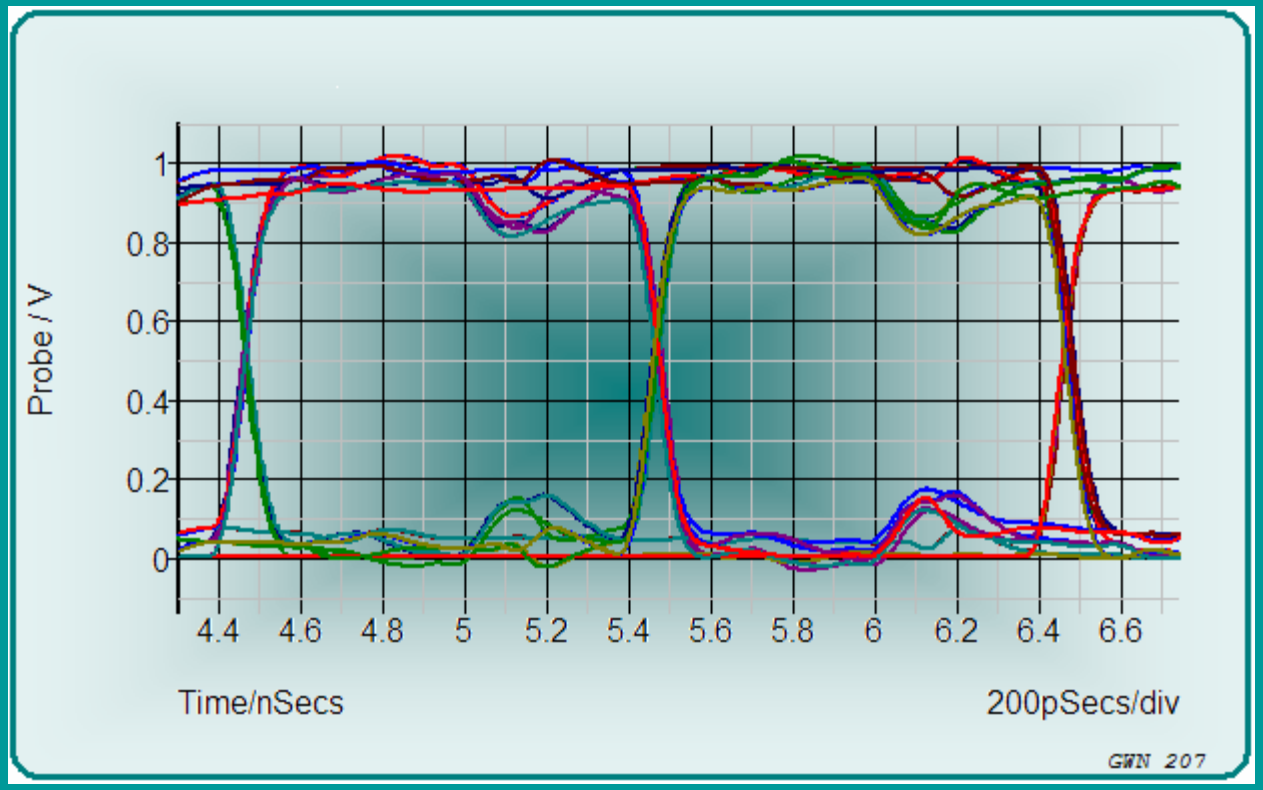
(the graphical periods are altered for easy comparison)

# TD thru method: Eye diagram



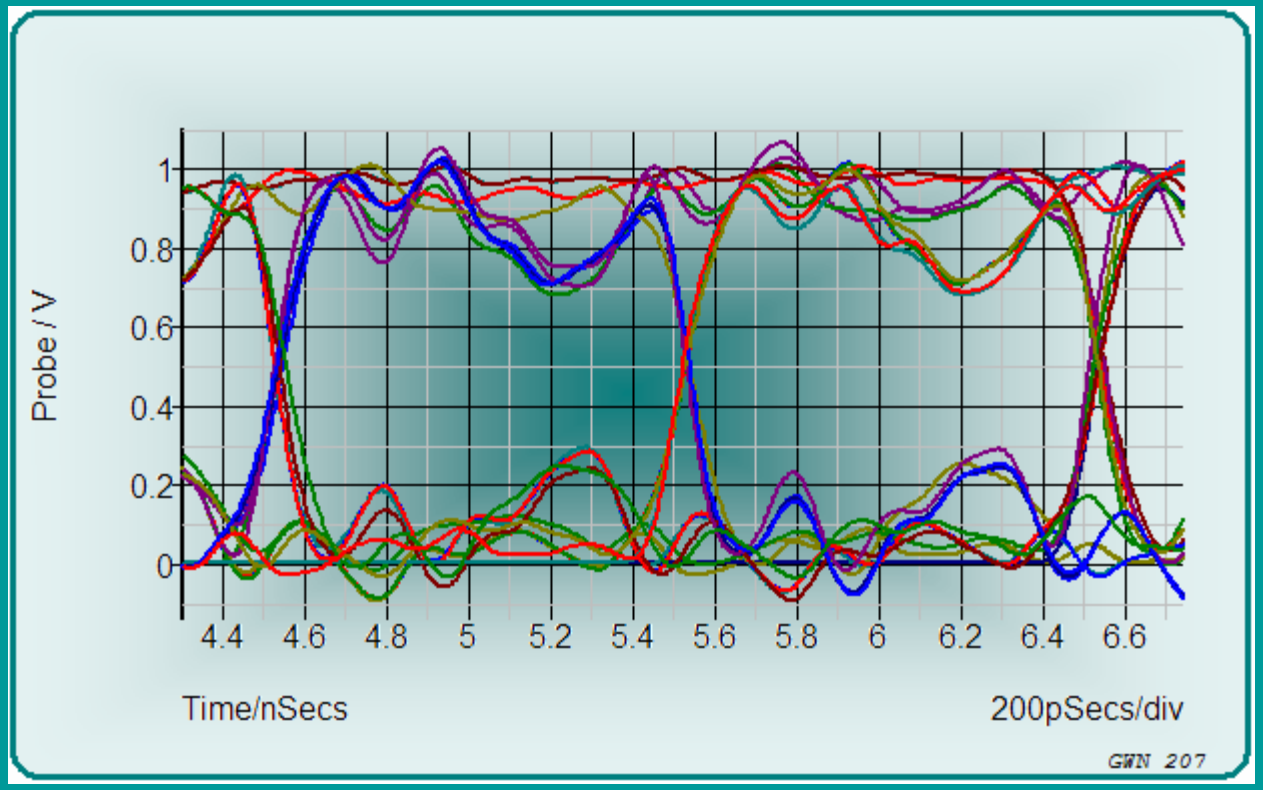

Eye diagrams are the result of a superposition of a number of pseudo-random pulses. They give a visual representation of operating margins

# Model results: Eye diagram




- Thru model into a 50 Ohm load, resonances minimized

# Model results: Eye diagram




- Thru model into a non-50 Ohm load (DUT=10kΩ, 2pF)

# Conclusion

- Time domain techniques are generally applied for reflection measurements.
- Frequency domain thru measurements can reveal resonances in components.
- Skew differs for reflection vs. transmission measurements.
- Time domain measurements may miss some detail.
- Resonances at elevated frequencies can contribute to reduced eye height, especially for non-50 Ohm DUT terminations.

# Thank you.