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Pushing the limits:
Variability in RF Measurements

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Problems

- Return loss demands are increasing due to PAM-4 and -8 modulation
- Insertion loss -1dB limit value is often crossed ‘gently’
- Upper frequency limits are increasing
- Incomplete communication about life in the fast (RF) lane

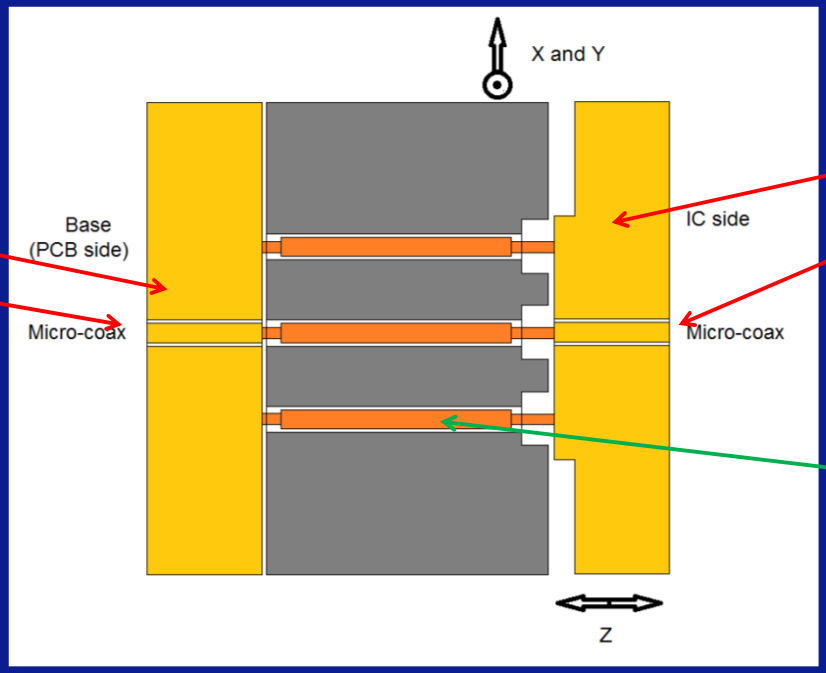
Objective and Approach

- Identify difficulties in achieving high accuracy measurements
- Examine variability
  - instrumentation error
  - repeated device insertions without any other changes
  - repeated 'from scratch' measurements
  - sensitivity to positioning error
- Highlight sensitivity in low return loss S11 cases (<-30dB)
- Develop understanding of underlying issues
- Measured data except where noted

Setup

- Agilent 8722C VNA option 10 / Agilent 8510C
- 50 MHz-40.05 GHz / 500 MHz – 110 GHz
- Effective risetime ~ 25 ps / 10 ps
- Coax probes
- Standard CAL w. hiRes S11 option
- XYZ station

Setup / Direction of Motion



ground
signal

Coaxial probe
ground
signal

Socket with
contacts

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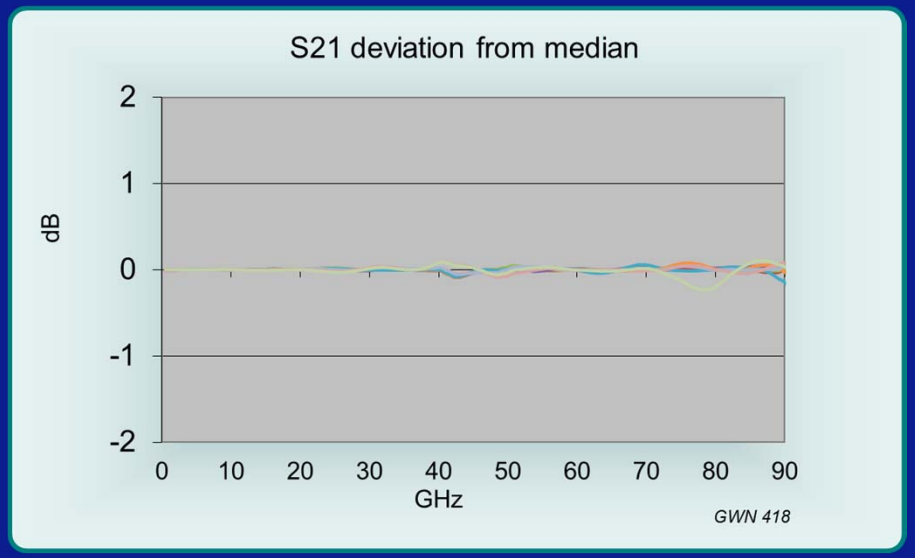
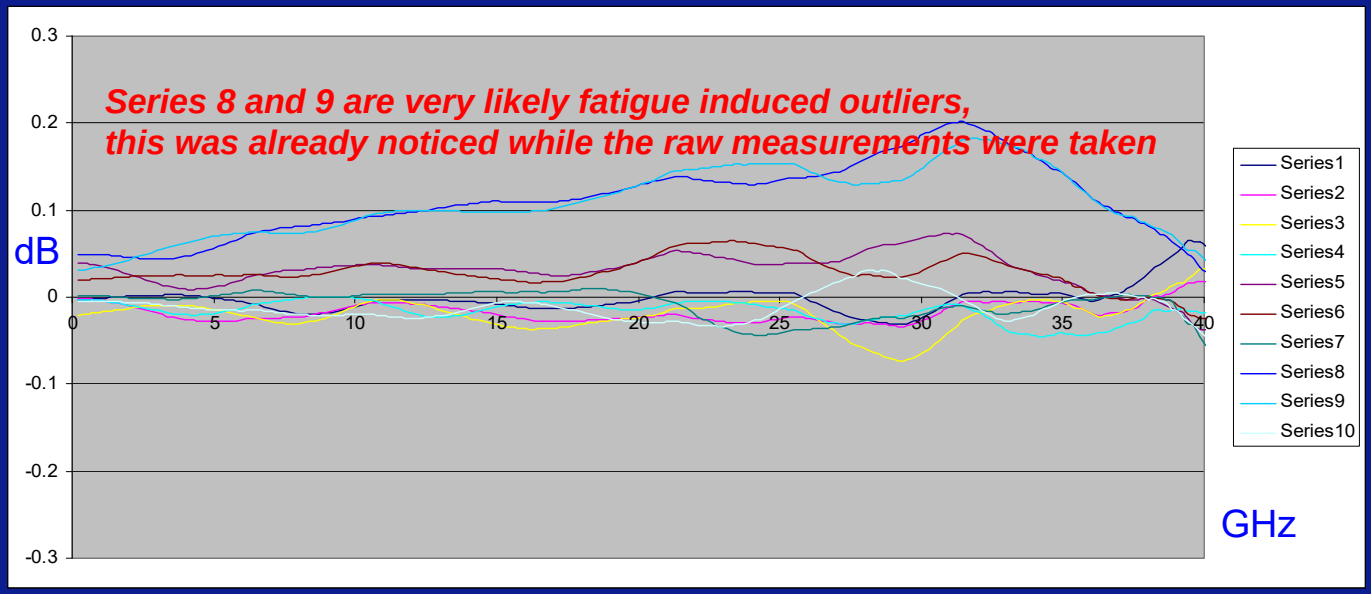
Insertion loss



Insertion loss

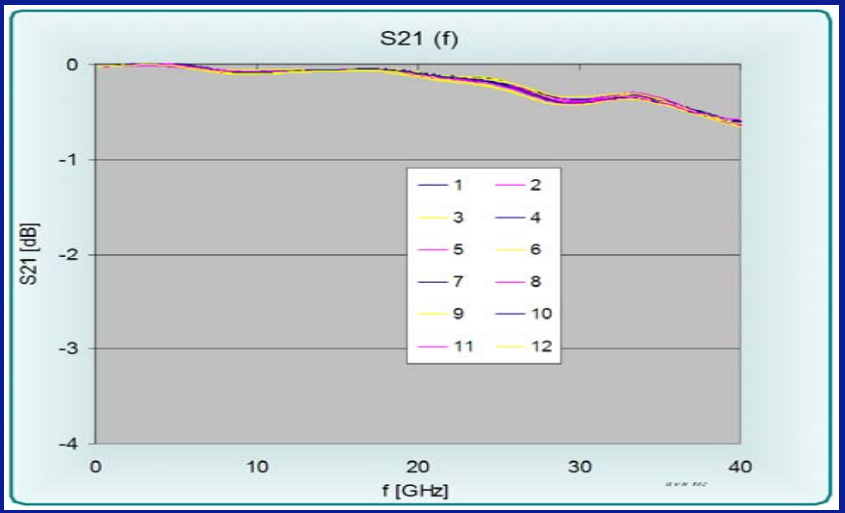
for 10 successive measurements (instrument error)

Insertion loss deviations



Deviation from median insertion loss for 10 successive device insertions
(10 calibrations /10 measurements)

Insertion / return loss



Insertion loss

Return loss

for 12 successive device insertions

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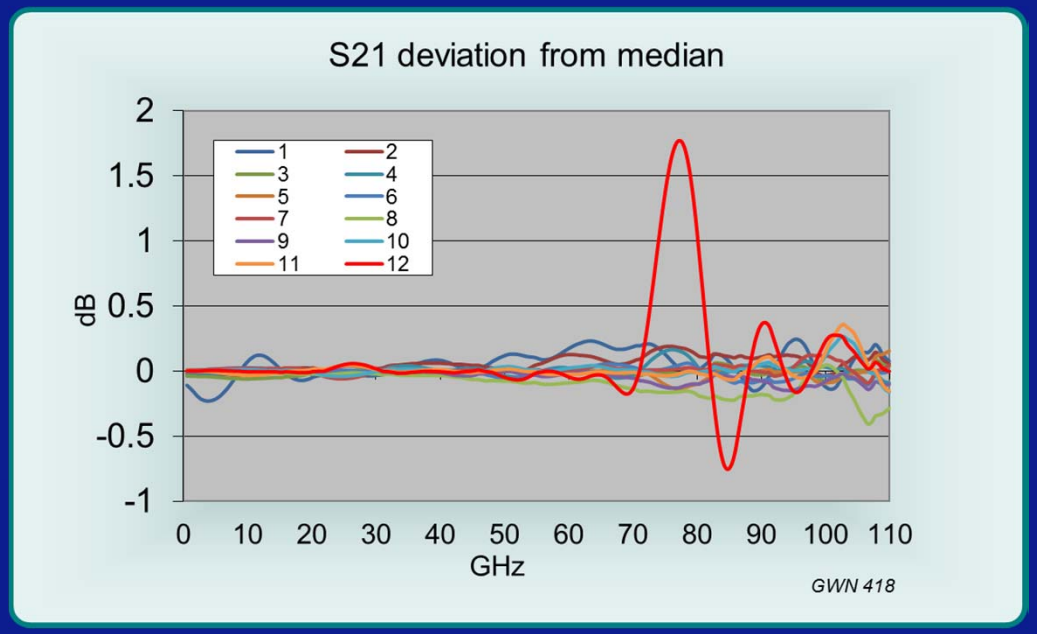
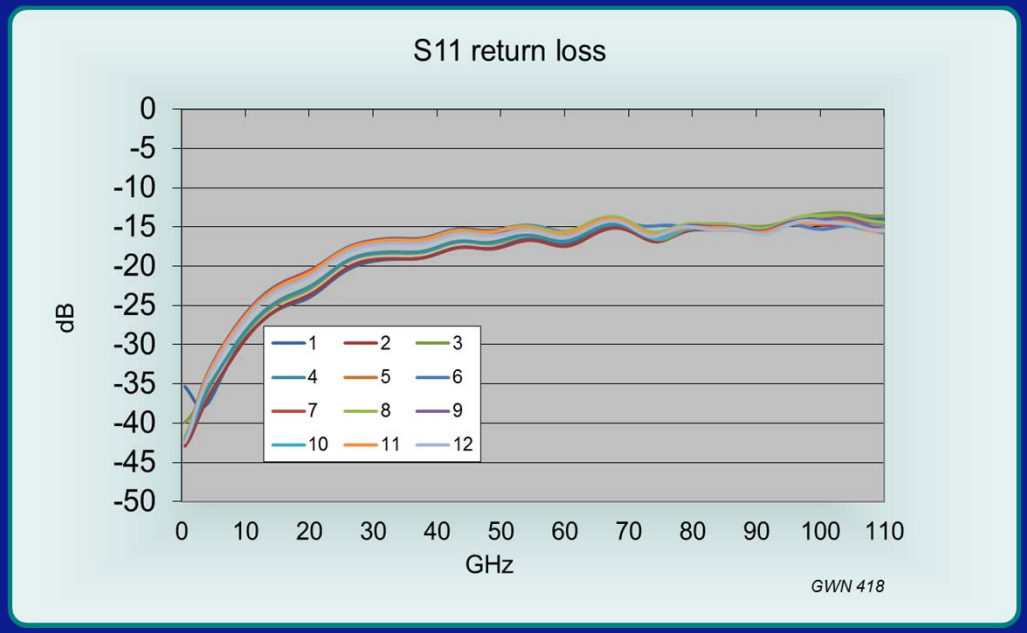
Insertion loss deviations to 110 GHz



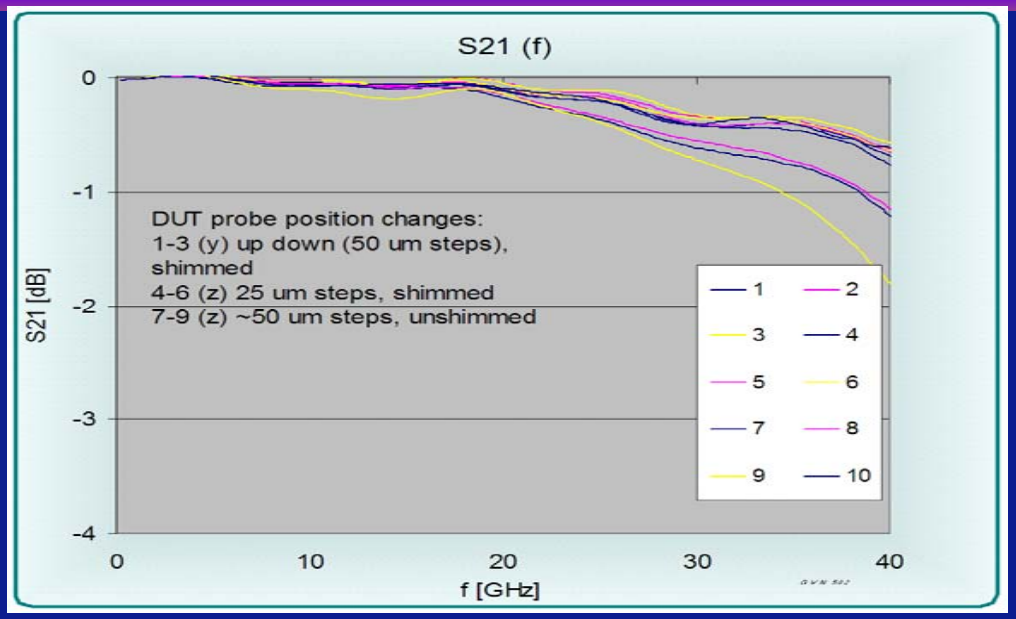
Deviation from median insertion loss for 12 successive device insertions

Return loss to 110 GHz



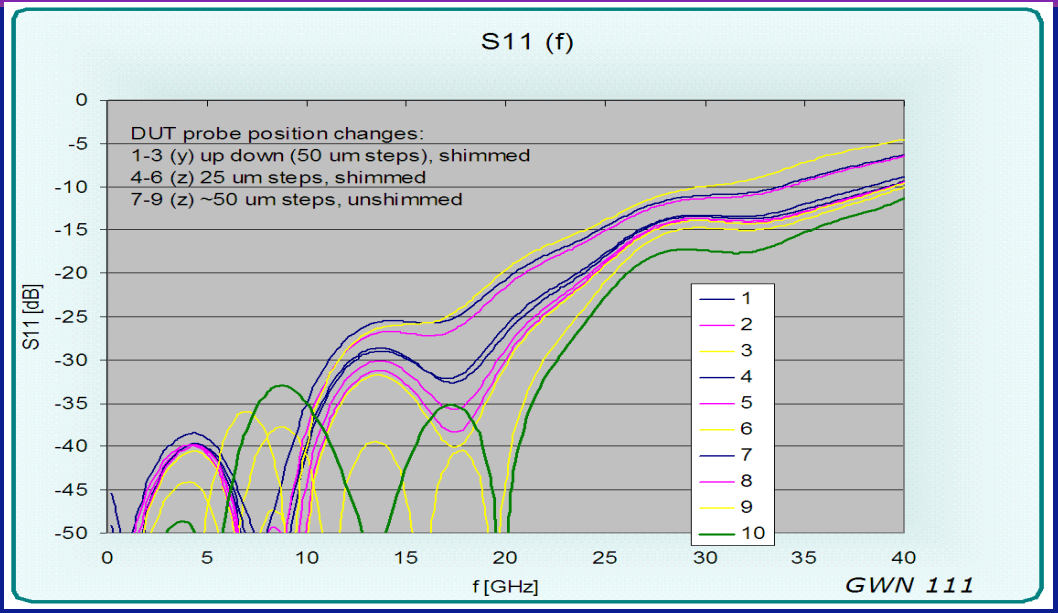
Return loss for 12 successive device insertions

Insertion loss



Insertion loss for 10 successive measurements where DUT side probe tip was moved about in Y and Z (one cal)

Return loss



Return loss for 10 successive measurements where DUT side probe tip was moved about in Y and Z (one cal)

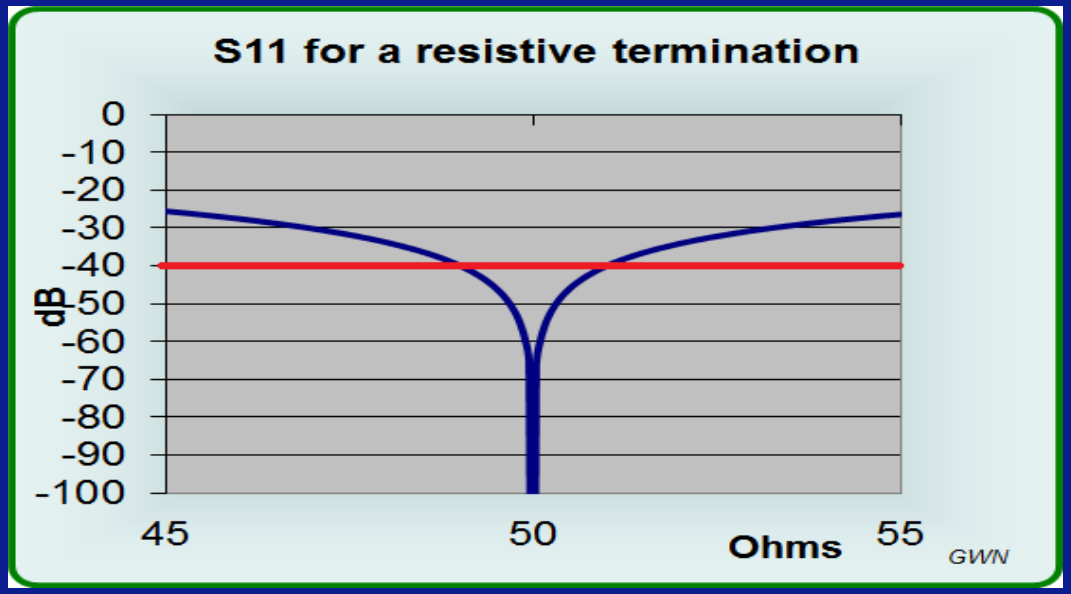
Return loss

$$RL(dB) = -20 * \log_{10}\left(\frac{Z_L - Z_0}{Z_L + Z_0}\right)$$

Return loss as a function of load impedance Z_L

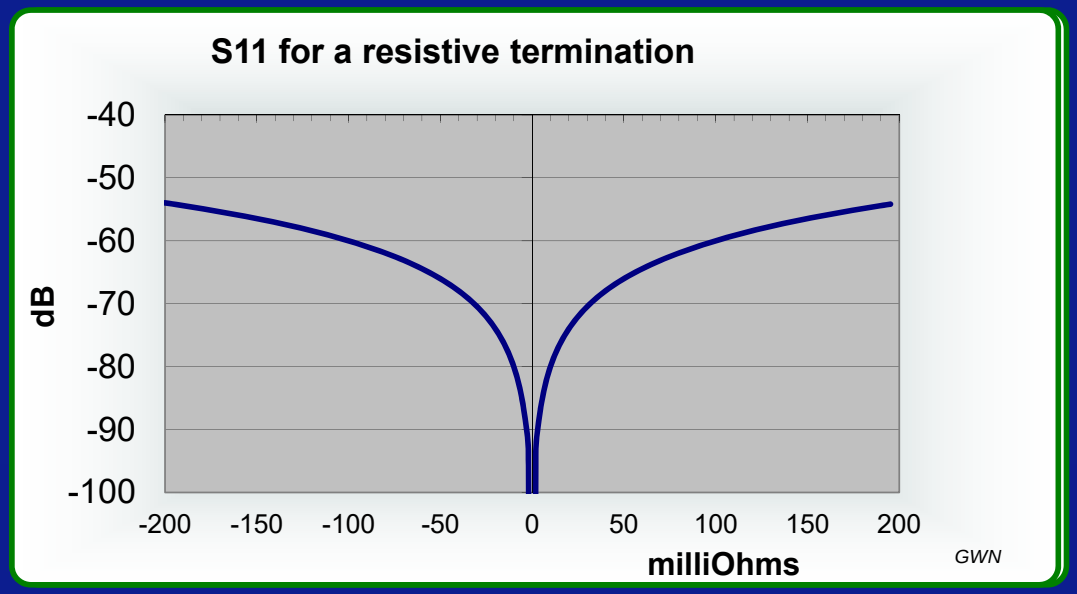
Z_0 is system impedance – typically 50 Ohms single ended / 100 Ohms differential

Return loss (calculated)



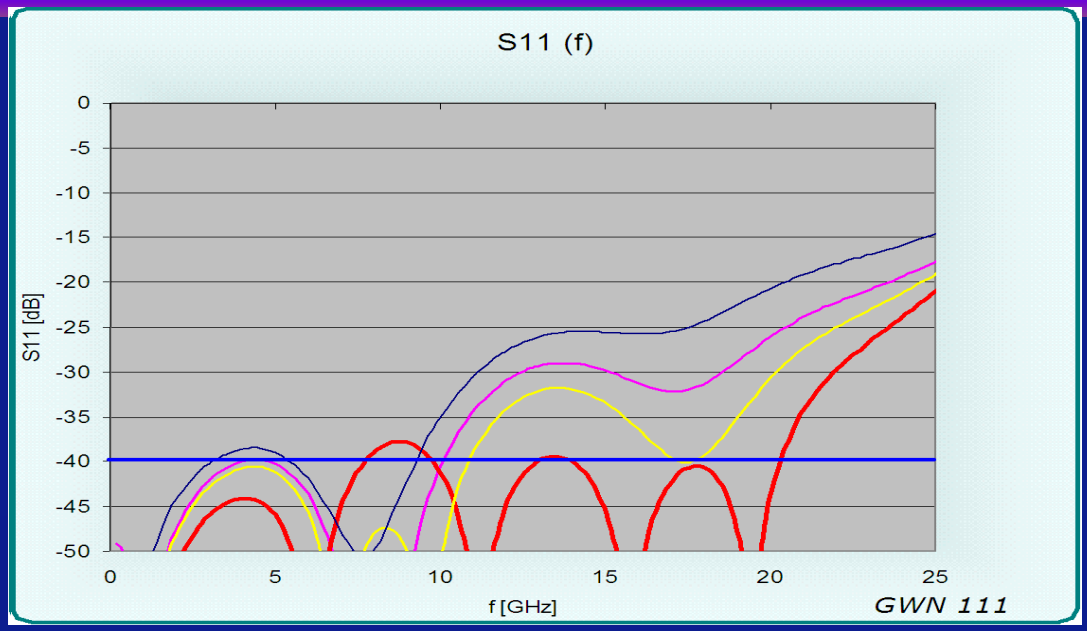
Return loss as a function of resistance

Return loss (calculated)



Return loss as a function of resistance
(deviation from nominal)

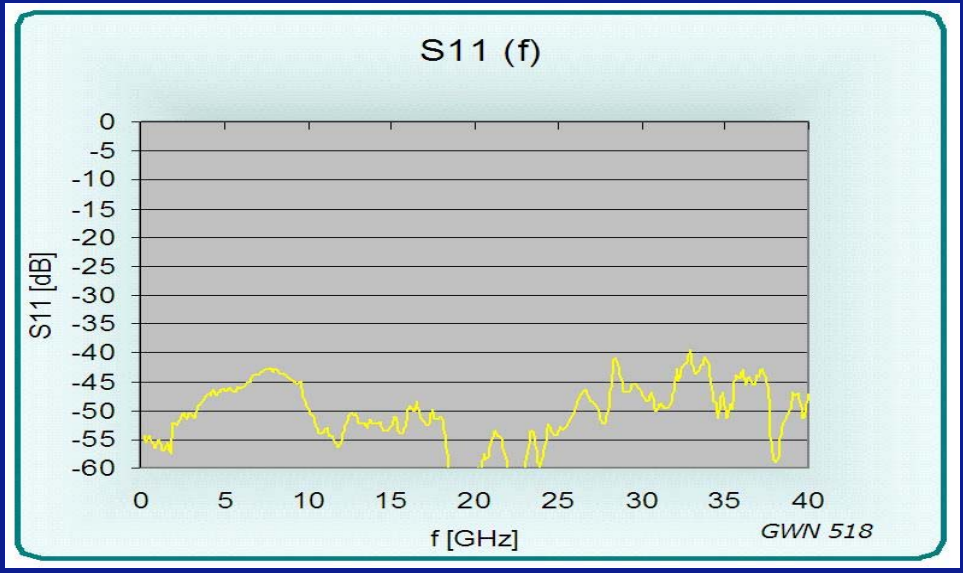
Return loss (measured)



Return loss (probe tip moved in Y and Z)

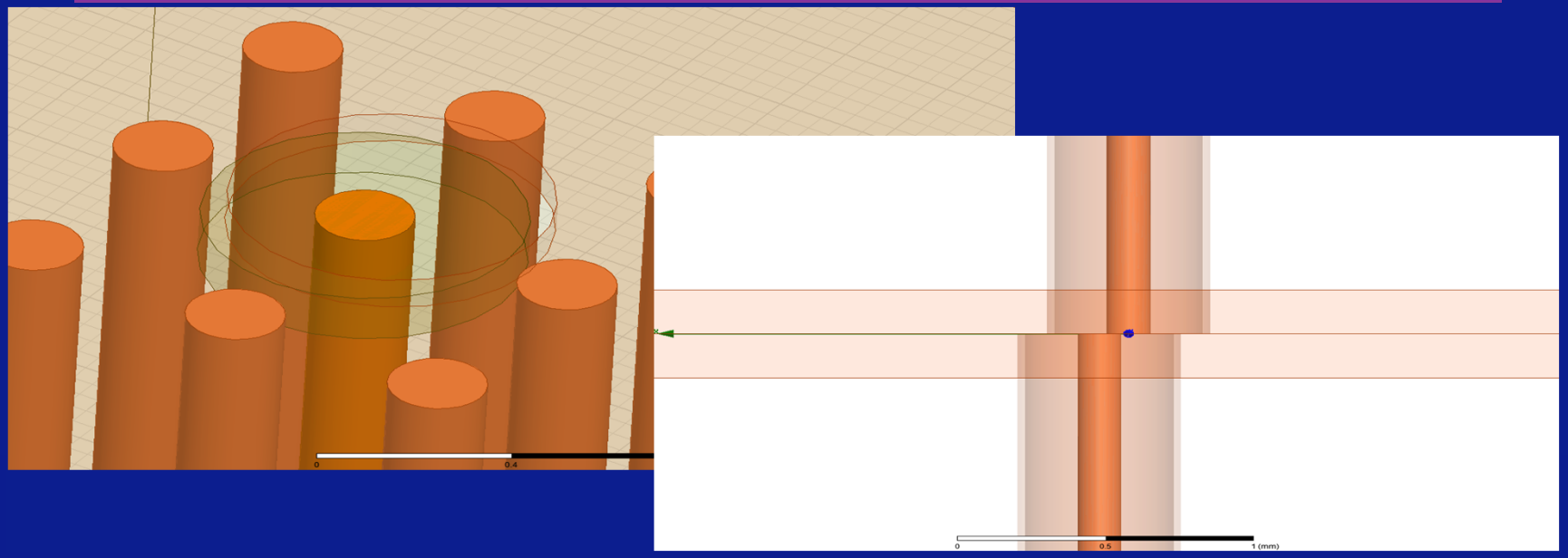
Note - “border crossings” will be extremely sensitive to small changes

Measurement challenge



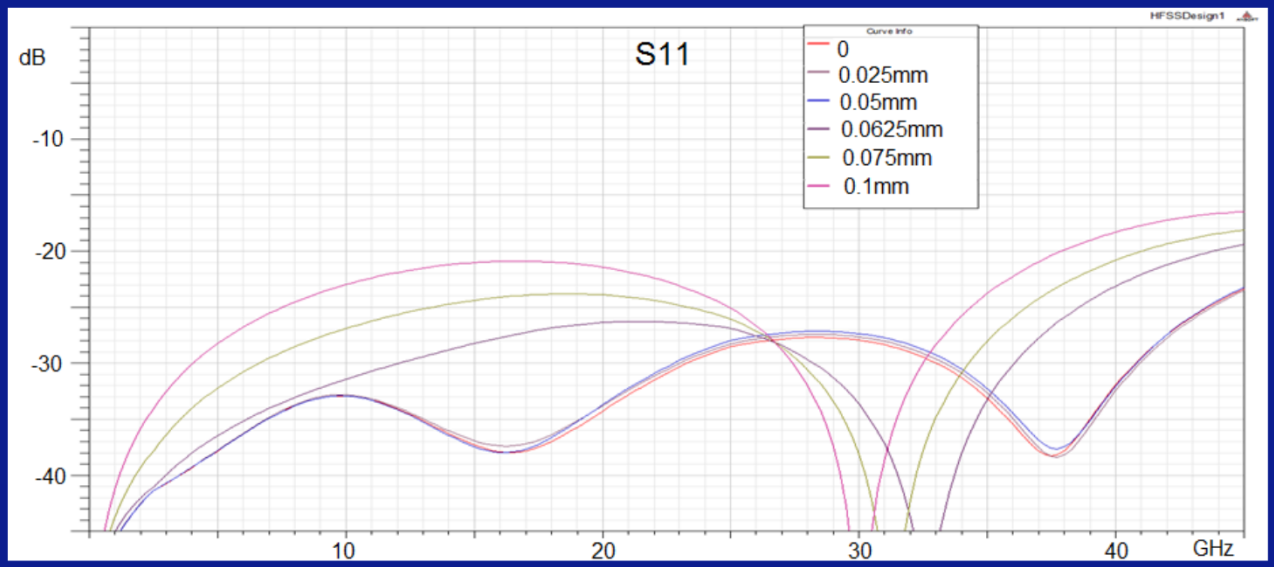
Measured return loss S11 after de/repositioning of probes (no DUT)

Simulated position sensitivity



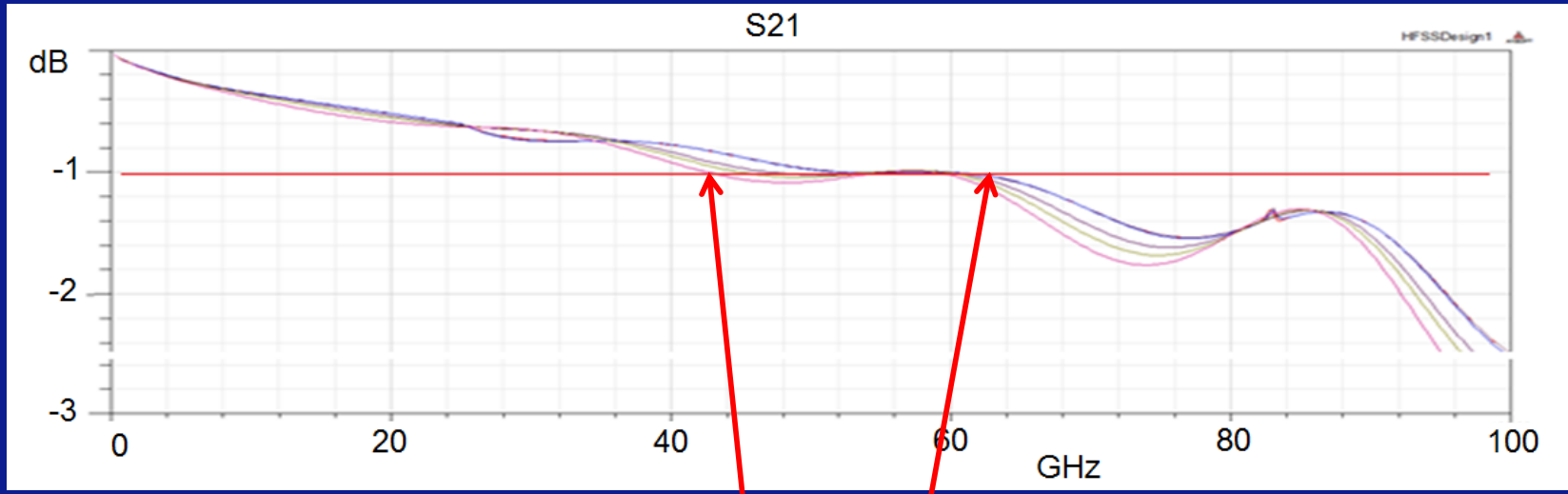
What variations are to be expected from lateral misalignment ?

Simulated sensitivity



S11 for DUT/probe lateral positioning of 0 –> 4 mils

Insertion loss (simulated)



Insertion loss variations

Note - "border crossings" can be extremely sensitive to small changes

- 1dB point changes from 42 to 63 GHz in this example

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Summary

Variability is typically low from insertion to insertion as long as return loss is in a “normal” range, i.e. between 0 and -30 dB

Return loss strongly depends on Cres for connections that have close to 50 Ohms characteristic impedance and optimal interfaces

For low values of return loss a strong DUT side probe position dependence may be observed (some positions chosen may be outside the normal test tolerance)

Insertion loss can be adversely affected by improper DUT probe position as well