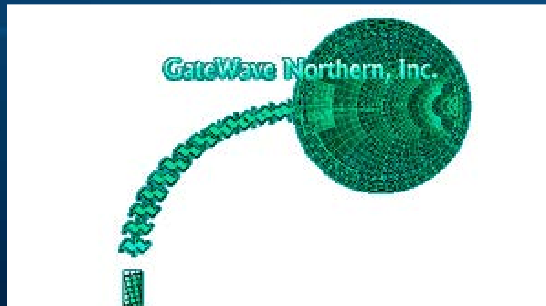
SW Test Workshop
Semiconductor Wafer Test Workshop
June 7 - 10, 2015 | San Diego, California

Measuring Electrical Probe Parameters Through a PCB



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Objective

- Examine reasons for measuring probe parameters through PCB
- Describe method for determining probe capacitance and inductance through a PCB
- Present results of different methods
- Explore accuracy

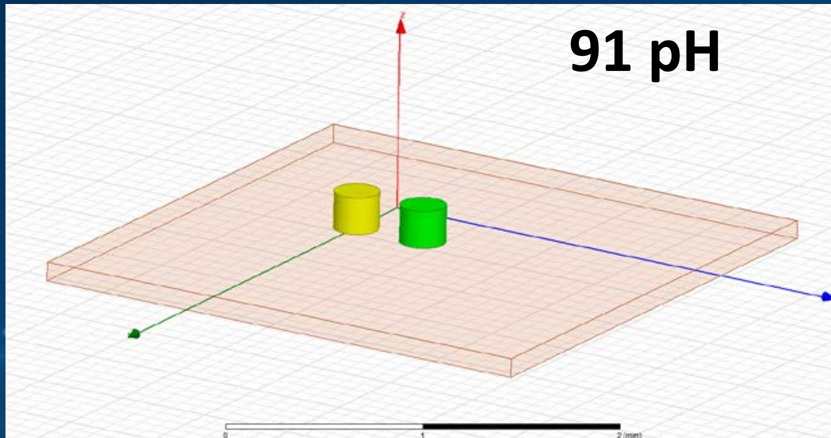
Approach

- Perform successive measurements of unpopulated vs. populated probe card
- Use 40 GHz vector network analyzer with time domain option, supplemented with SPICE simulations
- Extract L and C parameters from measurements
- Compare with model results (ANSYS HFSS 3D field modeler)

Potential reasons for thru-card measurements

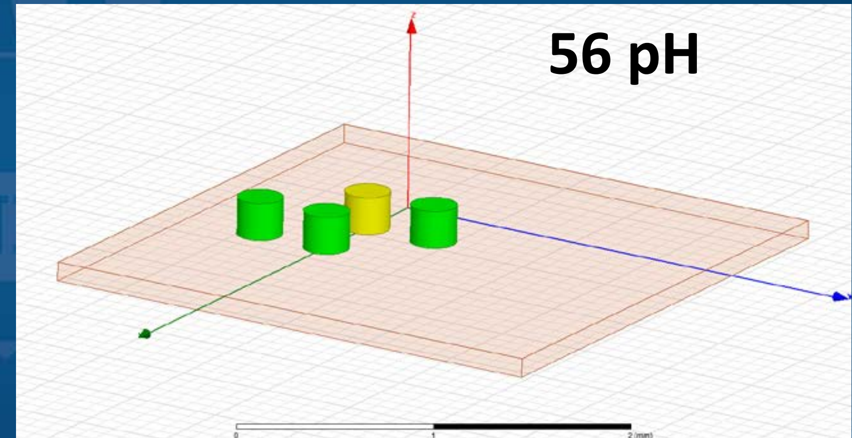
- Inclusion of specific return path locations (ground)
- Desire to characterize contributions of a space transformer or other interface
- Evaluation of optimizations
- Card is already assembled
- ‘Bucket of probes’ without a suitable ‘holder’ for individual measurements
- Probes can not be readily individually characterized, e.g. MEMS

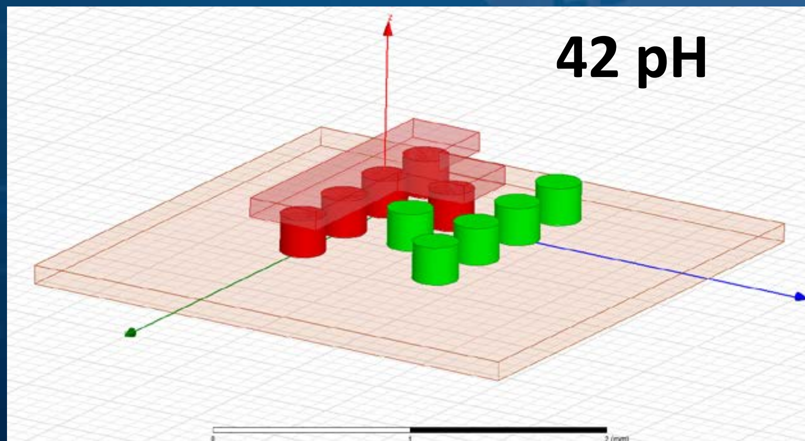
One motivation for thru-card measurements: Different signal/ground/power configurations in a BGA



1mm long probes: 505 pH

1mm long probes: 326 pH

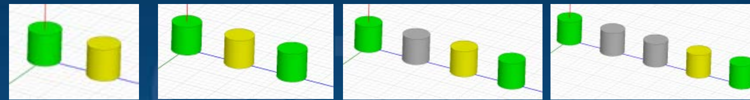




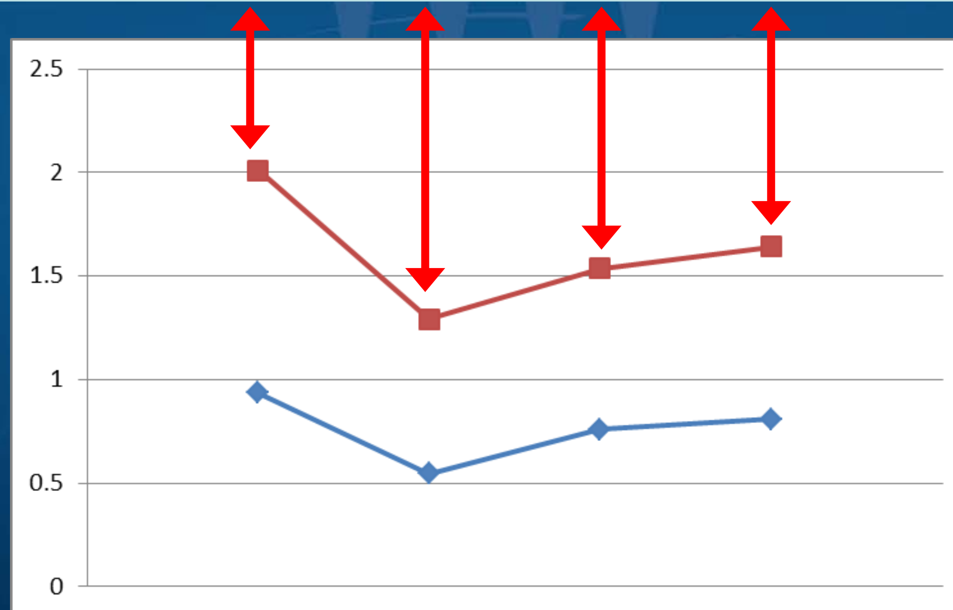
Loop inductances for short and long probes

1mm long probes: 221 pH

Inductance as a function ground configuration in a linear array

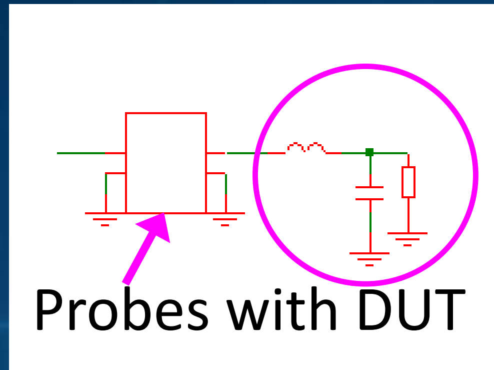


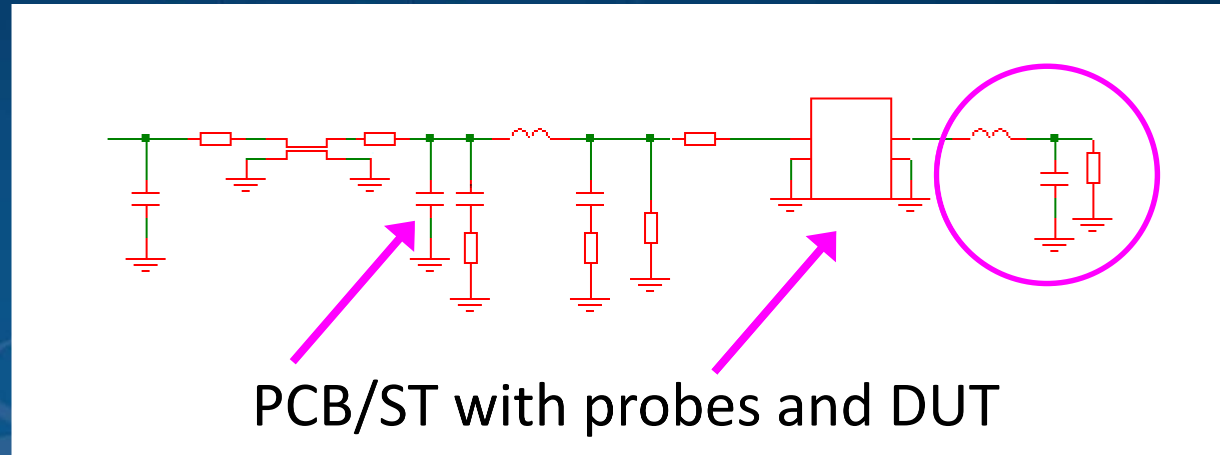
	Inductance:				
pitch	G-S	G-S-G	G-x-S-G	G-x-x-S-G	
x1	0.94	0.55	0.76	0.81	nH
x2	2.01	1.29	1.54	1.64	nH

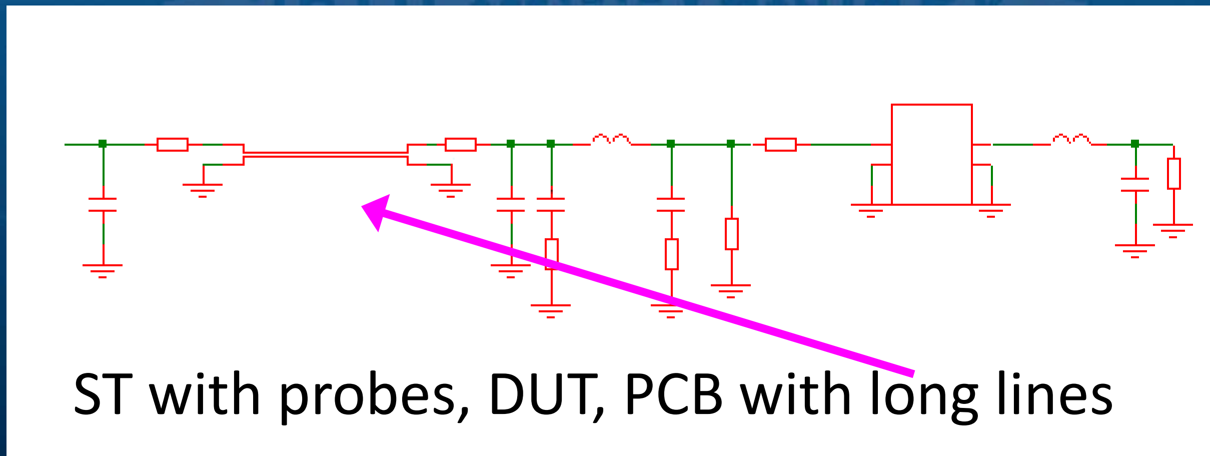


L depends significantly on configuration - does not scale with pitch

Probe card/interposer/space transformer signal path to be measured







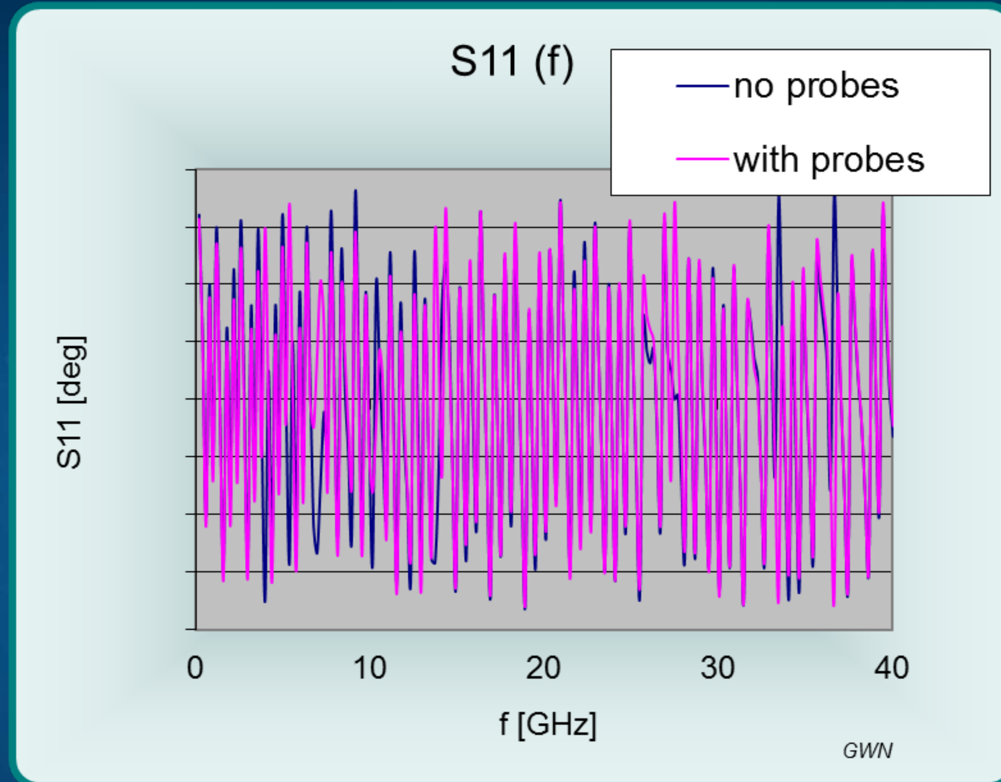
Measurement sequence

Open or short on PCB/ST .... measure phase at PCB

....then open or short on PCB/ST plus probes

....and measure phase again at PCB

Phase ϕ for open circuited probes



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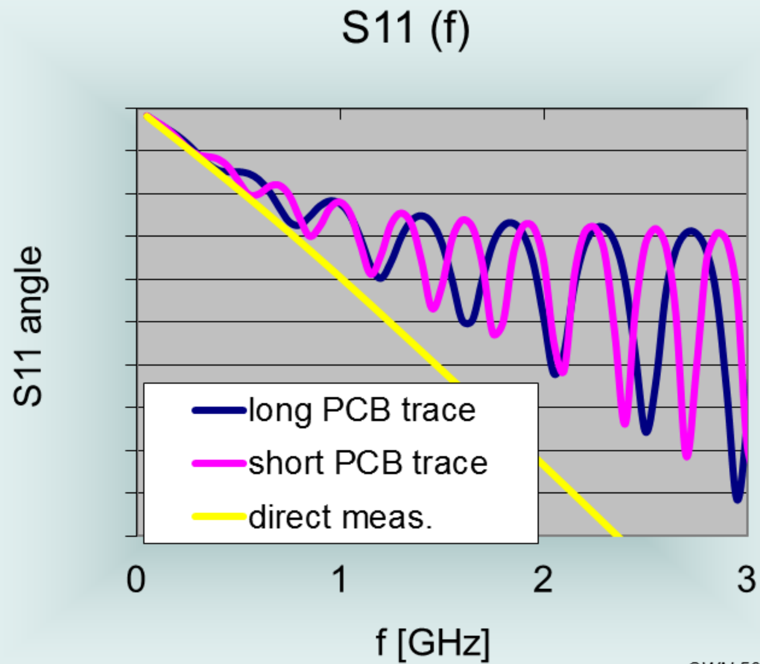
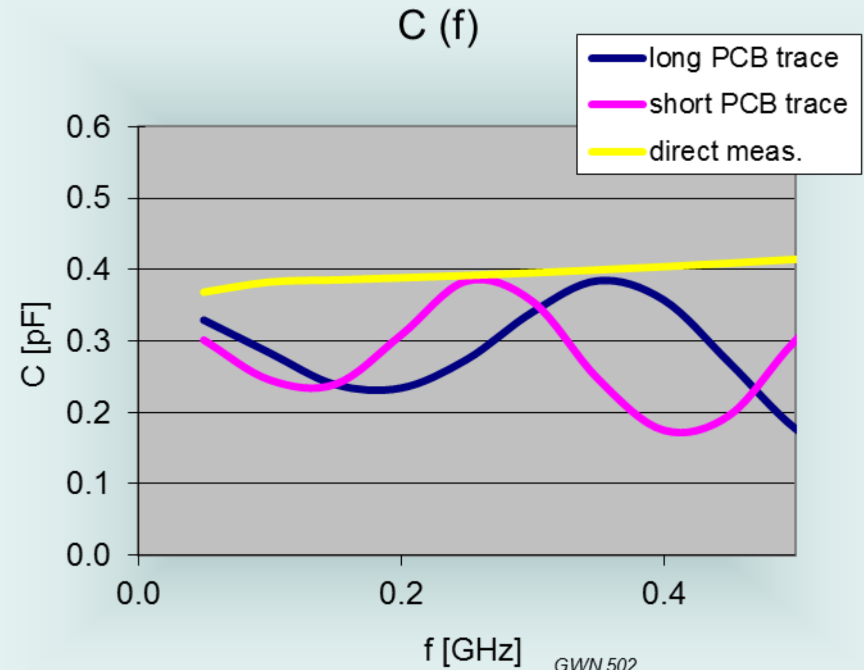
Measurement thru PCB as a function of frequency results in large variations of phase.
Is this really a viable option ?

Why frequency dependent measurements ?

- Ferromagnetic materials, e.g. Ni
- Advanced composites with nanoparticles
- MEMS on doped Si with multi-layer structures
- ‘Engineered’ materials with frequency dependent properties
- Path dependent performance variations

Examine ϕ at lower frequencies

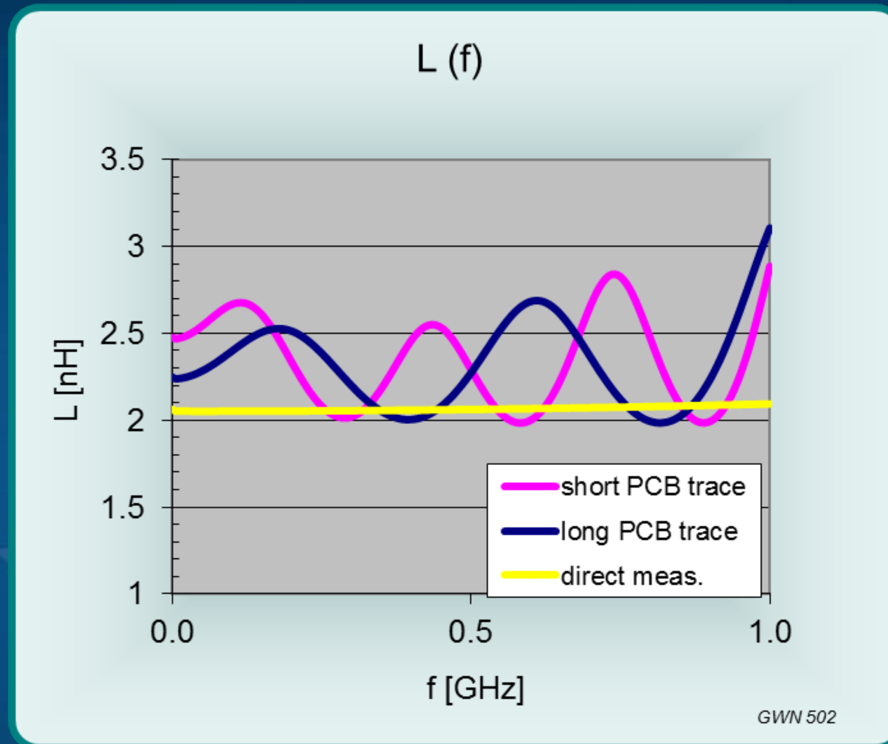




Phase ϕ and capacitance as a function of frequency

Difference vs. direct measurement of probes only

Inductance



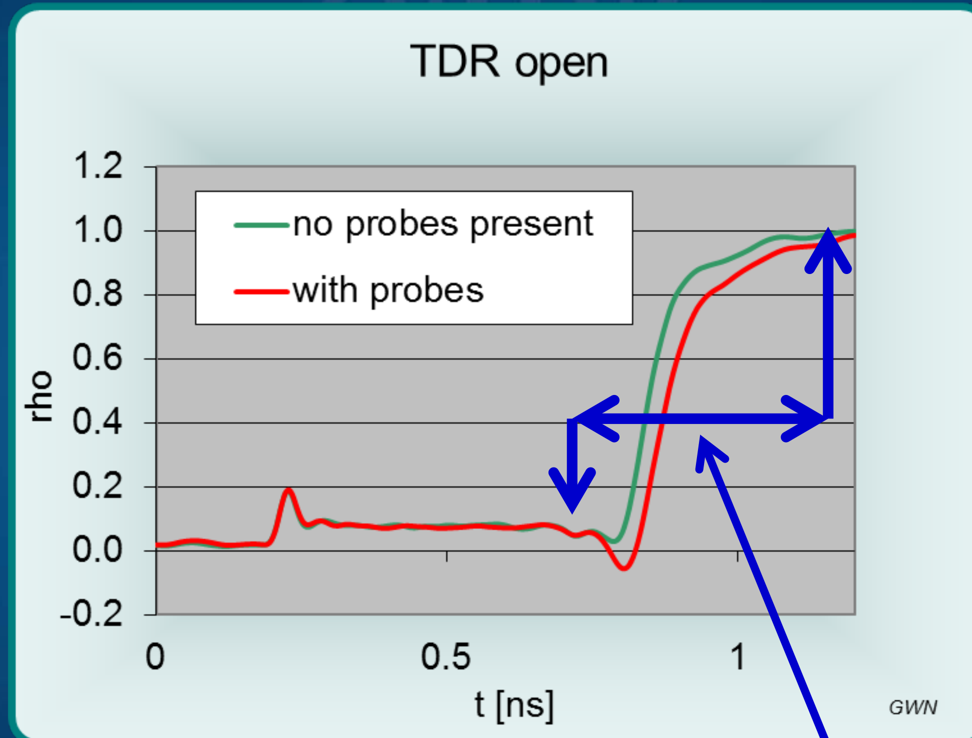
Inductance as a function of frequency

Difference vs. direct measurement of probes only

Basic thru-card measurements

- Simple calibration open/short with/without probes yields approximate results only at low frequencies
- Potentially significant error terms appear at normal operating frequencies
- Some form of improved calibration (or evaluation of data) is needed

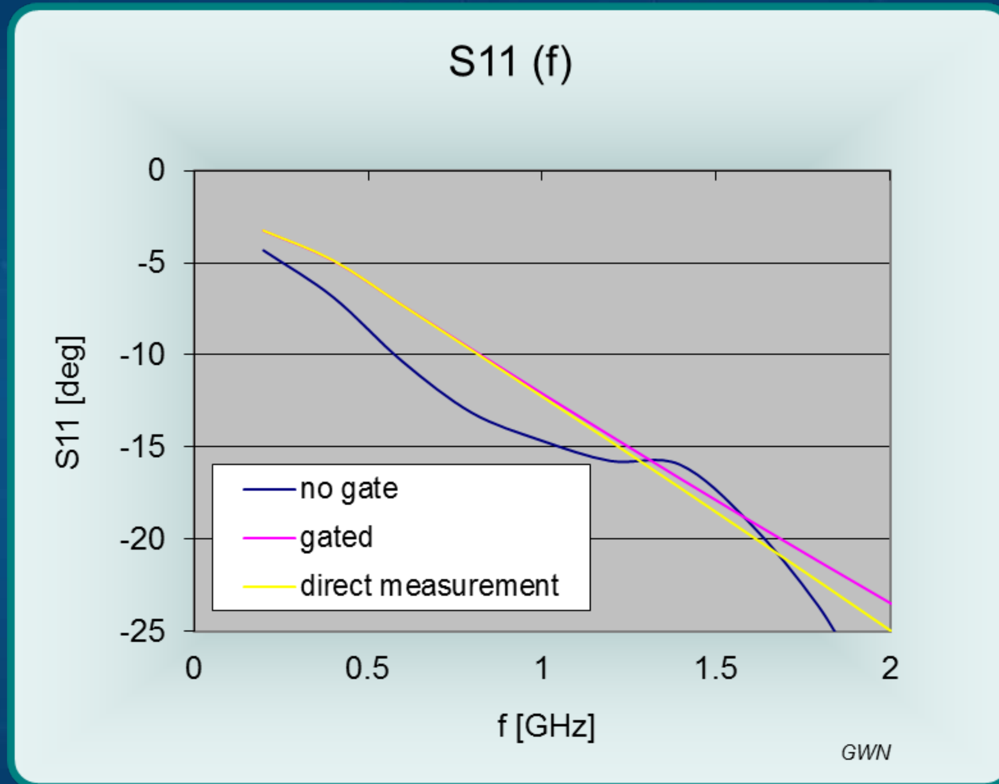
TDR for open circuited probes



Time frame of interest

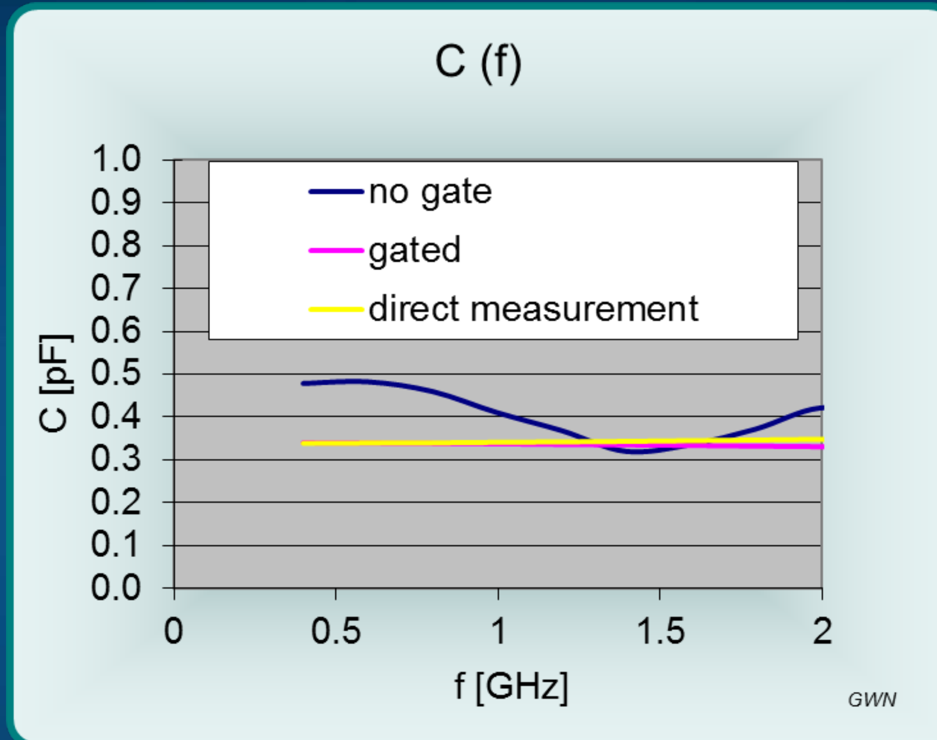
Measured through PCB

Phase ϕ for open circuited probes



Measured through PCB vs. direct measurement, gated and ungated

Capacitance as a function of frequency

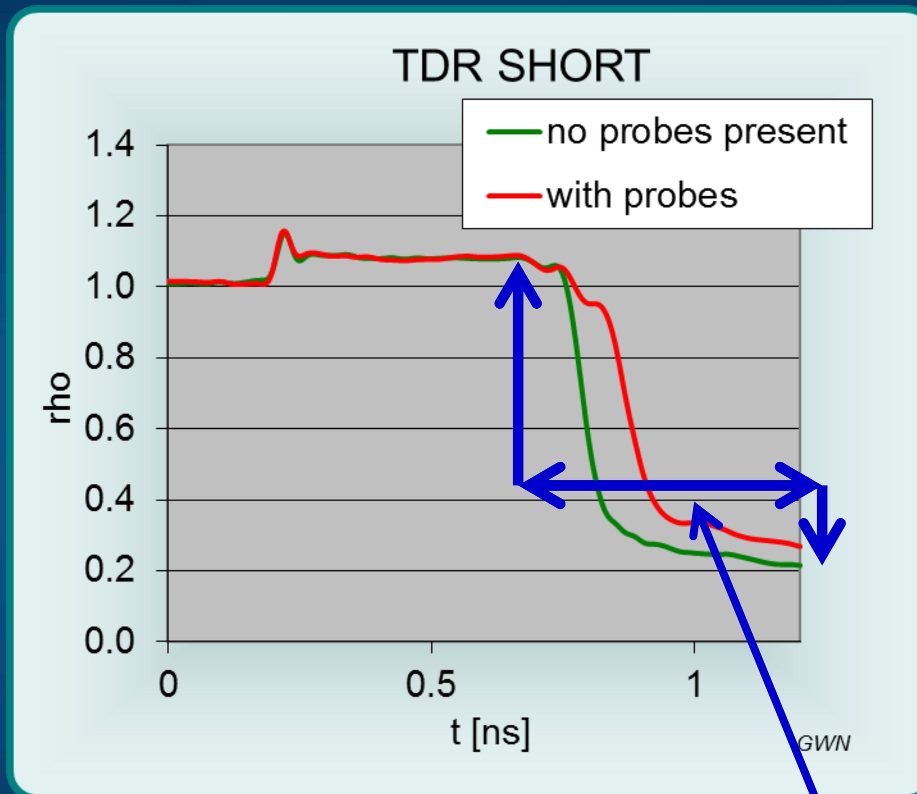


Capacitance:			
0.400	0.335	0.344	pF

Ungated - gated - direct

(Values at low frequencies)

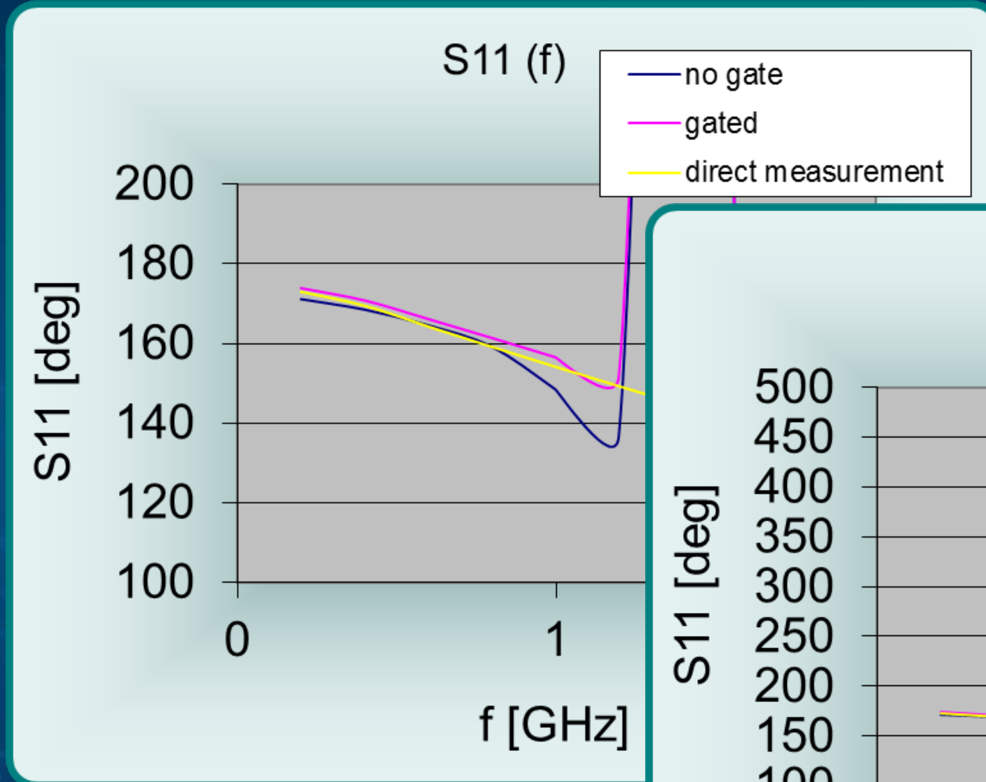
TDR for short circuited probes

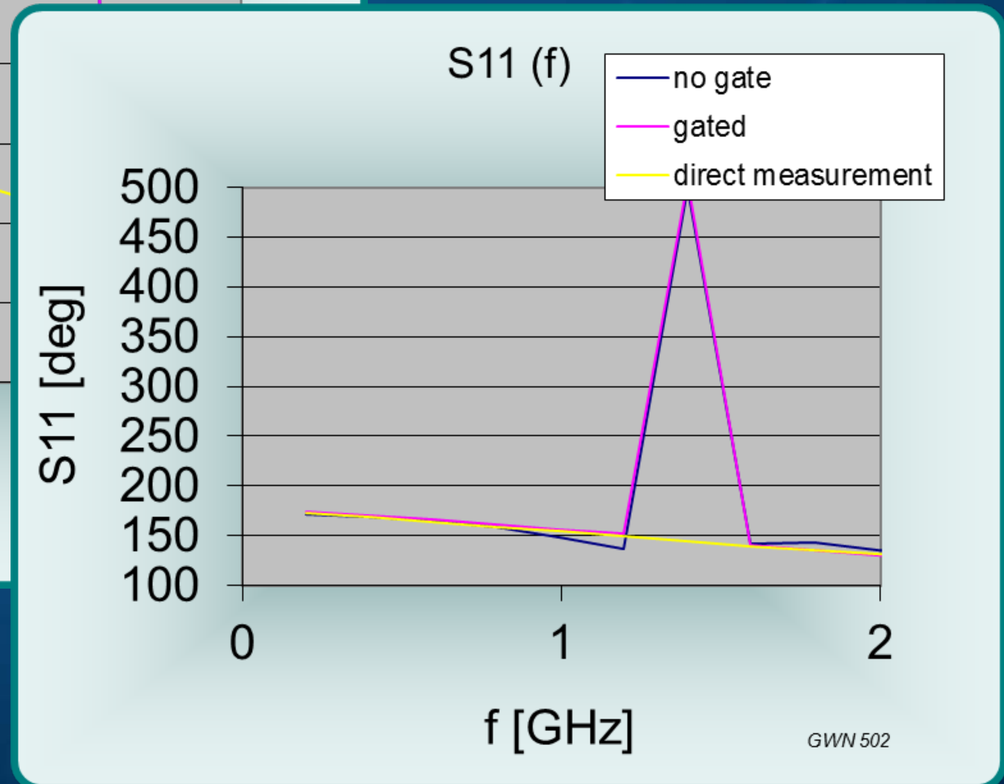


Time frame of interest

Measured thru PCB

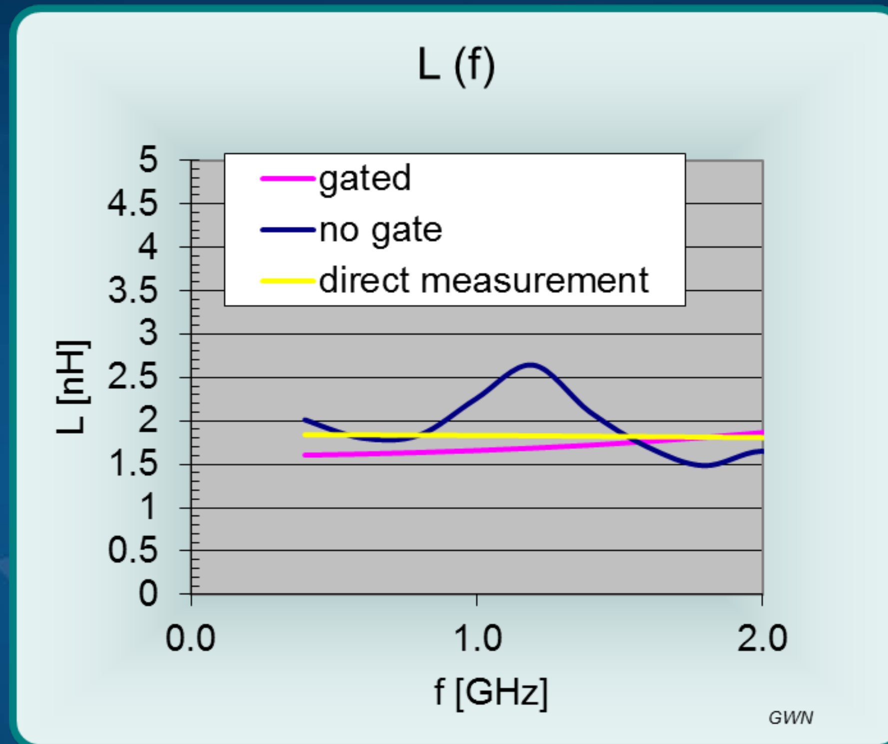
Phase ϕ for short circuited probes





Measured through PCB, calibrated

Inductance as a function of frequency

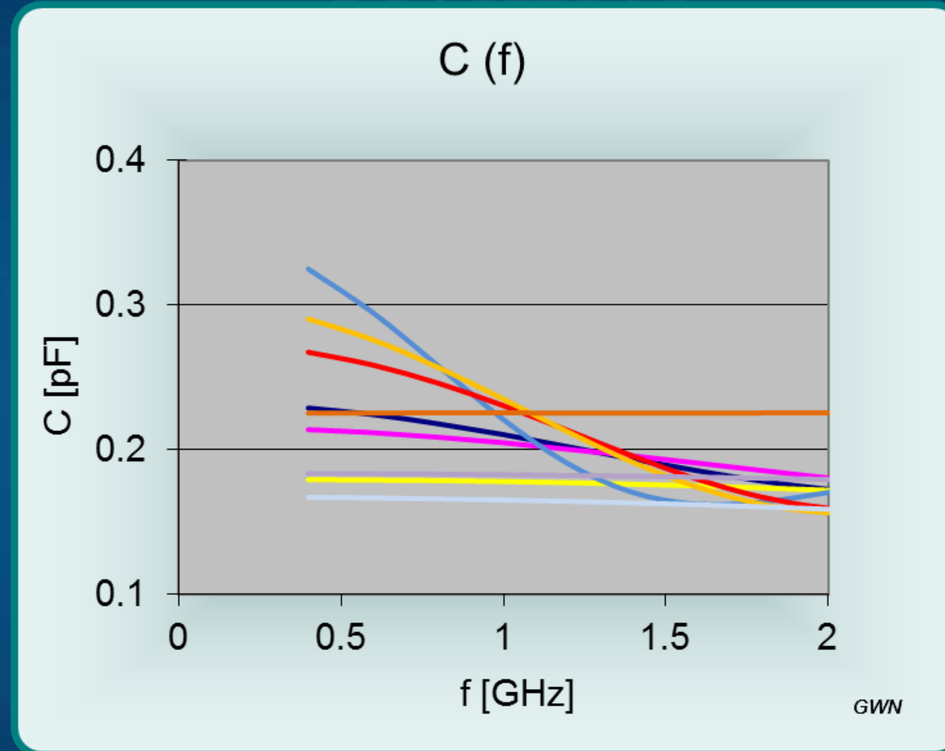


Inductance:			
1.85	1.75	1.82	nH

Ungated - gated - direct

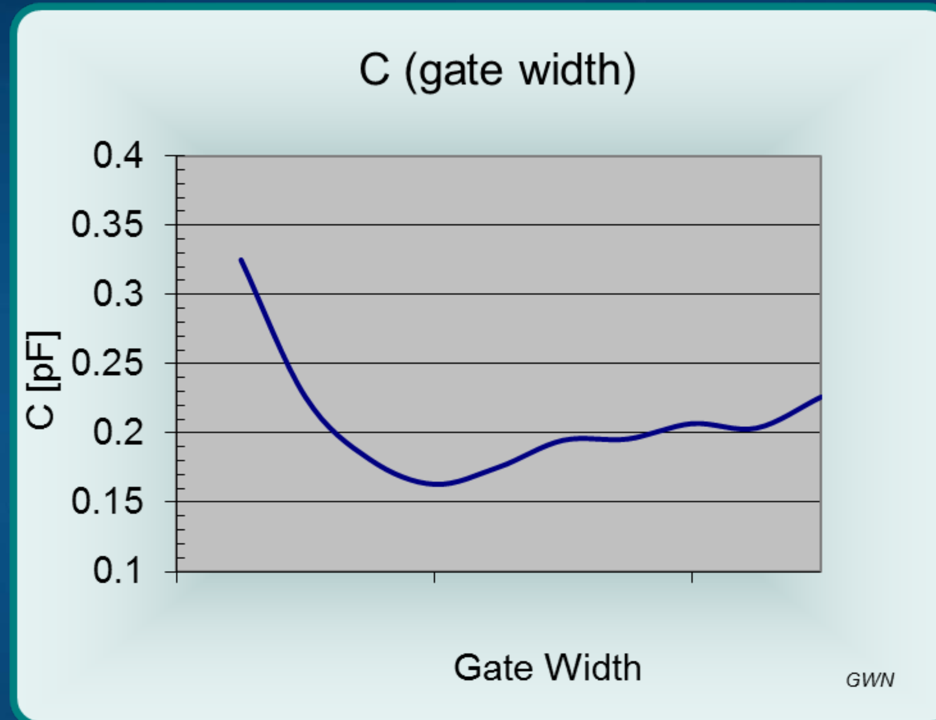
(Values at low frequencies)

Error terms - C as a function of frequency for different gate widths



Gate width has a significant impact on accuracy
(measurements taken on a different sample than previous results)

Capacitance as a function of gate width

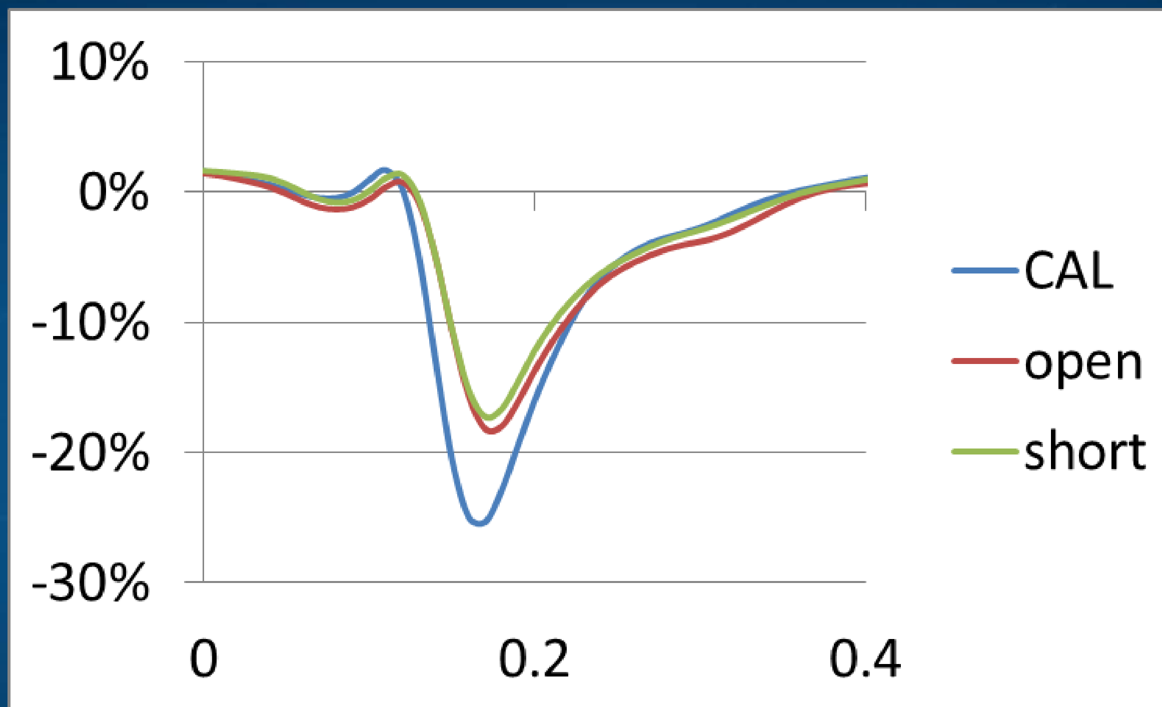


Evaluation of C at low frequencies and different gate widths reveals region of relative 'stability' of results

Gated thru-card measurements

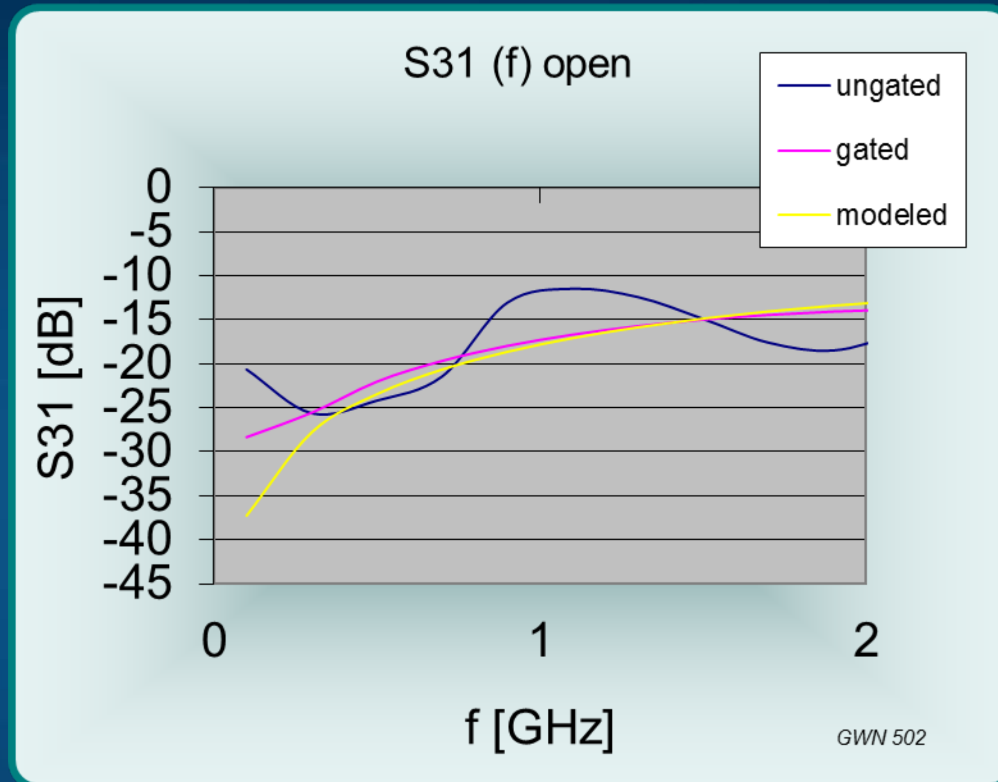
- Calibration open/short with/without probes plus time-gating yields results up to moderate frequencies
- Error terms for different gate widths, time positions and rise times must be carefully considered

Application of technique to crosstalk: Time domain crosstalk for adjacent probes



Time domain measurement of crosstalk is not necessarily very helpful in mutual inductance and capacitance determination

Crosstalk for open circuited probes



From calibrated open/short circuited measurement it becomes possible to develop a model for mutual L, C parameters

Mutual parameters

Site		Cm		M	
ungated		0.281	pF	0.597	nH
gated		0.217	pF	0.453	nH
modeled		0.211	pF	0.439	nH

The gated measurements yield an almost unrealistically accurate estimate for the mutual parameters in this case

Conclusion

- Thru-card measurements are possible
- Measurements through probe card without the use of 'suitable range restrictions' delivers inaccurate results
- Gating can provide results that closely match actual conditions
- Gates have to be applied cautiously and results verified via sensitivity analyis