VNA measurements of 6mm buttons in button block

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Outline

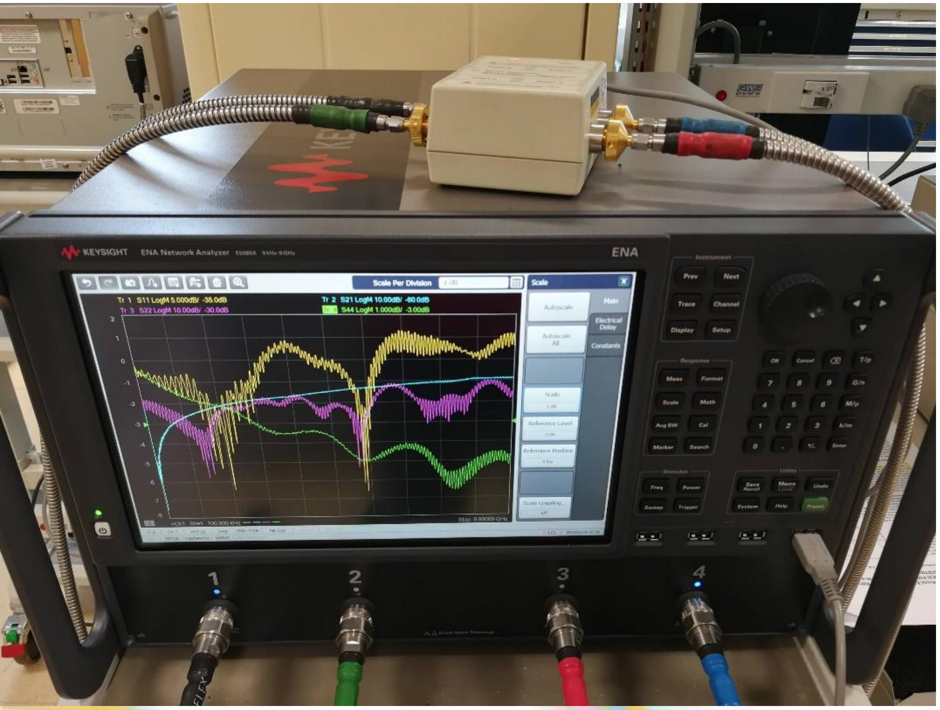
- Motivation
- Measurements
- Some initial statistics
- Conclusions

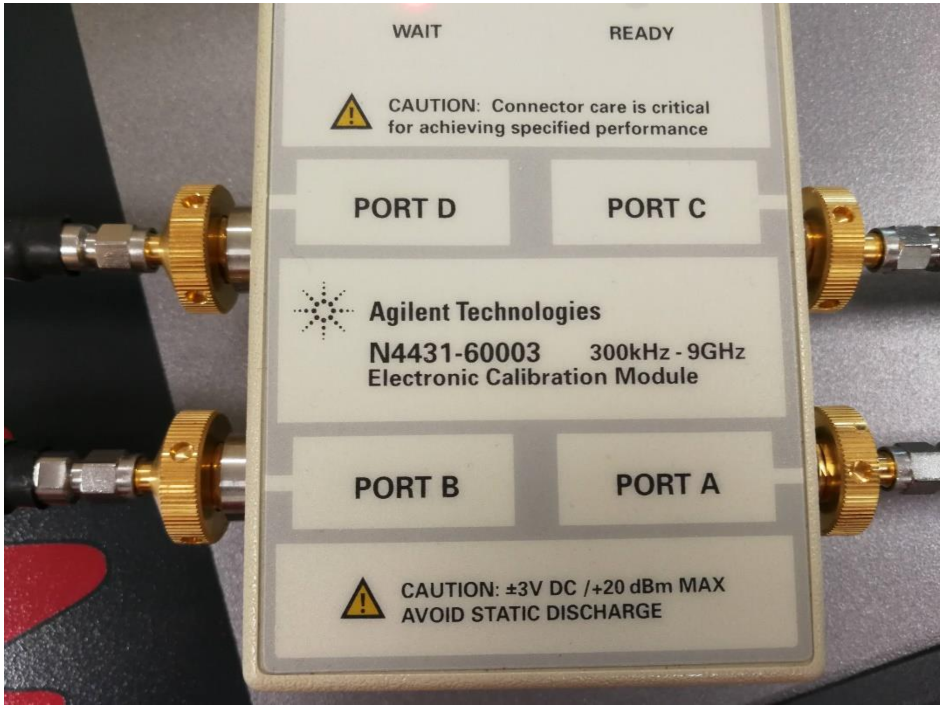
Motivation

- Determine electrical centre of button block
- Goal is to use Lambertson method
- Choose classic tool: Vector Network Analyser
- How well can S params be measured @ -80dB?
  - Statistical errors
  - Systematic errors
  - Reproducibility
- Value of ’full S-parameter calibration’

Equipment and Settings

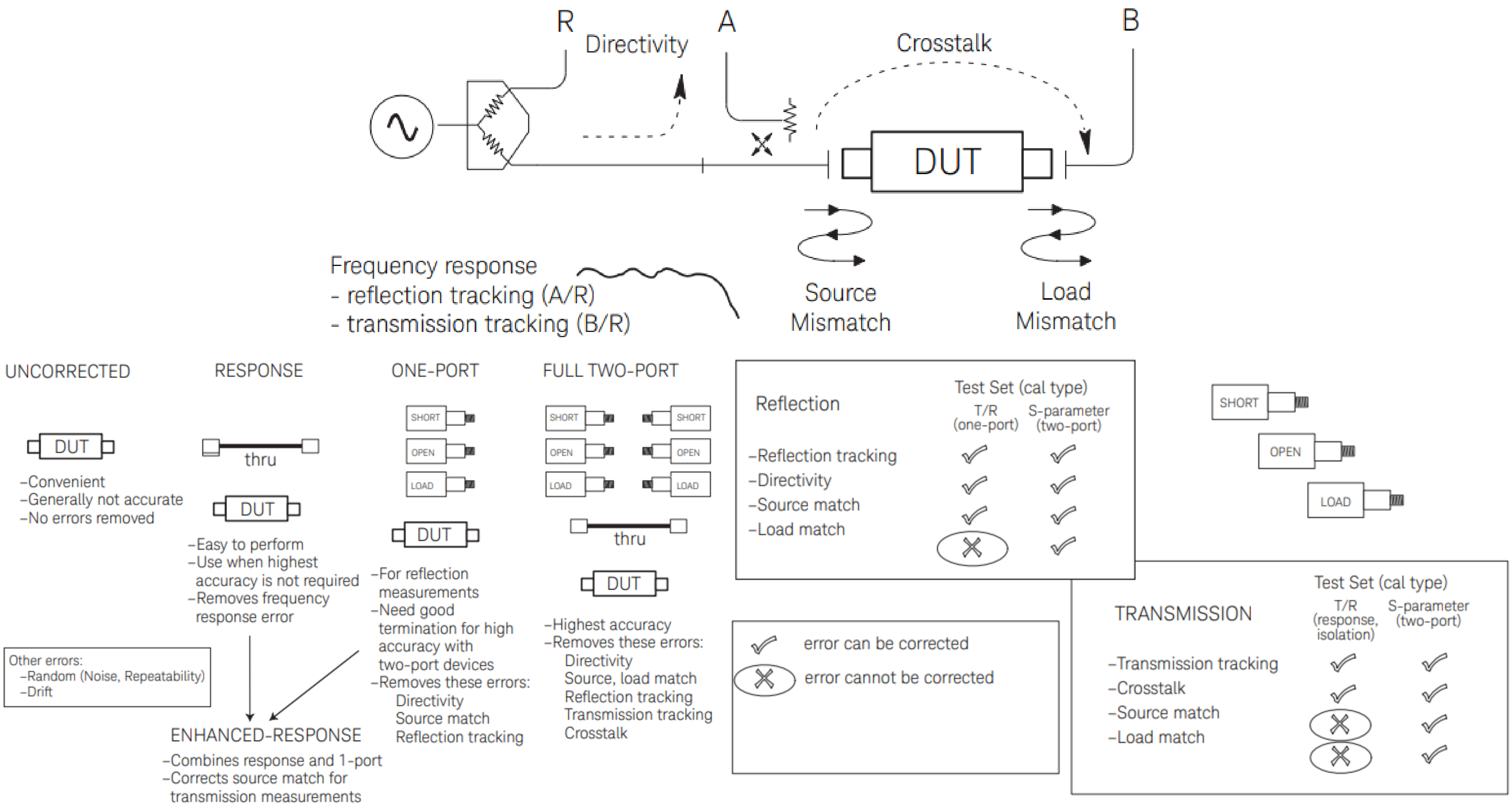
- Keysight E5080A 9kHz-9GHz 4-port VNA
  - Sweep 100kHz-9GHz
  - Power +15dBm
- N4431-60003 4 port electronic calibration unit





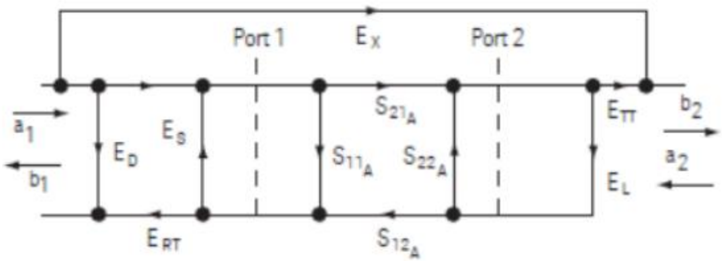
Calibration

- *Applying Error Correction to VNA Measurements* http://literature.cdn.keysight.com/litweb/pdf/5965-7709E.pdf

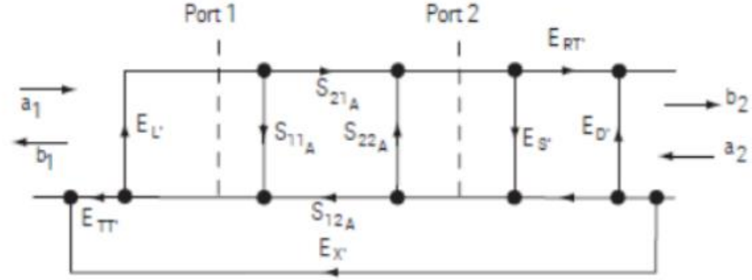


12-term Calibration

Forward model



Reverse model



E_D = Fwd Directivity
E_S = Fwd Source Match
E_{RT} = Fwd Reflection Tracking
E_L = Fwd Load Match
E_{TT} = Fwd Transmission Tracking
E_X = Fwd Isolation

$E_{D'}$ = Rev Directivity
$E_{S'}$ = Rev Source Match
$E_{RT'}$ = Rev Reflection Tracking
$E_{L'}$ = Rev Load Match
$E_{TT'}$ = Rev Transmission Tracking
$E_{X'}$ = Rev Isolation

$$S_{11a} = \frac{\left(\frac{S_{11m}-E_D}{E_{RT}}\right)\left(1+\frac{S_{22m}-E_D'}{E_{RT}'}E_S'\right) - E_L\left(\frac{S_{21m}-E_X}{E_{TT}}\right)\left(\frac{S_{12m}-E_X'}{E_{TT}'}\right)}{\left(1+\frac{S_{11m}-E_D}{E_{RT}}E_S\right)\left(1+\frac{S_{22m}-E_D'}{E_{RT}'}E_S'\right) - E_L' E_L\left(\frac{S_{21m}-E_X}{E_{TT}}\right)\left(\frac{S_{12m}-E_X'}{E_{TT}'}\right)}$$

$$S_{21a} = \frac{\left(\frac{S_{21m}-E_X}{E_{TT}}\right)\left(1+\frac{S_{22m}-E_D'}{E_{RT}'}(E_S'-E_L)\right)}{\left(1+\frac{S_{11m}-E_D}{E_{RT}}E_S\right)\left(1+\frac{S_{22m}-E_D'}{E_{RT}'}E_S'\right) - E_L' E_L\left(\frac{S_{21m}-E_X}{E_{TT}}\right)\left(\frac{S_{12m}-E_X'}{E_{TT}'}\right)}$$

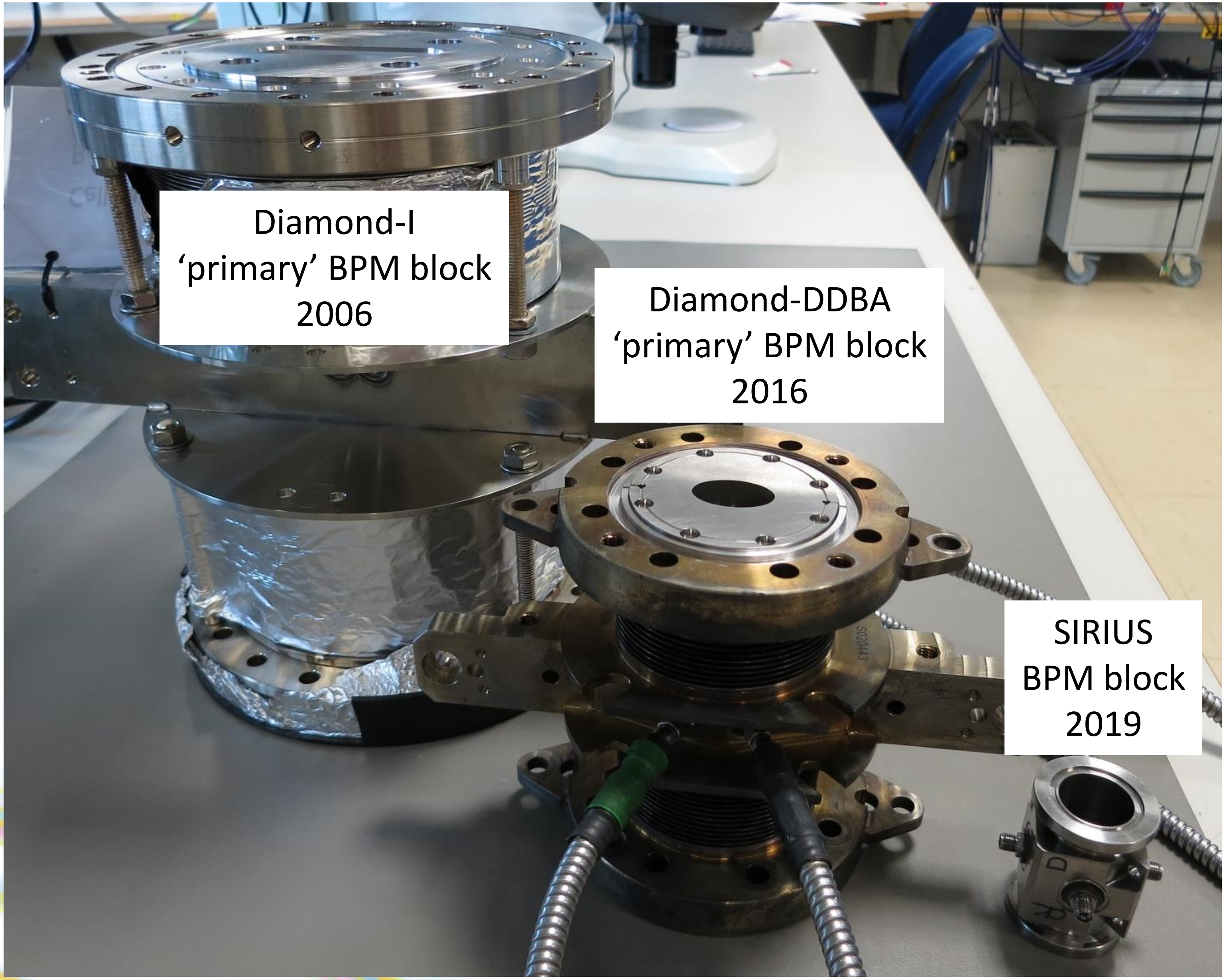
$$S_{12a} = \frac{\left(\frac{S_{12m}-E_X'}{E_{TT}'}\right)\left(1+\frac{S_{11m}-E_D}{E_{RT}}(E_S-E_L')\right)}{\left(1+\frac{S_{11m}-E_D}{E_{RT}}E_S\right)\left(1+\frac{S_{22m}-E_D'}{E_{RT}'}E_S'\right) - E_L' E_L\left(\frac{S_{21m}-E_X}{E_{TT}}\right)\left(\frac{S_{12m}-E_X'}{E_{TT}'}\right)}$$

$$S_{22a} = \frac{\left(\frac{S_{22m}-E_D'}{E_{RT}'}\right)\left(1+\frac{S_{11m}-E_D}{E_{RT}}E_S\right) - E_L'\left(\frac{S_{21m}-E_X}{E_{TT}}\right)\left(\frac{S_{12m}-E_X'}{E_{TT}'}\right)}{\left(1+\frac{S_{11m}-E_D}{E_{RT}}E_S\right)\left(1+\frac{S_{22m}-E_D'}{E_{RT}'}E_S'\right) - E_L' E_L\left(\frac{S_{21m}-E_X}{E_{TT}}\right)\left(\frac{S_{12m}-E_X'}{E_{TT}'}\right)}$$

- Notice that each actual S-parameter is a function of all four measured S-parameters
- Analyzer must make forward and reverse sweep to update any one S-parameter

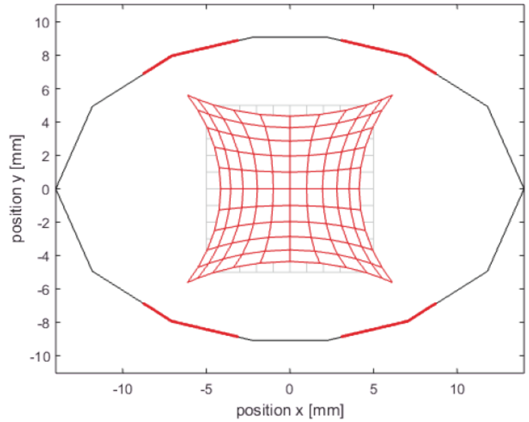
This is just for two ports, with four ports this get even more complicated!

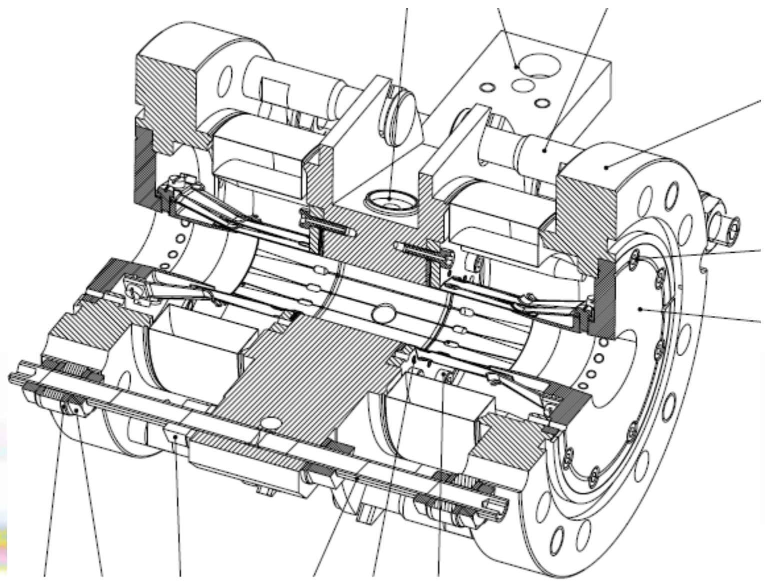
Generations of Button Blocks



DDBA Button Block

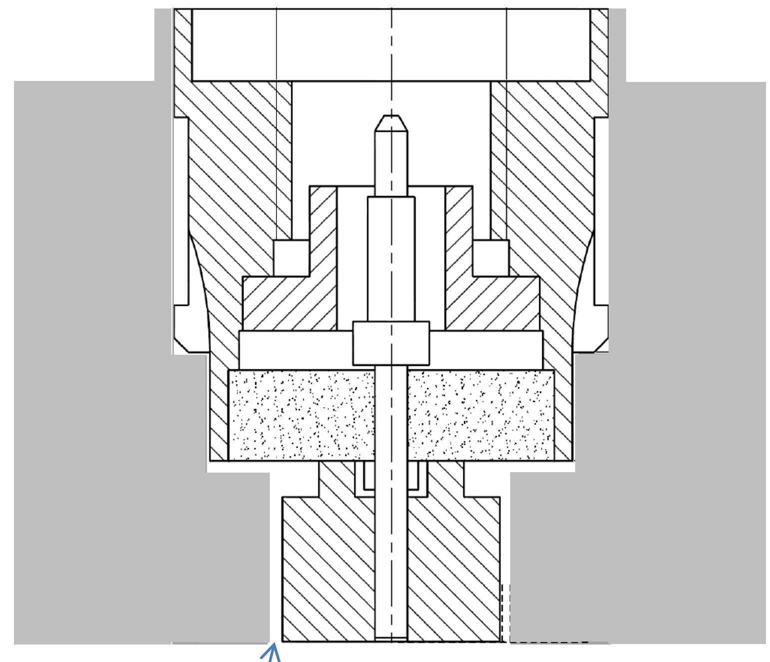
26mm wide, 18mm high





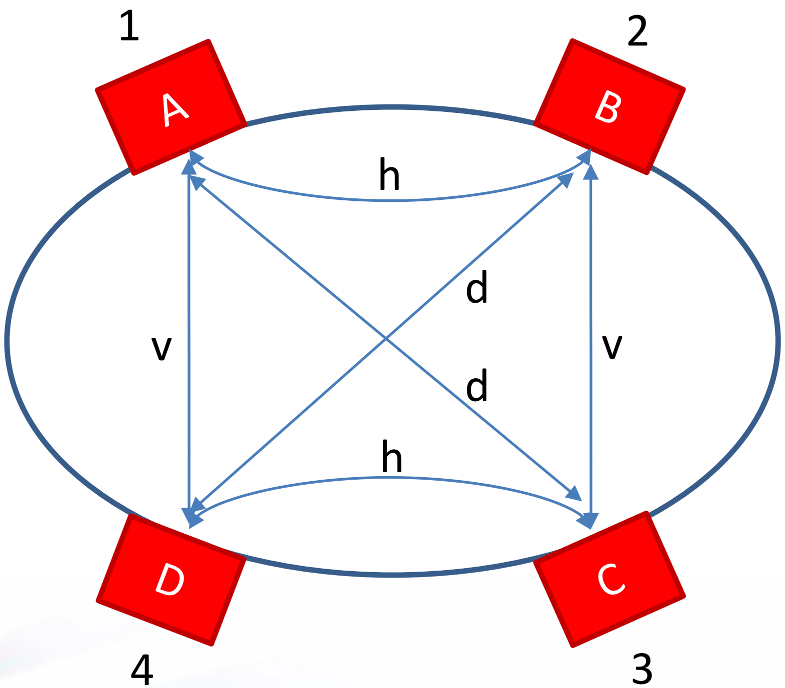
Drawing courtesy FMB Berlin

DDBA button is equivalent to
ESRF-EBS 6mm button
(but with Moly button not 316LN)



0.3mm gap between
button and hole

Lambertson in 1 minute



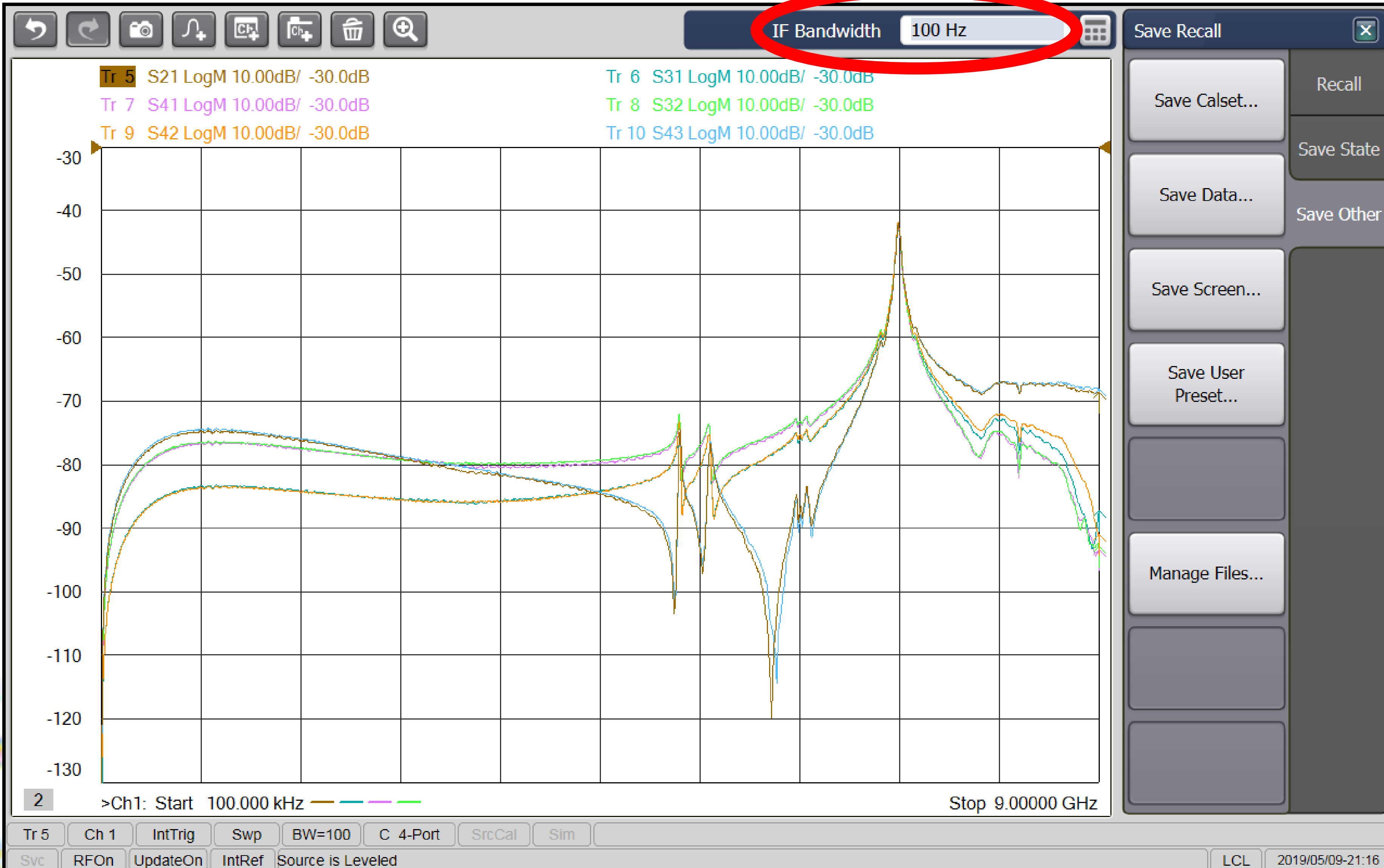
$$S_{21} = AhB$$
$$S_{42} = BdD$$
$$S_{14} = DvA$$

$$\frac{S_{21}S_{14}}{S_{42}} = \frac{AB * DA}{BD}\frac{hv}{d} = A^2 * c_1$$

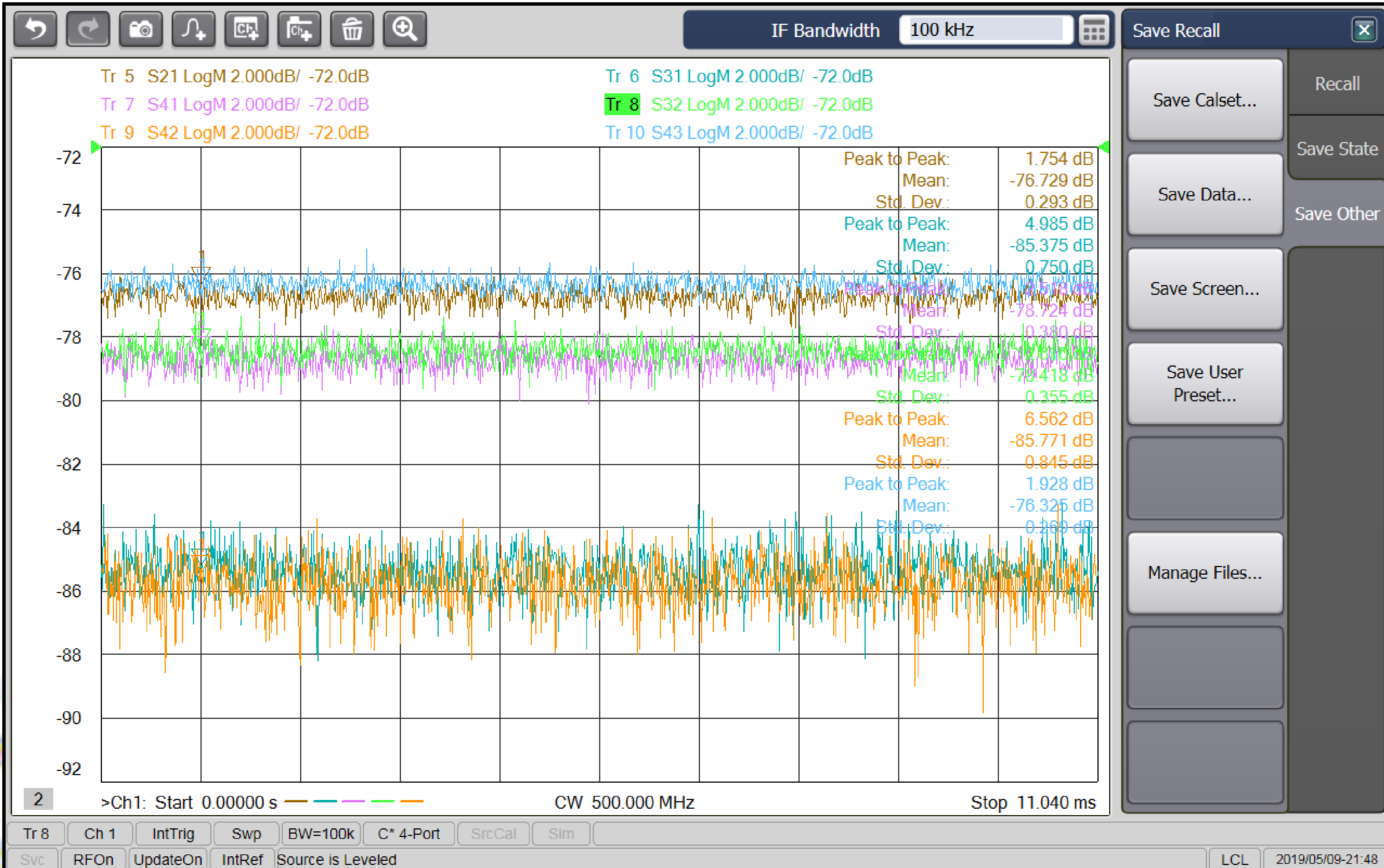
- Repeat for other buttons
- Repeat with other equations for other Lambertson types

DDBA Buttons Sweep

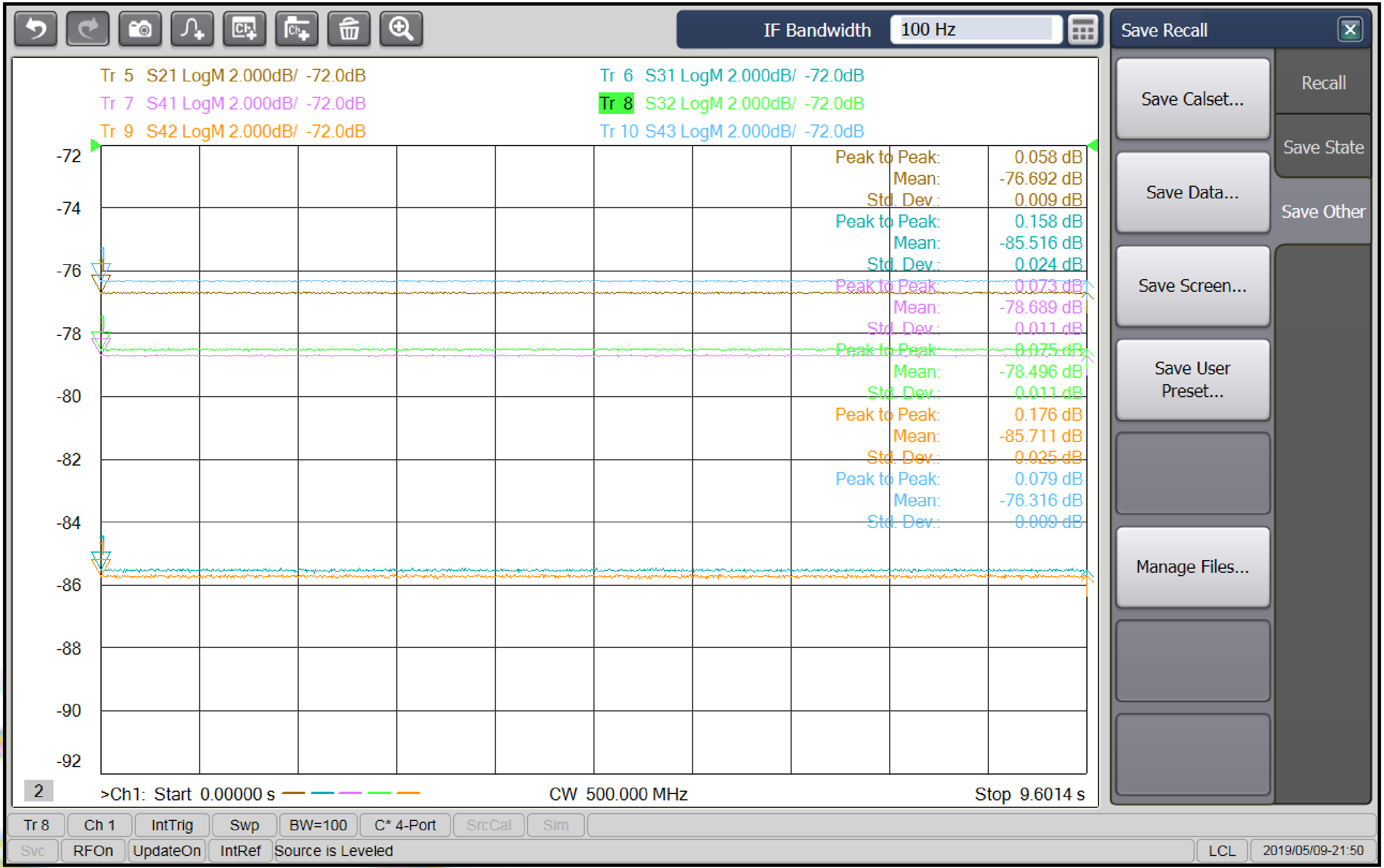
Improved DDBA buttons Sweep



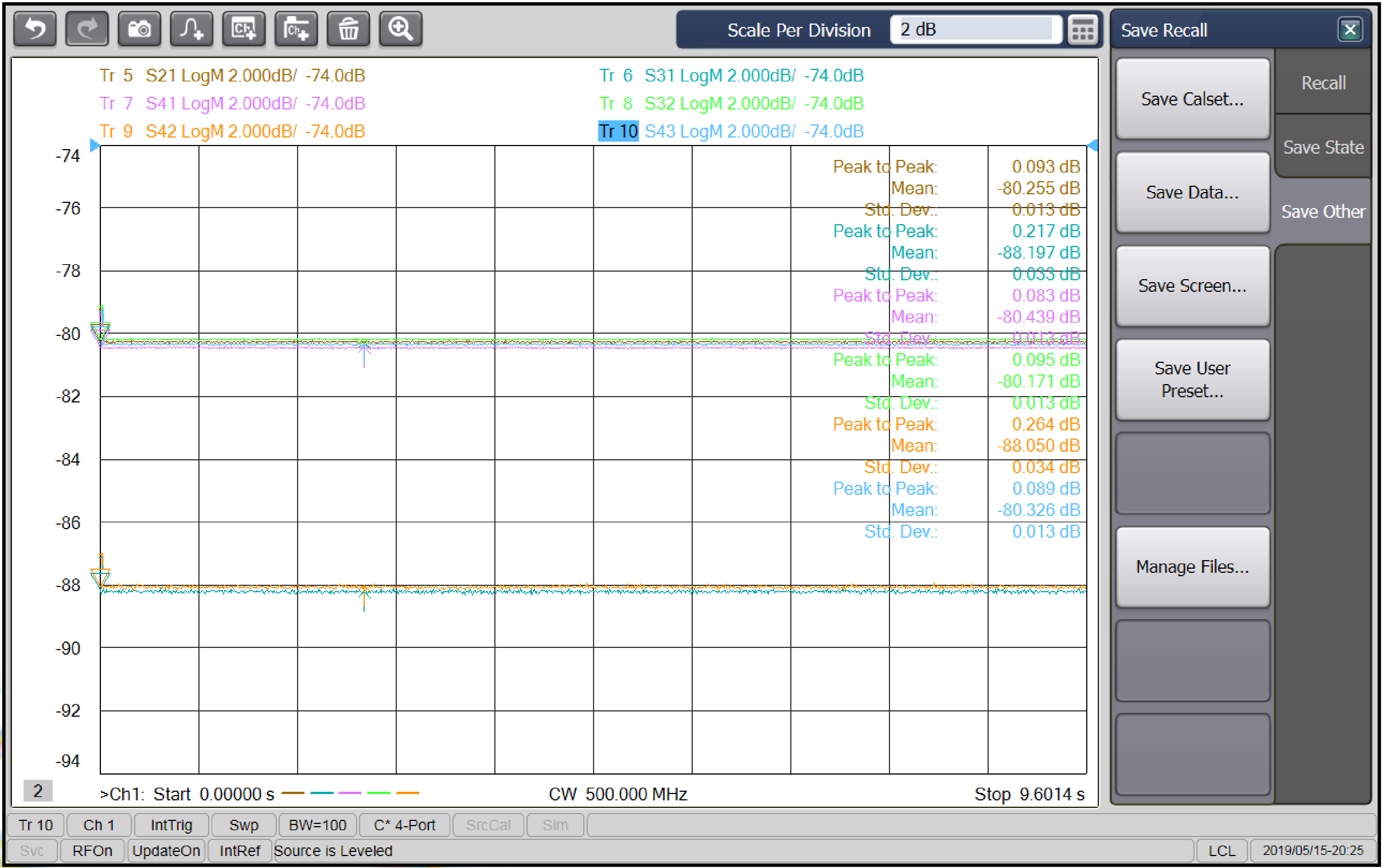
0 Hz Sweep@500MHz over Time



Low IF Sweep@500MHz



SIRIUS buttons



Lambertson Type Analysis

- Convert S-parameters to linear gains and XY offsets in matlab:

```
S = abs(sparameters(filename).Parameters);
gains = sqrt(squeeze([S(2,1,:).*S(1,4,:)./S(4,2,:)...
    S(2,1,:).*S(3,2,:)./S(3,1,:)...
    S(3,2,:).*S(4,3,:)./S(4,2,:)...
    S(1,4,:).*S(4,3,:)./S(3,1,:)]));
xy = 7000*([-1 1 1 -1;1 1 -1 -1]*gains)./repmat(sum(gains),2,1);
```

- Calculate statistics for all three cases
- Compare
  - measurement
  - measurement one day later (not disconnected)
  - three back-to-back measurements
  - disconnect and re-connect

Quick Statistics

All offset calculated for scale factor 7mm and displayed in µm

	Day1	Day2-1st	Day2-2nd	Day2-3rd	Day2-remade
X1±1σ	42.4 +/- 3.1	42.8 +/- 3.1	42.8 +/- 3.1	42.8 +/- 3.1	40.5 +/- 3.1
Y1±1σ	-67.7 +/- 2.4	-67.4 +/- 2.3	-67.3 +/- 2.5	-67.5 +/- 2.5	-79.6 +/- 2.5
X2±1σ	41.5 +/- 3.4	42.7 +/- 3.3	42.8 +/- 3.3	42.7 +/- 3.3	40.5 +/- 3.4
Y2±1σ	-66.8 +/- 2.1	-67.3 +/- 2.0	-67.2 +/- 2.2	-67.3 +/- 2.1	-79.5 +/- 2.2
X3±1σ	41.8 +/- 2.7	42.8 +/- 2.7	42.8 +/- 2.7	42.9 +/- 2.7	40.4 +/- 2.7
Y3±1σ	-67.1 +/- 2.8	-67.4 +/- 2.8	-67.2 +/- 3.0	-67.5 +/- 3.0	-79.5 +/- 3.0

Conclusions/Discussion

- VNA:
  - Can measure with sufficient resolution
  - Reproducibility excellent
  - Reconnections produce larger deviations
- Lambertson:
  - Anybody who has the original paper, please forward
  - Presumably it requires symmetry in the geometry
  - Do the different types tell us something about symmetry?
- Real BPM:
  - Not well matched ports will read differently
  - Cables and connectors will change readings again
- Bluesky:
  - Could we add Lambertson like test into BPM?
  - Is there value in determining the button capacitance from time domain transformed S_{nn} –sweep, would that give comparable button gain?