DG8SAQ VNWA Tutorial

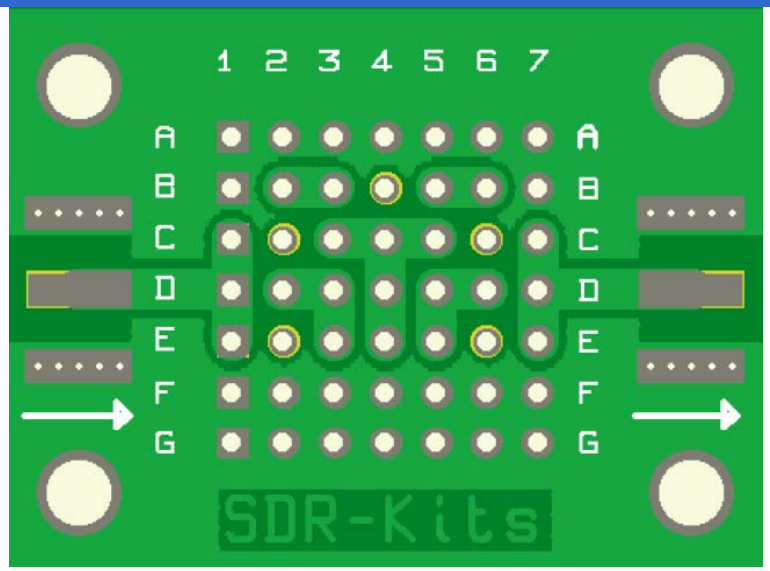
Experiments with the DG8SAQ VNWA and the SDR-Kits Test Board

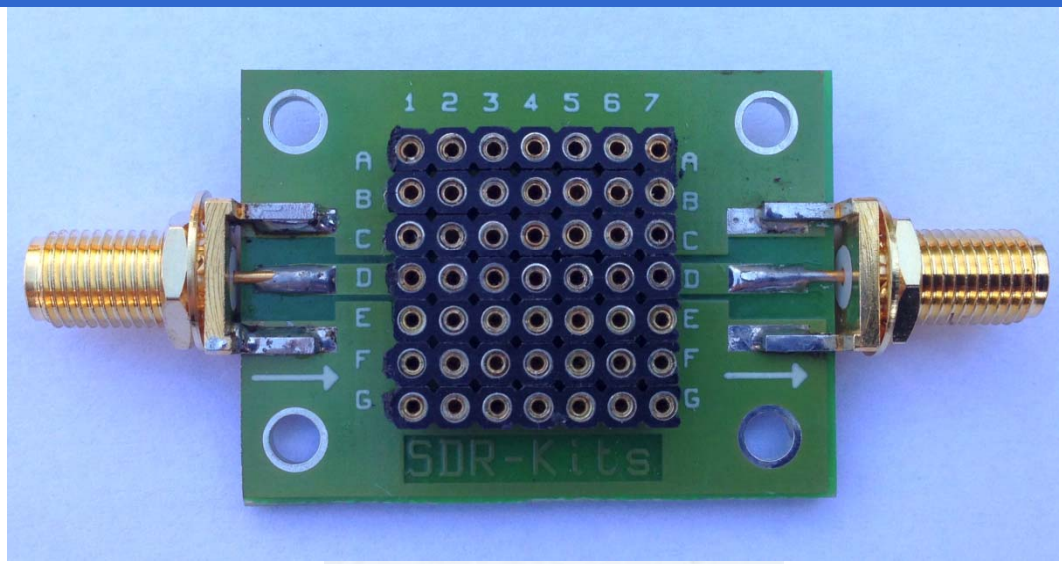
Tom BAIER

DG8SAQ

This is an excerpt from my Ham Radio 2013 presentation which has been slightly extended (slides 6, 20 and 21 added).

Test Board for HF Experiments



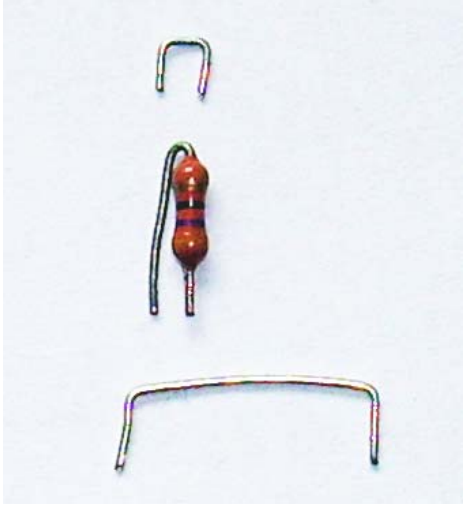


Calibration Standards:

Short:

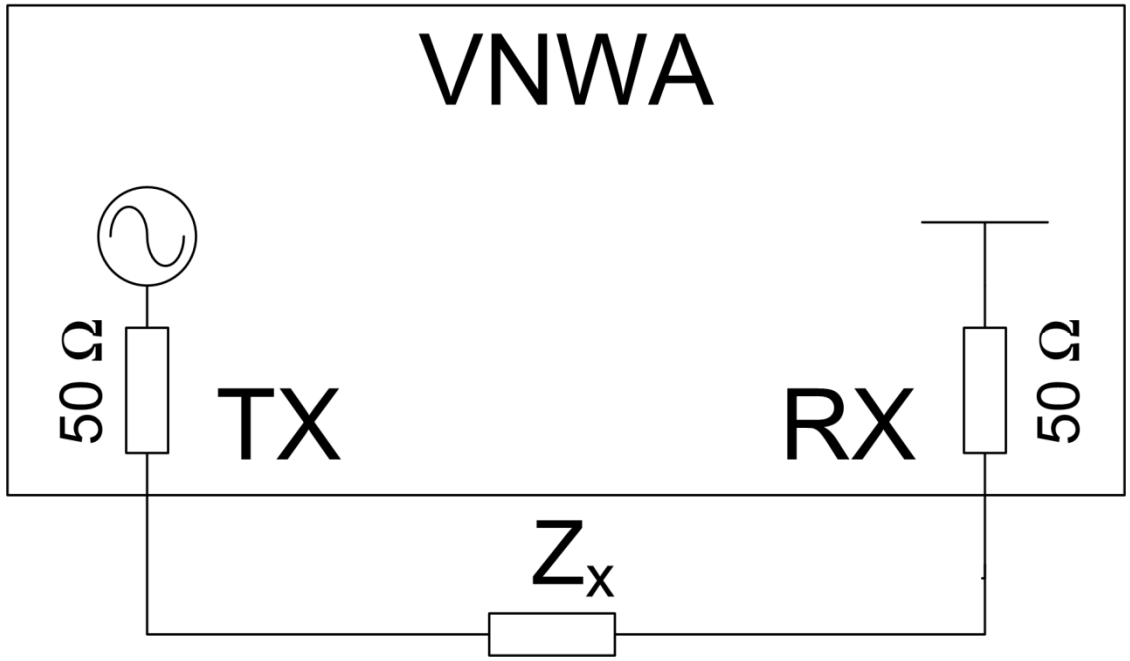
Load = 47Ω:

Thru:



Open = n.c.

Measuring „Load“-Resistor without SOL-Calibration?

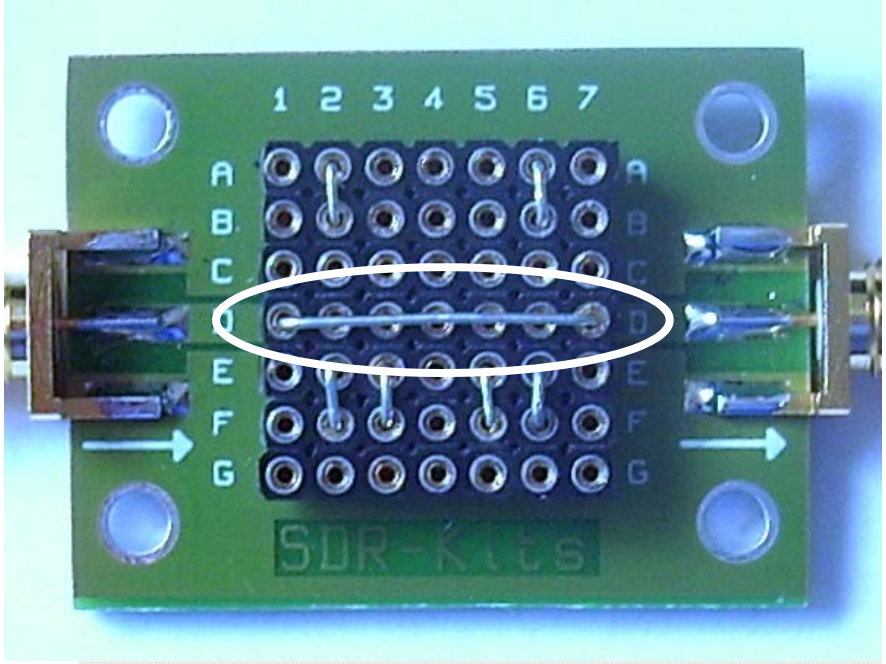


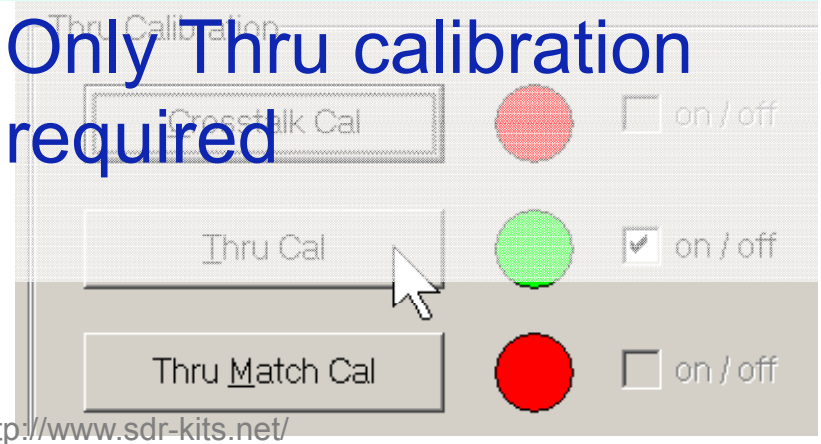
Works, because VNWA TX and RX port impedances are exactly 50 Ω.

- only Thru calibration required!

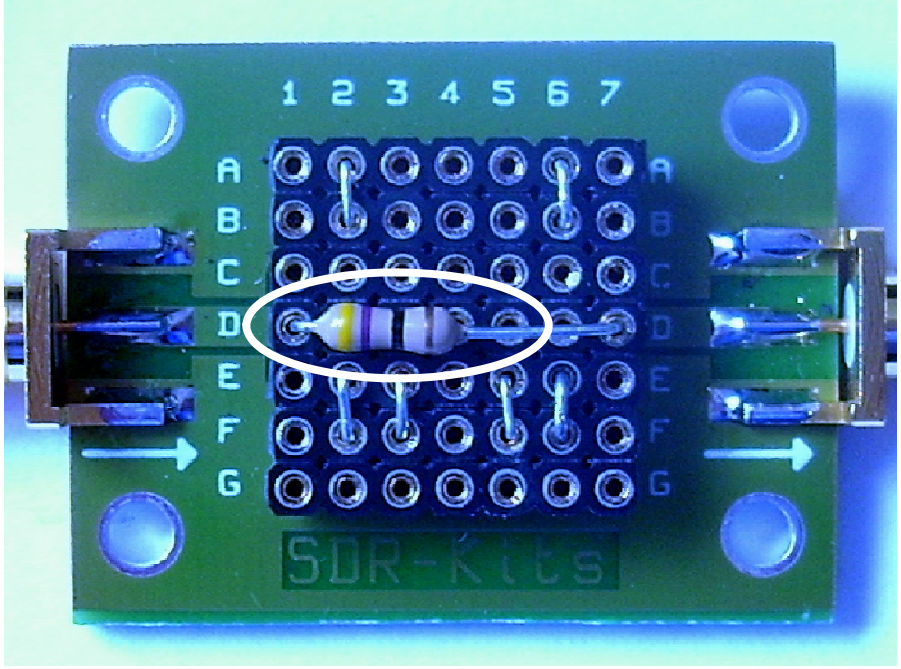
Z_x = 47 Ω yield ≈3,4 dB insertion loss.

Measuring „Load“-Resistor in Transmission (=S_{21}-Measurement)



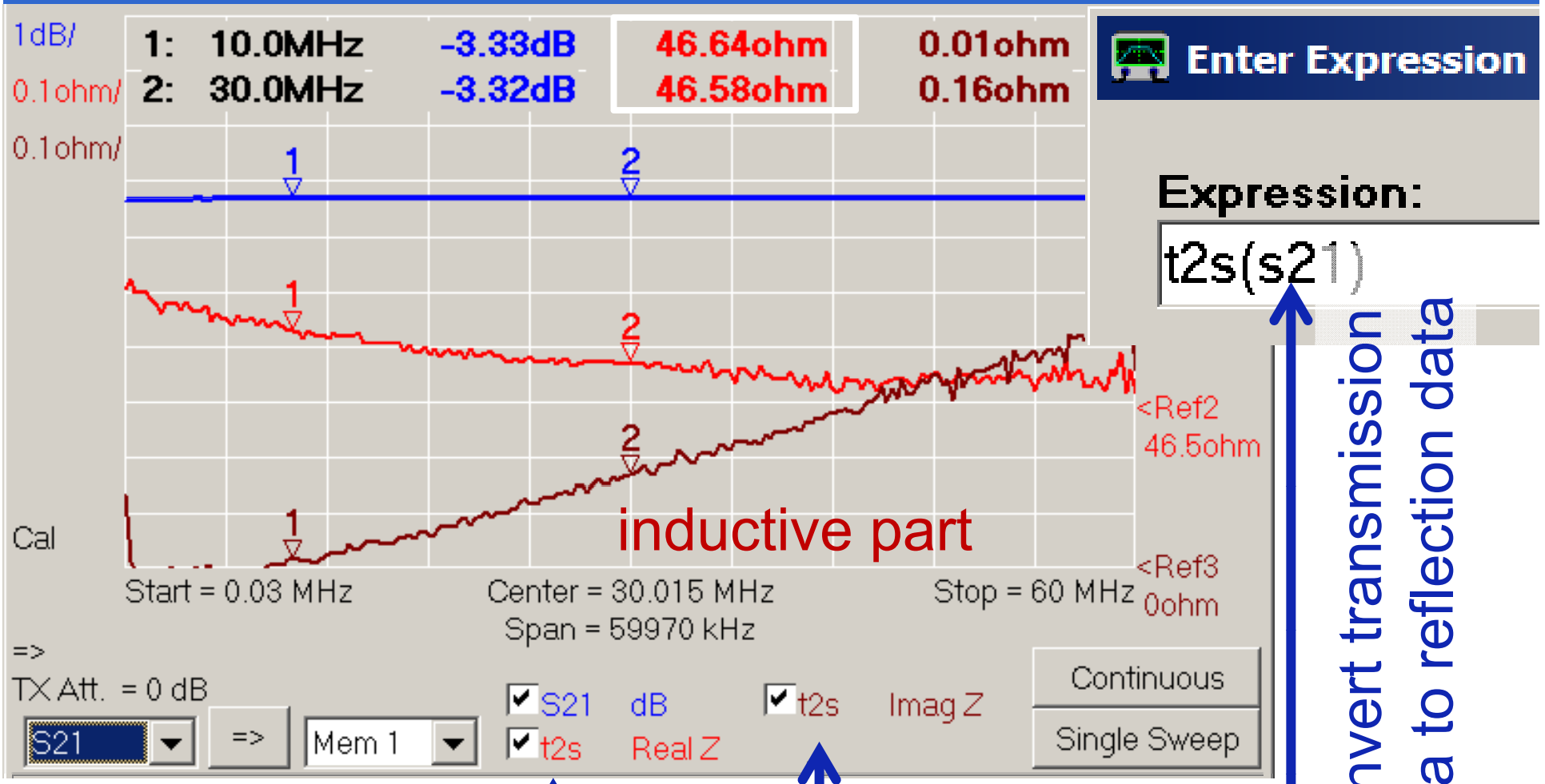


Only Thru calibration required

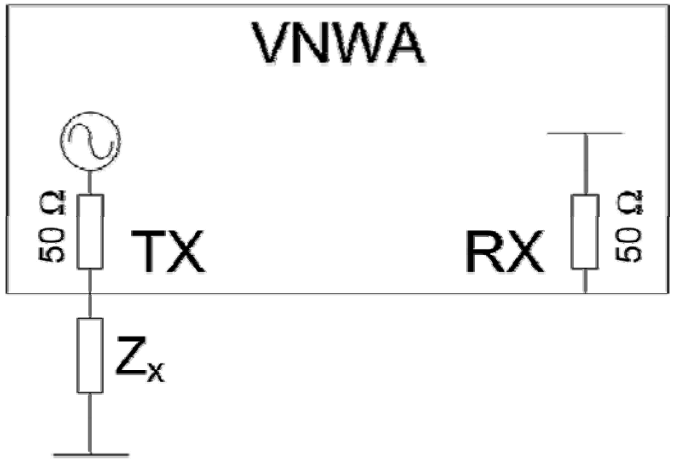


Measurement:
Resistor between TX and RX

Measuring „Load“-Resistor
Result = 46,6 Ω

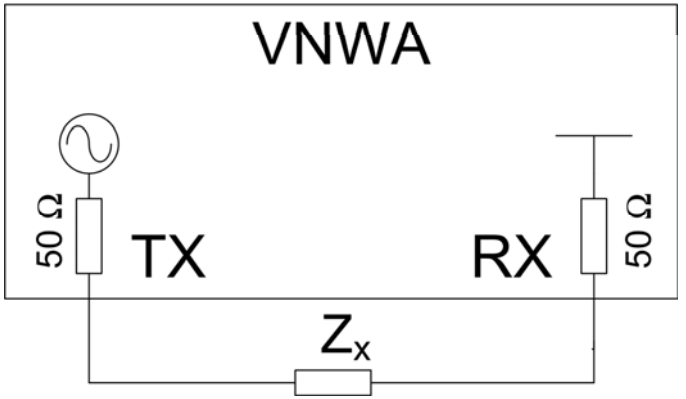


Reflection Data vs. Transmission Data



normalized impedance:

$$z \overset{!}{=} \frac{Z_x}{50\Omega}$$



$$S_{11} = \frac{z-1}{z+1}$$

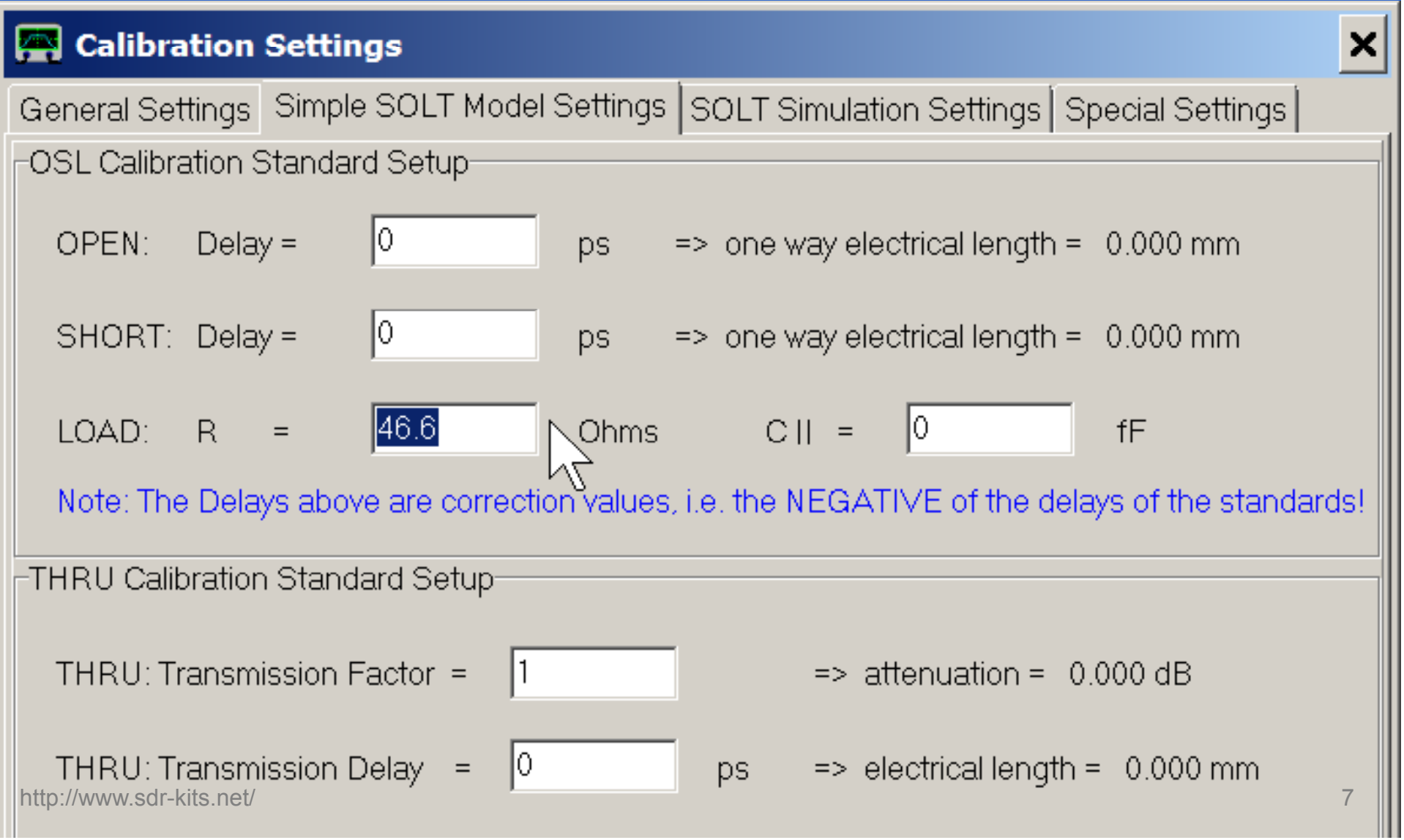
$$S_{21} = s2t(S_{11})$$

$$S_{11} = t2s(S_{21})$$

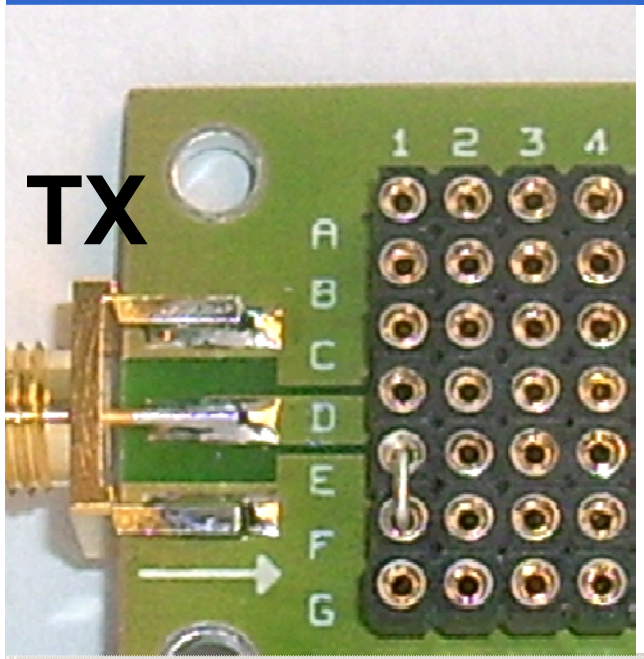
$$S_{21} = \frac{2}{z+2}$$

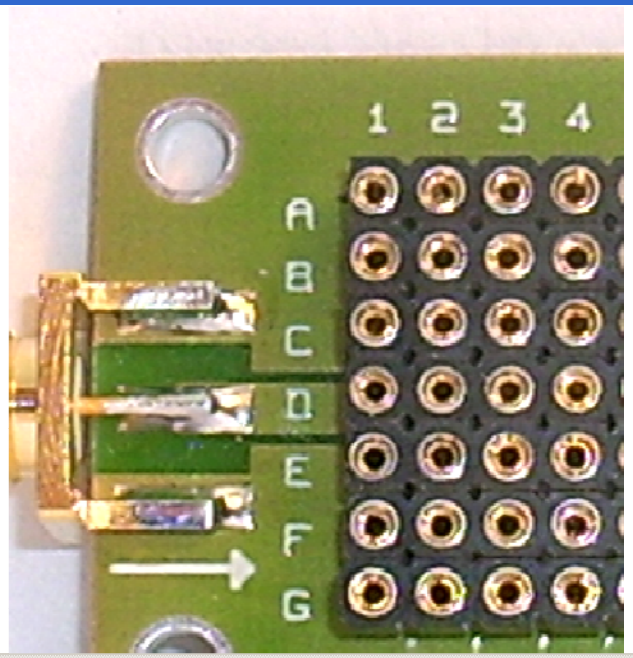
These conversions can be performed with VNWA Custom traces.

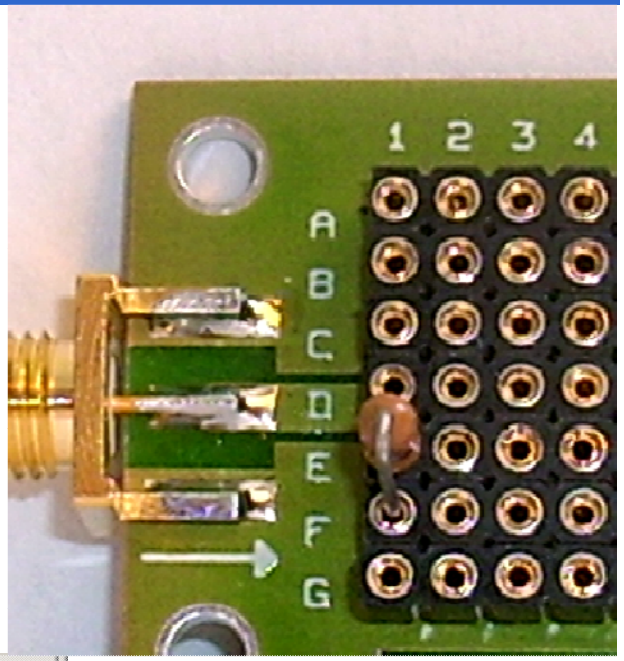
Simple Calibration Standard Model: Only measured Load-Resistance



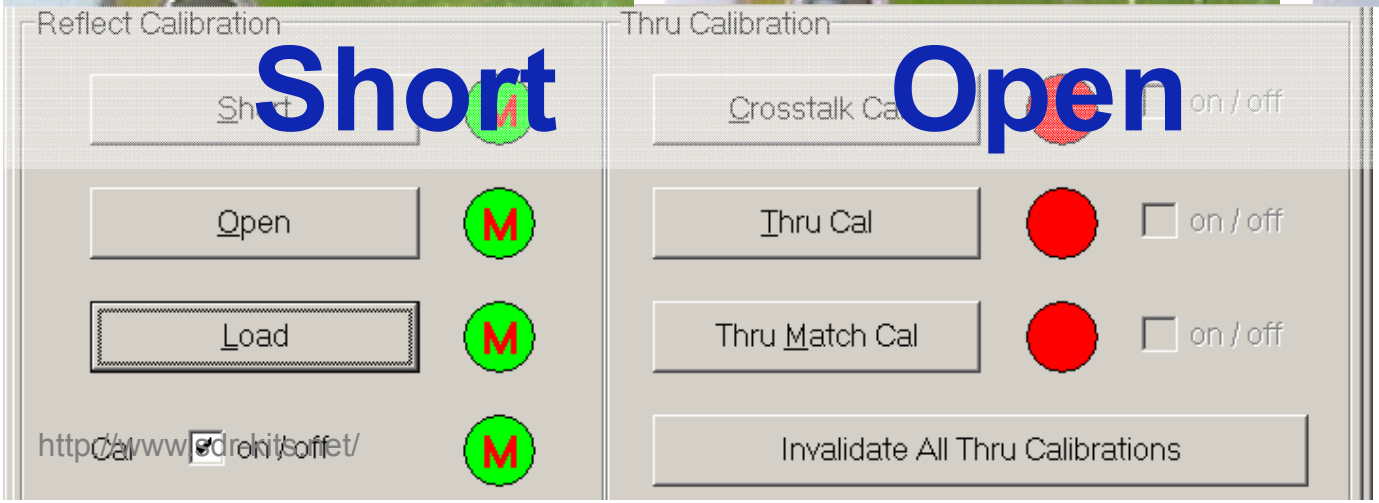
SOL-Calibration for S_{11}-Measurement



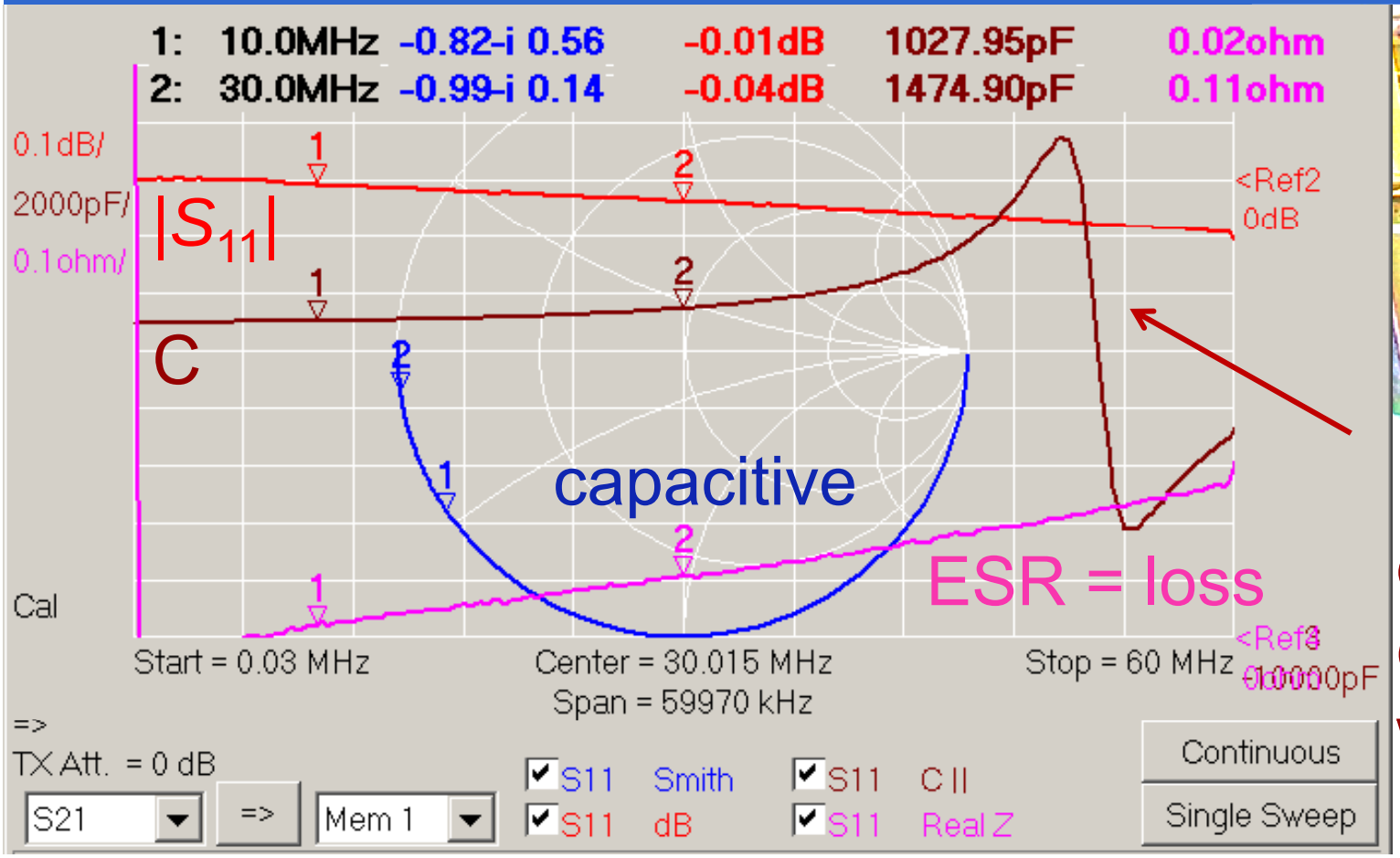


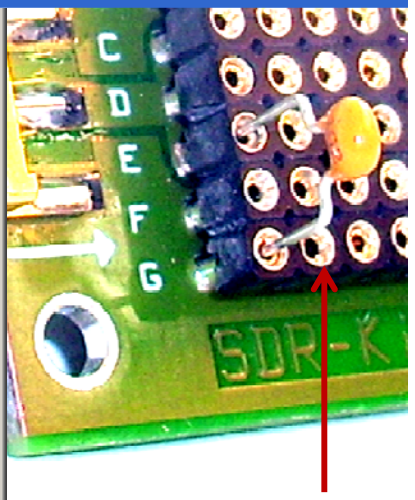


Short **Open** **Load**



Reflexion Measurement (S_{11}) of a 1 nF Capacitor





Resonance due to component wires

Capacitor reflects almost total power, $|S_{11}| \approx 0$ dB

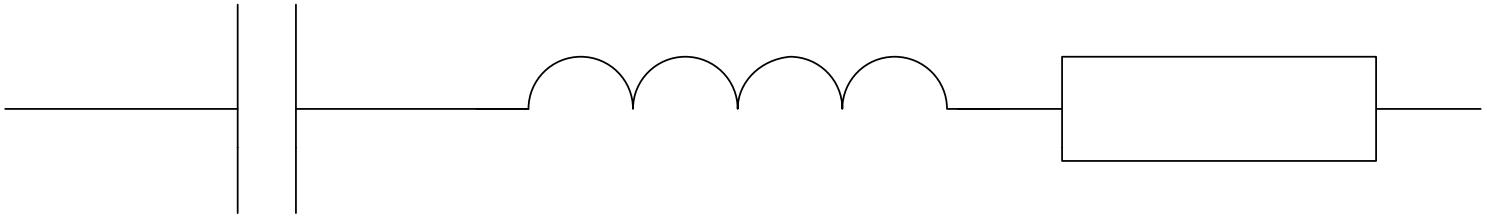
Modelling of Measurement Result in VNWA using Custom-Trace

Enter Expression 2 for trace 2:

Impedance to Reflecion coefficient

Expression:

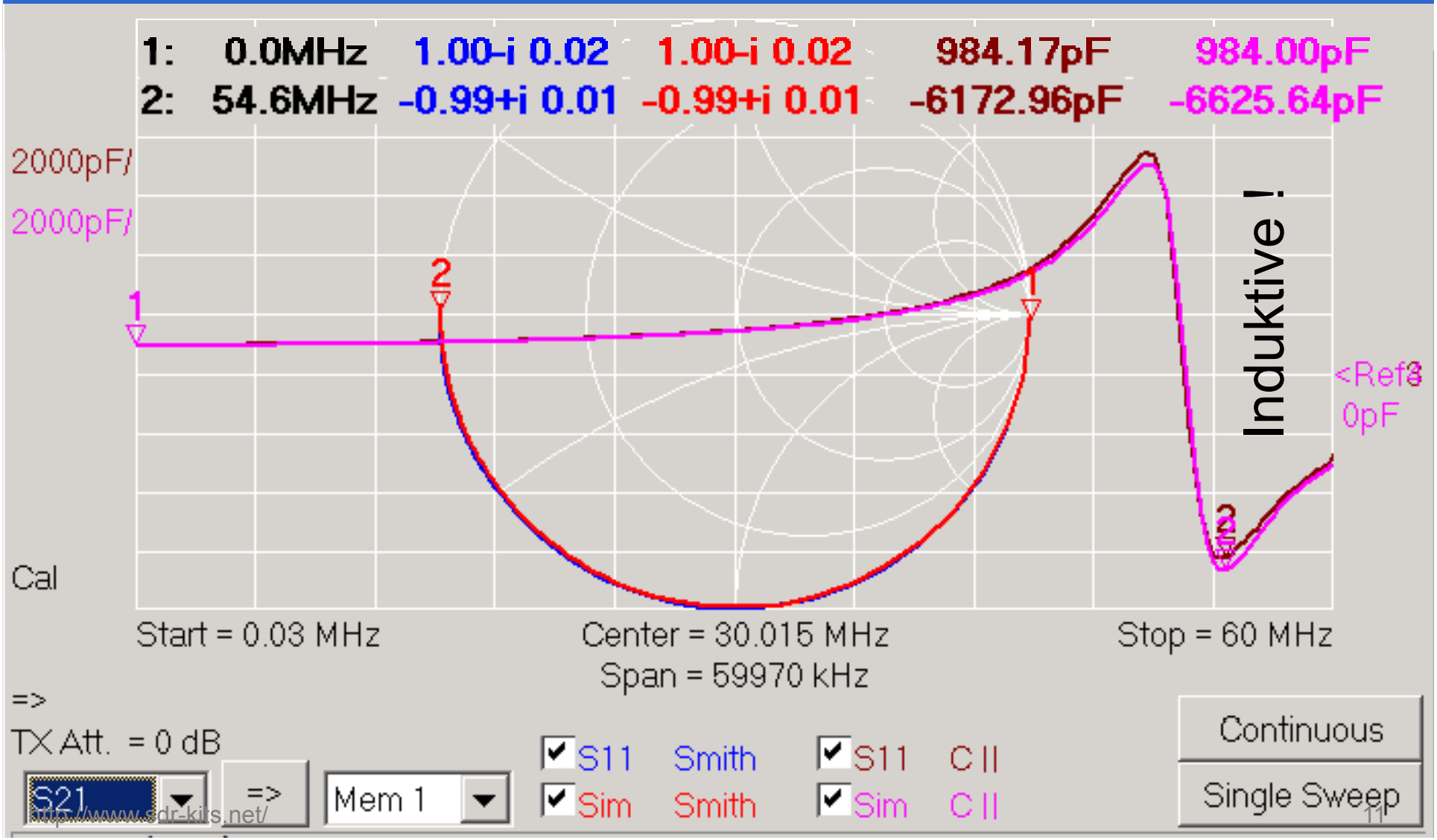
z2s(1/(j*w*0.984e-9)+j*w*9.3e-9+0.22)



0,984 nF 9,3 nH 0,22 Ω

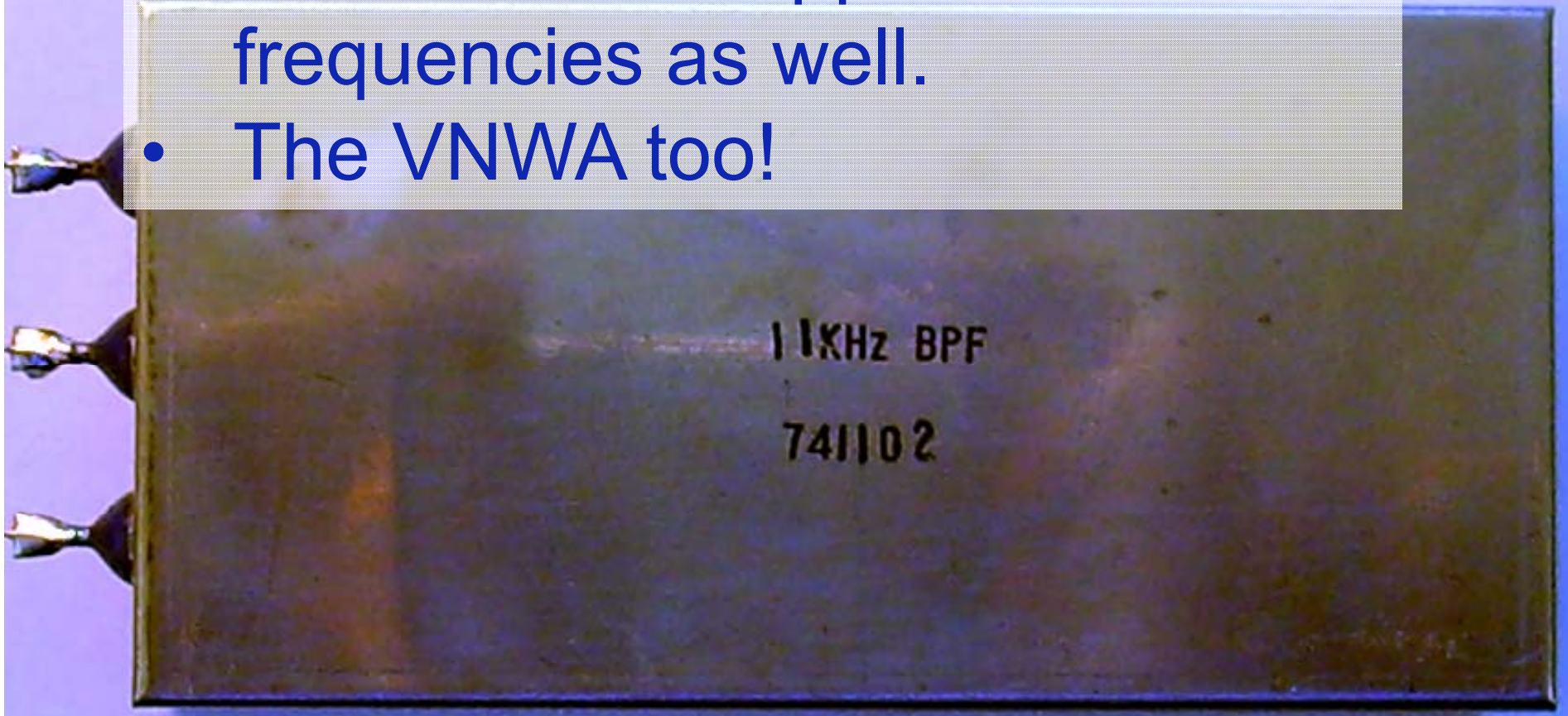
einfaches Modell

The Model is quite accurate!

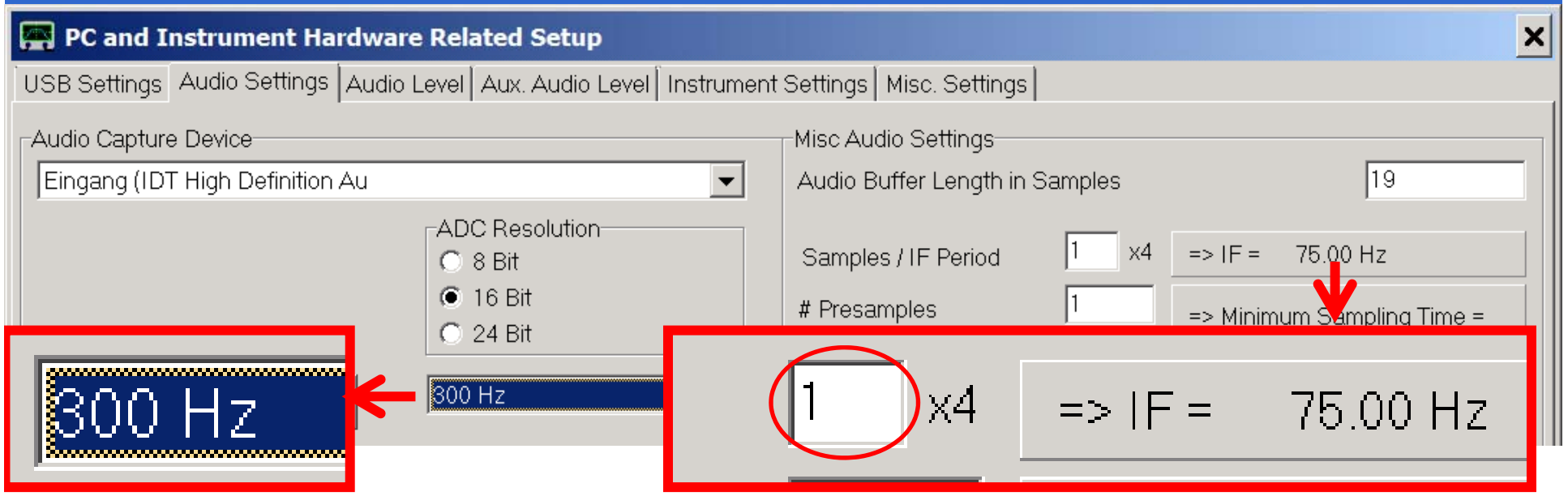


Two Port Measurement of a 12 kHz Band Pass Filter

- S-Parameters applicable to low frequencies as well.
- The VNWA too!



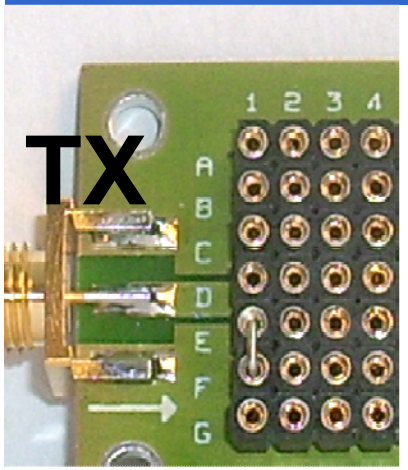
Special VNWA Settings for low Frequencies

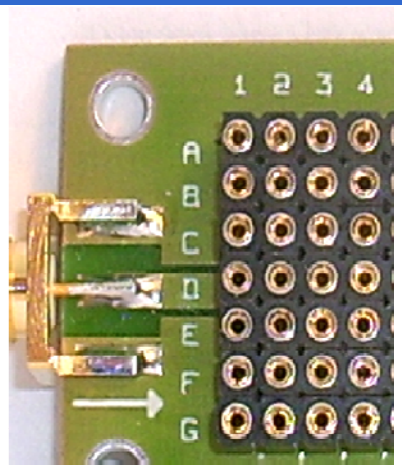


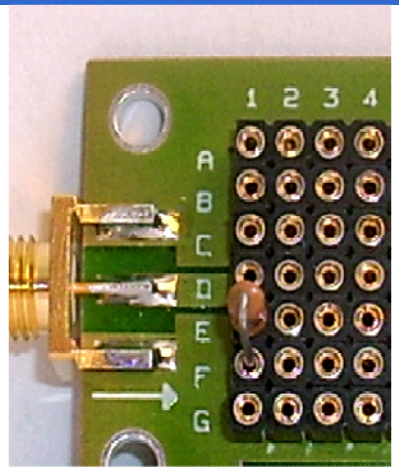
Lowest sample rate 300 Hz
→ Nyquist limit 150 Hz
→ Measurements down to ≈150 Hz possible

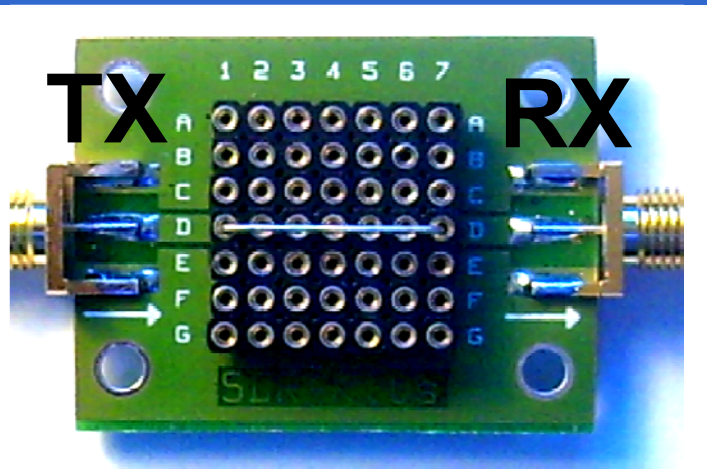
IF must be within Codec frequency range (20 Hz…16kHz)

SOLT-Calibration for 2-Port Measurements









Short **Open** **Load** **Thru**

Reflect Calibration

Short

Open

Load

Cal on / off

Thru Calibration

Crosstalk Cal on / off

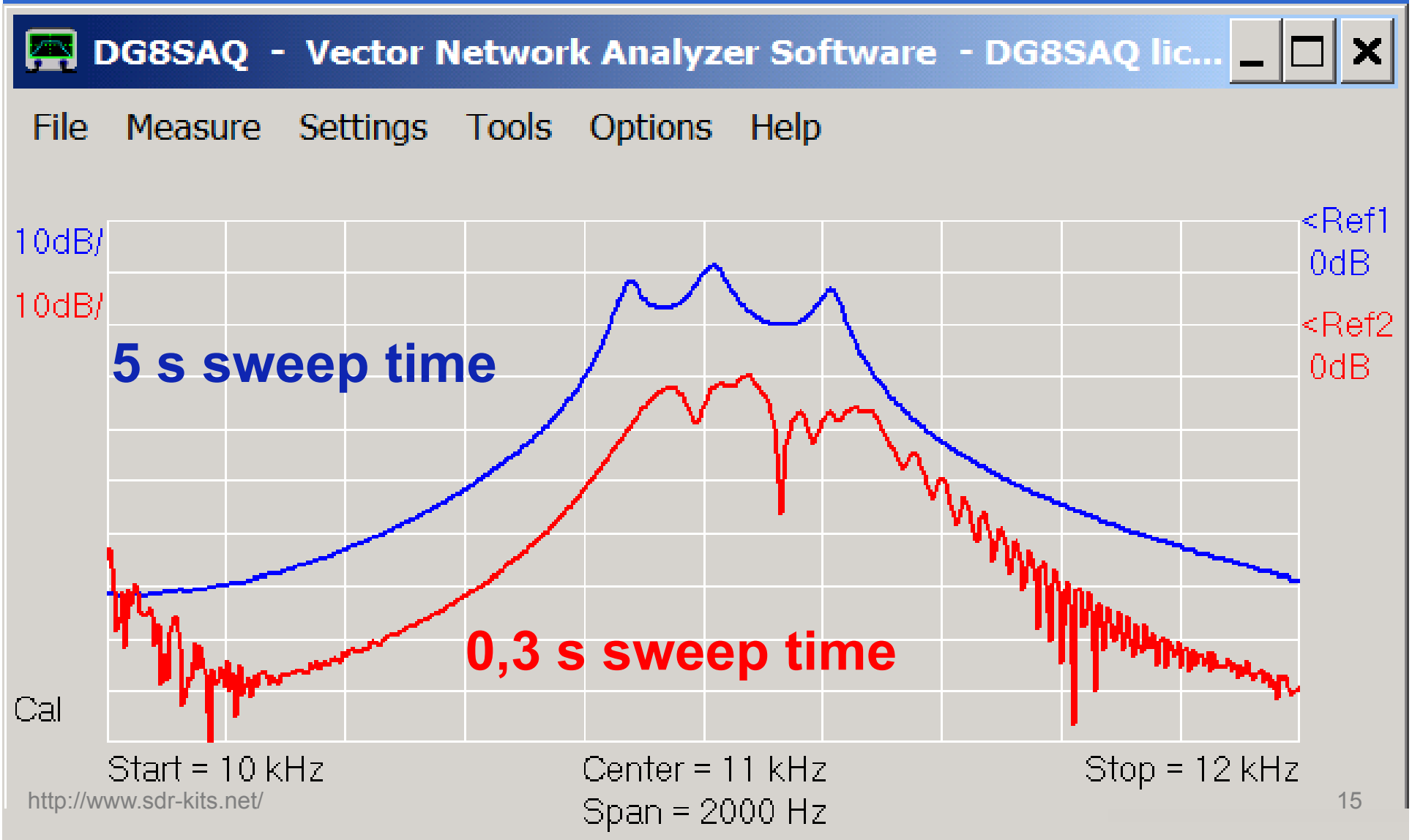
Thru Cal on / off

Thru Match Cal on / off

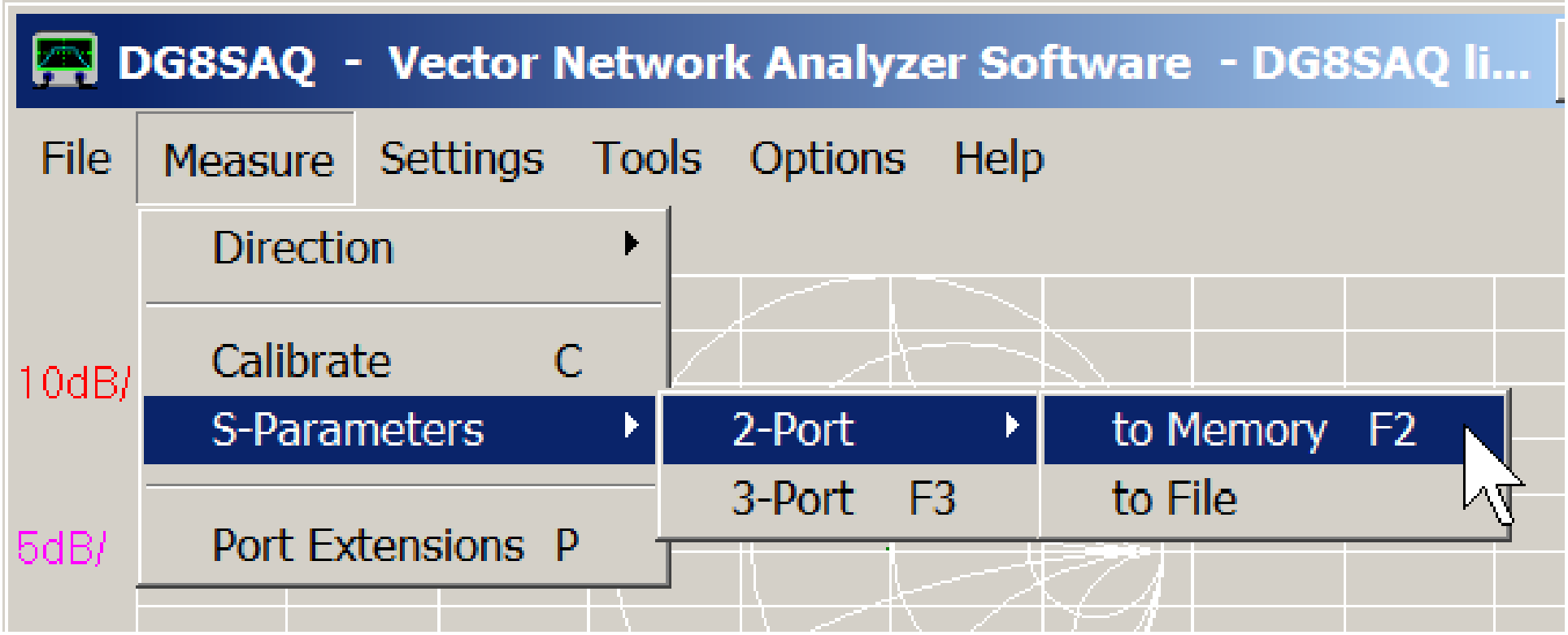
Invalidate All Thru Calibrations

http://www.sdr-kits.net/

Beware: Steep Skirt Filters require Time to settle to changing Stimulus!

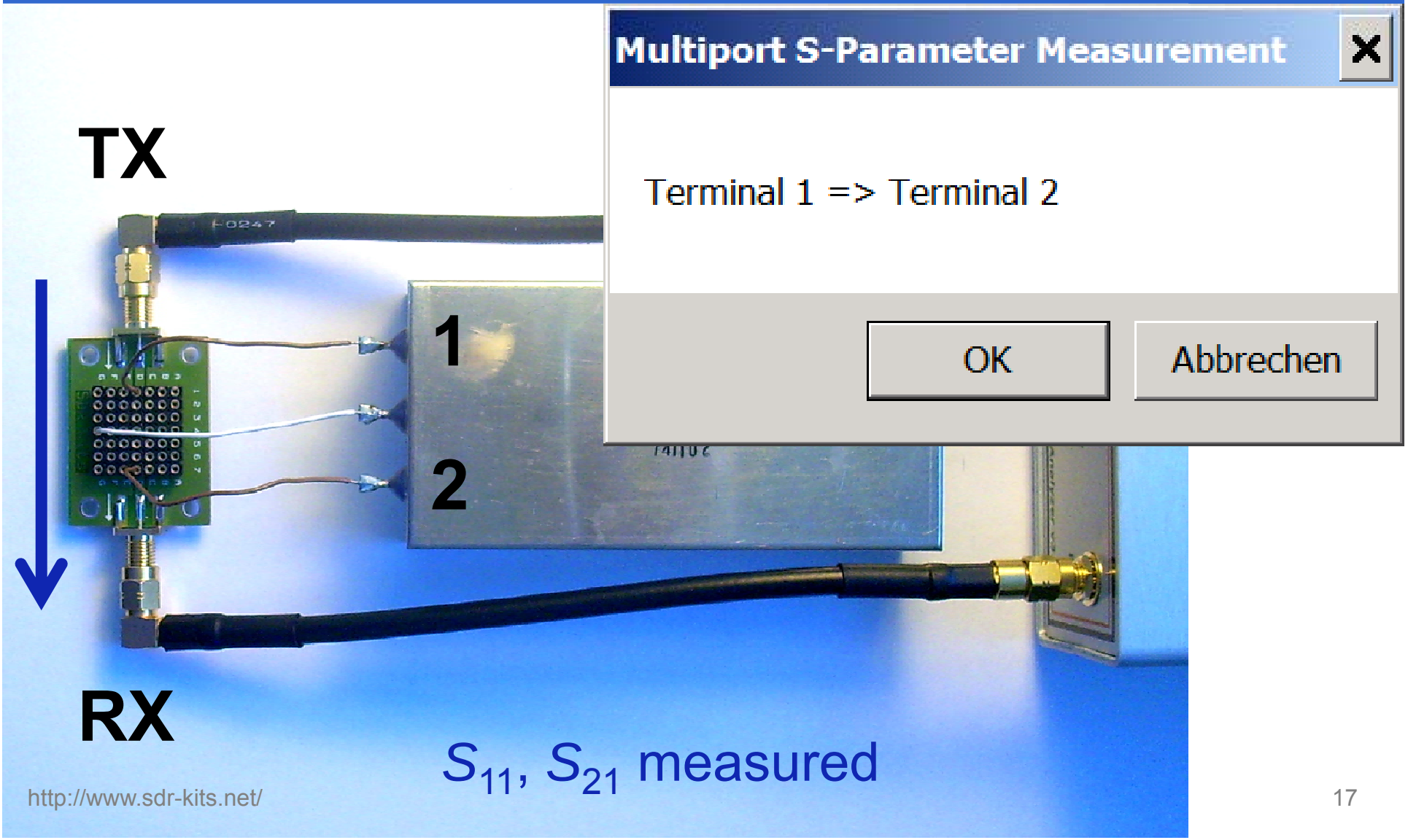


Two Port Measurement of a 12 kHz Band Pass Filter

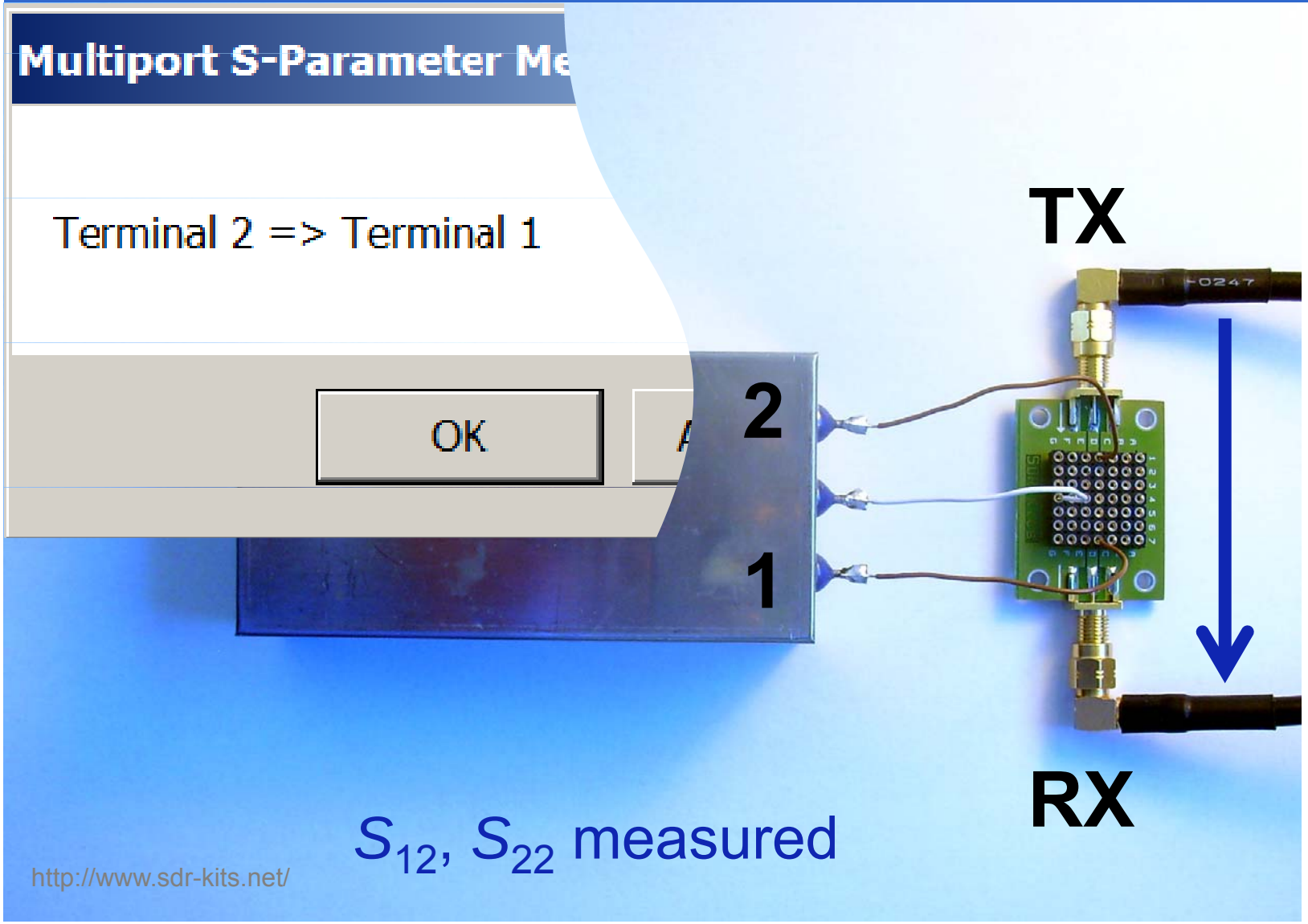


We need to measure all four S-parameters (S_{11}, S_{21}, S_{12}, S_{22}) …

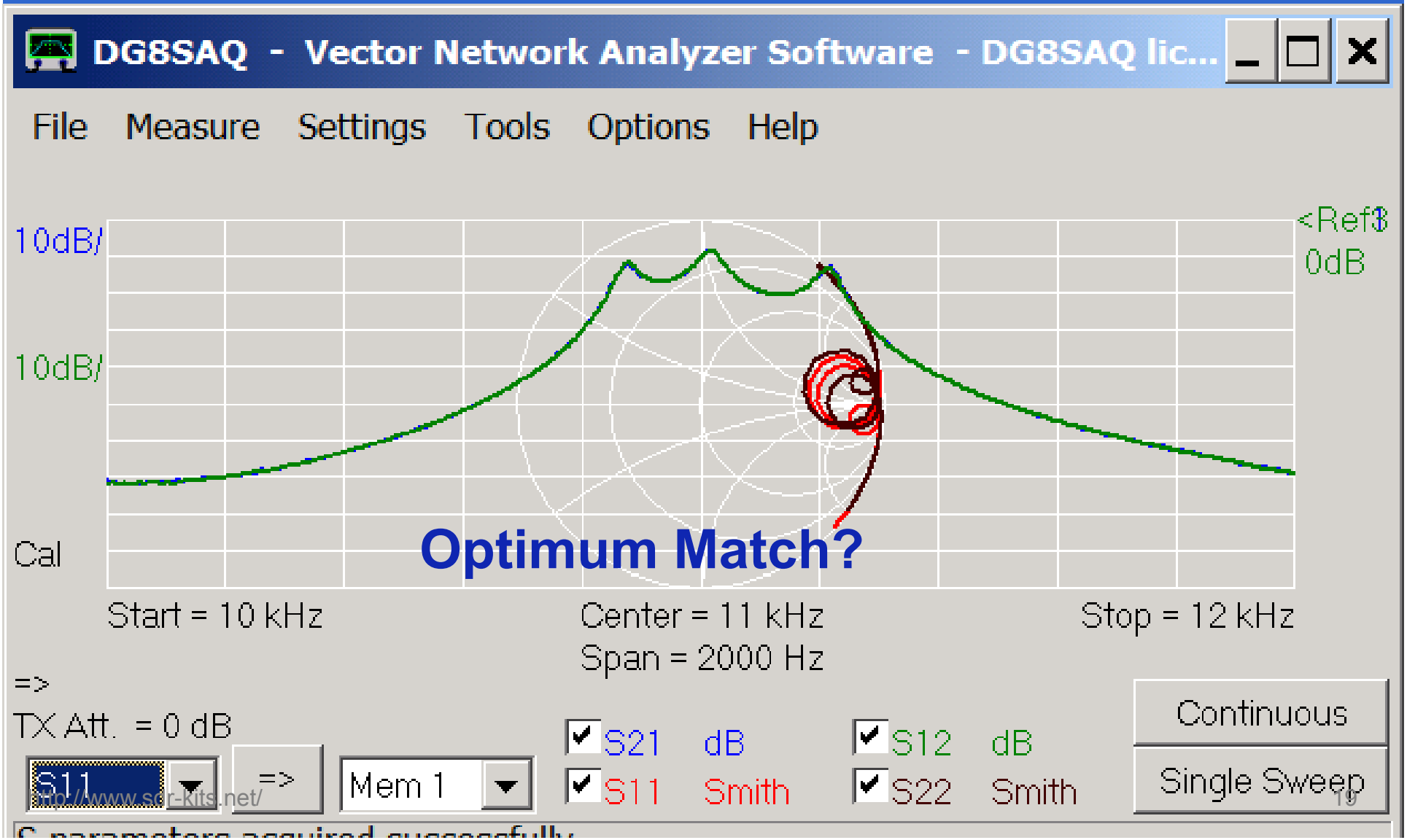
Two Port Measurement of a 12 kHz Band Pass Filter: Forward Measurement



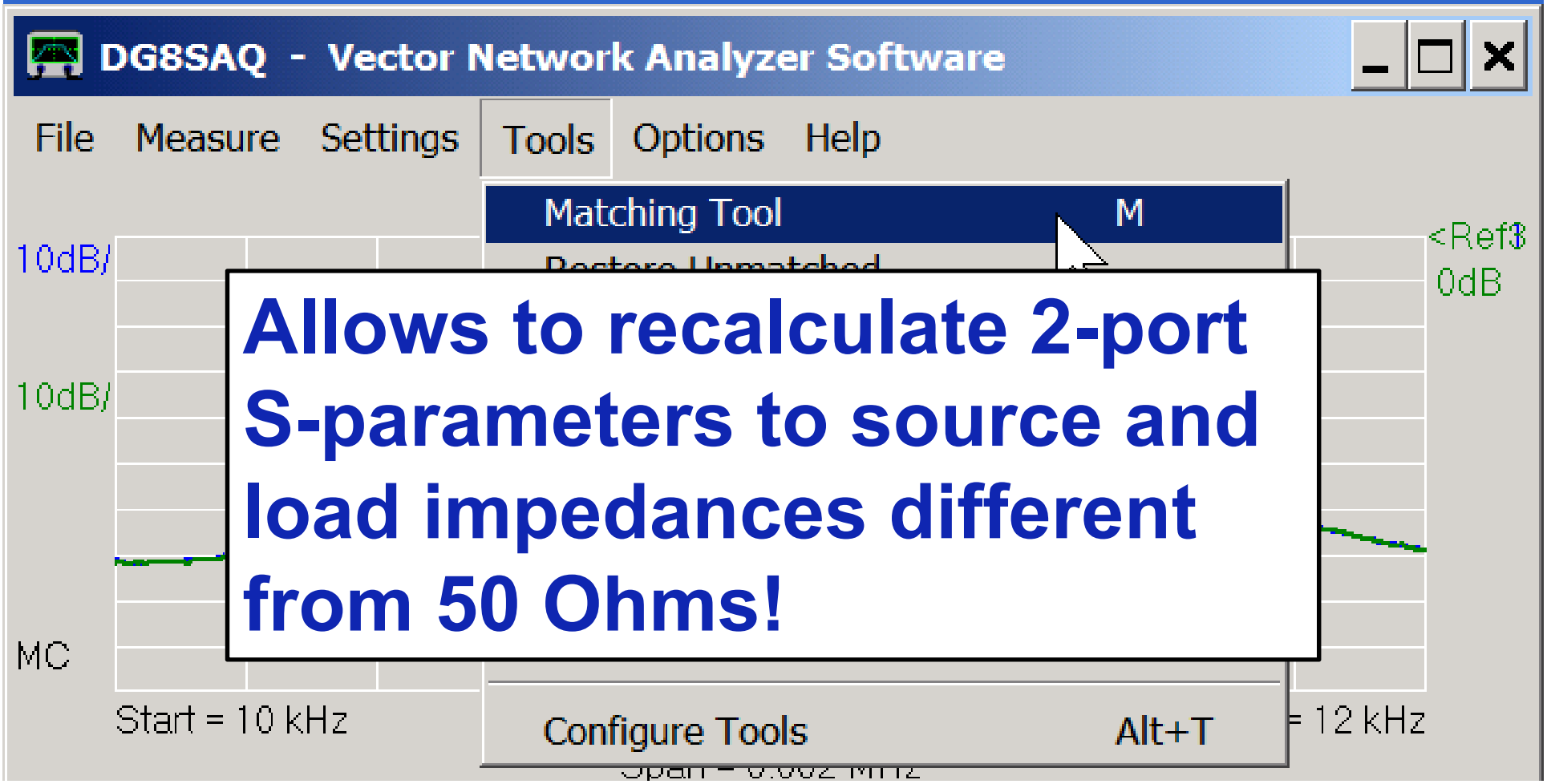
Two Port Measurement of a 12 kHz Band Pass Filter: Reverse Measurement



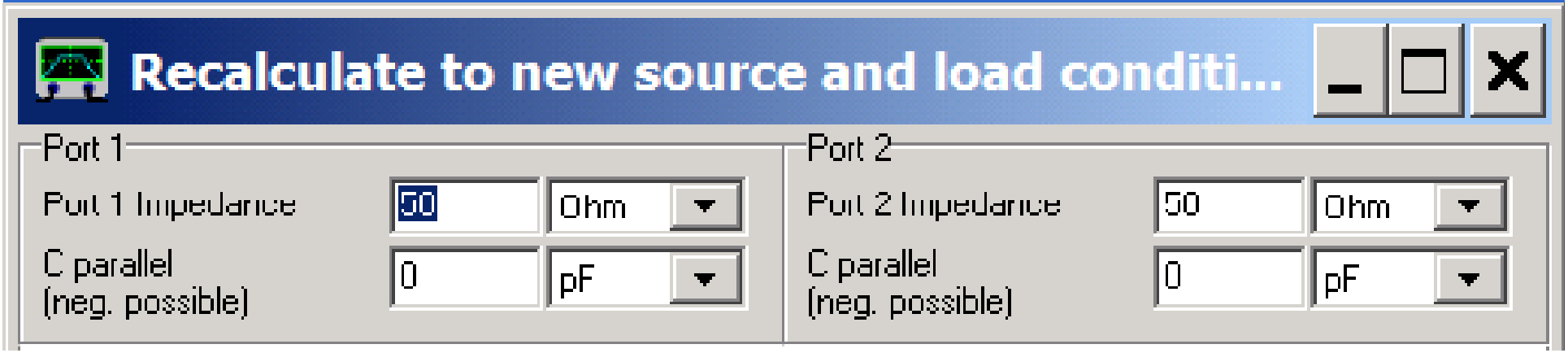
What are measured 2-Port S-Parameters good for?



VNWA Matching Tool (1)



VNWA Matching Tool (2)



Complex conjugate of *source* impedance

=

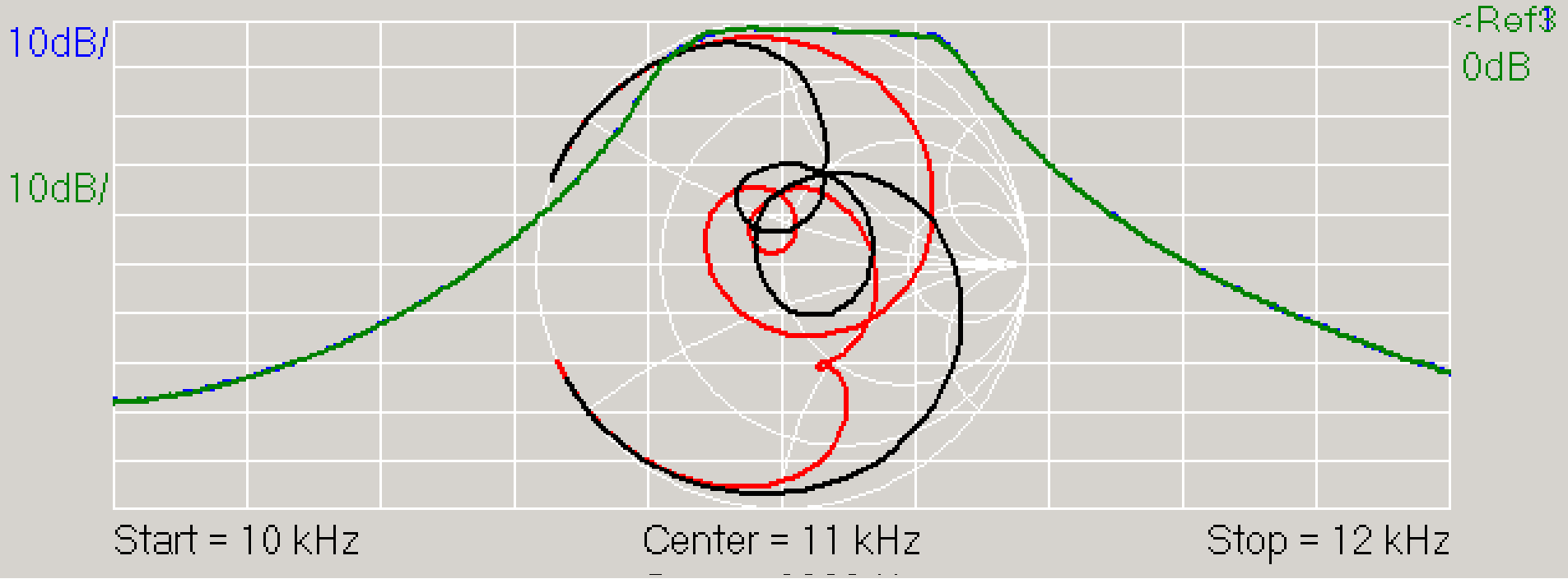
filter *input* impedance

Complex conjugate of *load* impedance

=

filter *output* impedance

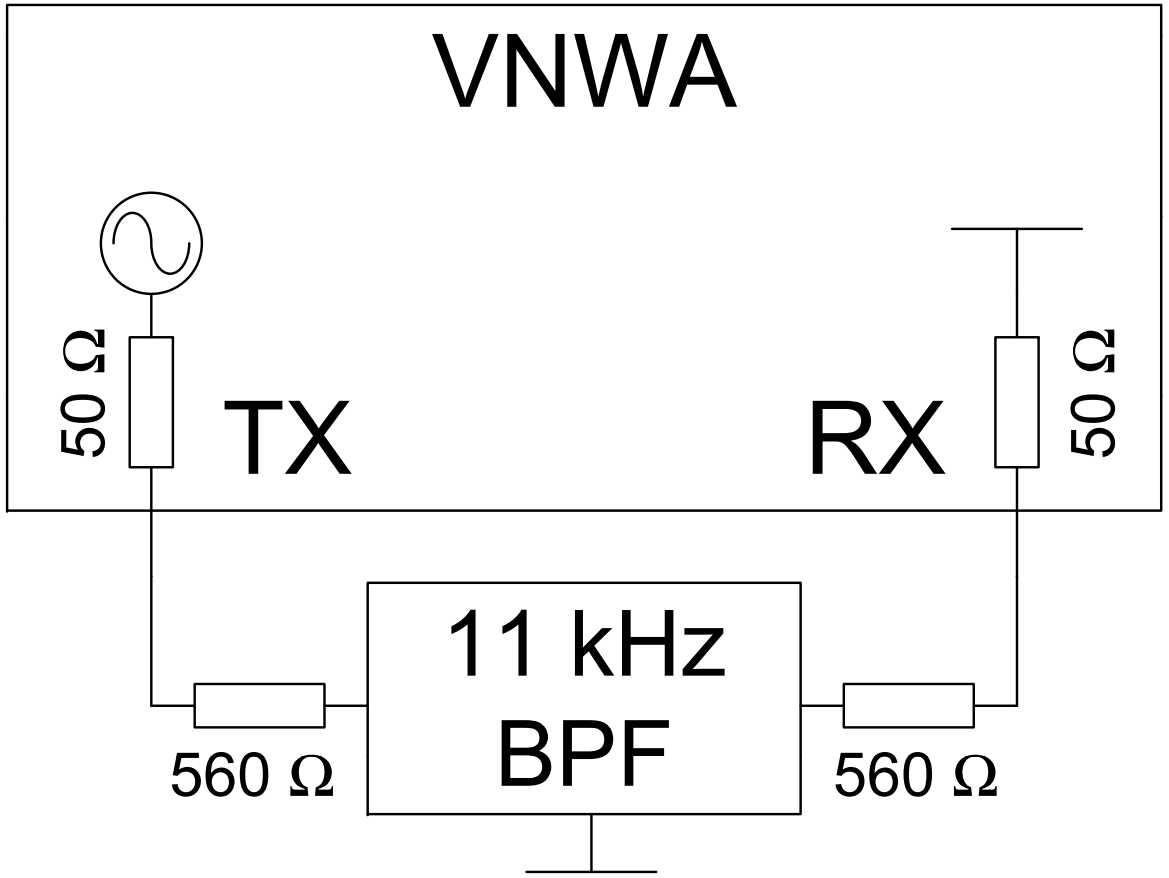
Matching Analysis with VNWA Matching Tool
Optimum: $Z_{in} = Z_{out} = 610\ \Omega$



Recalculate to new source and load conditi...

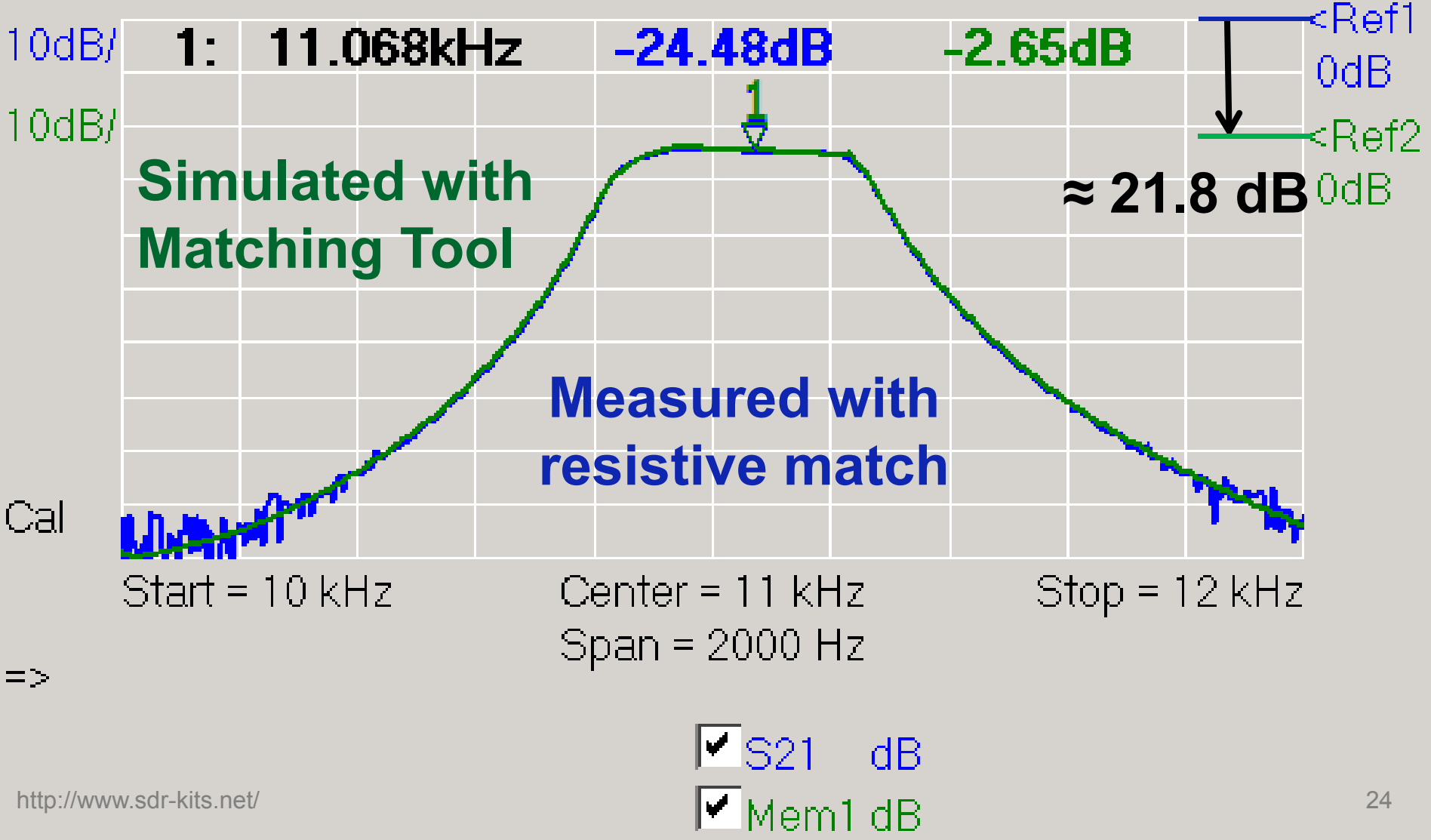
Port 1			Port 2		
Port 1 Impedance	610	Ohm	Port 2 Impedance	610	Ohm
C parallel (neg. possible)	0	pF	C parallel (neg. possible)	0	pF

Forced Impedance Match using Resistors

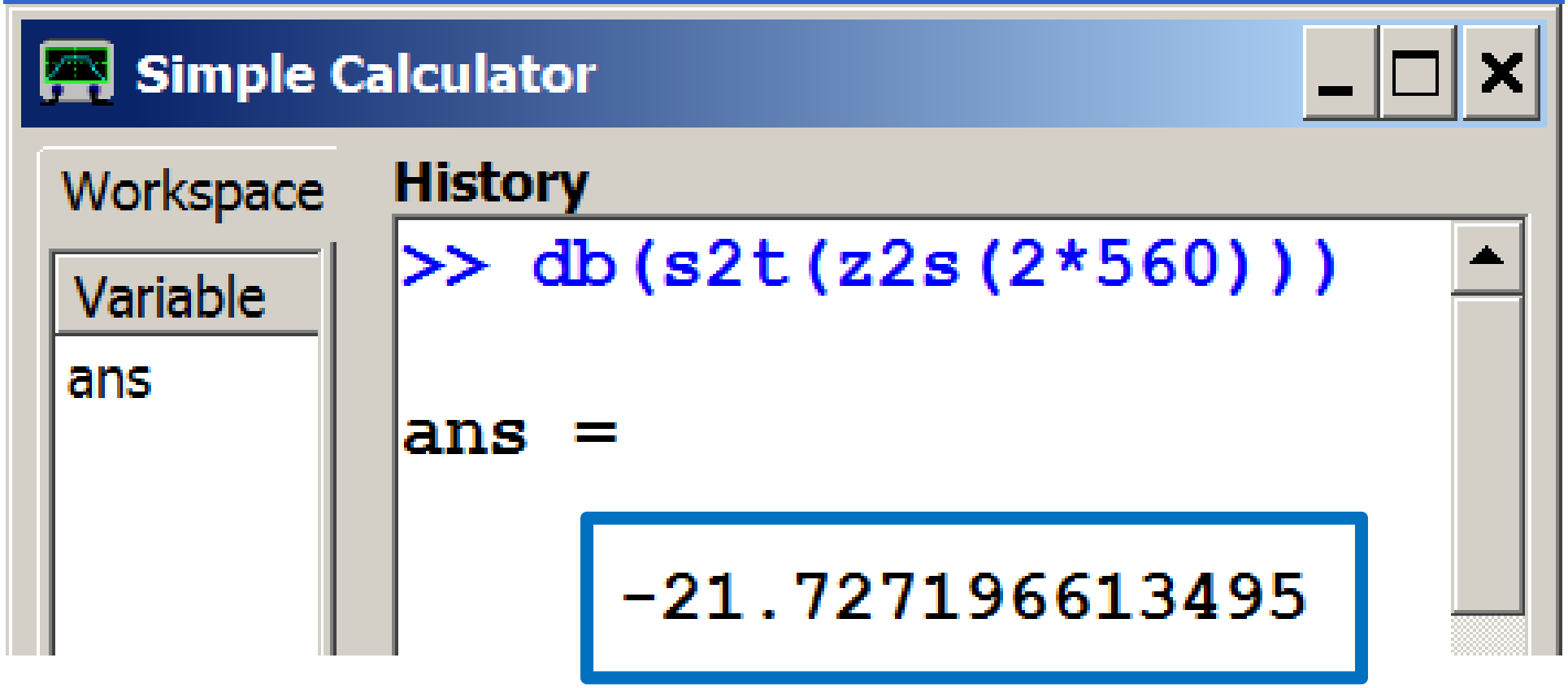


50 Ω + 560 Ω = 610 Ω

Match works except for increased Loss



Effect of two 560 Ω Resistors in Signal Path: VNWA Complex Calculator



21,7 dB additional attenuation ✓

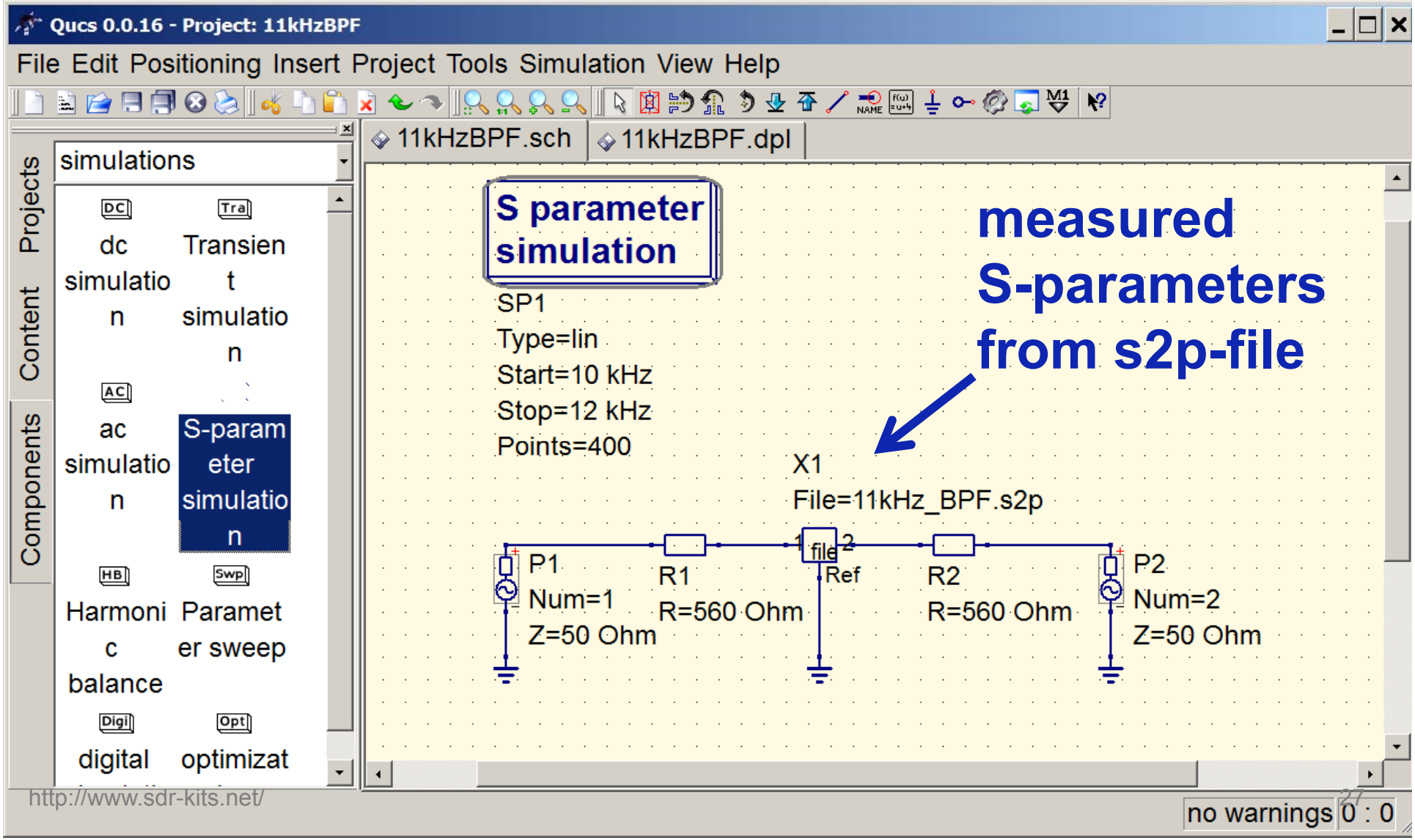
This can also be „properly“ simulated!
Simulation Tool QUCS

Qucs

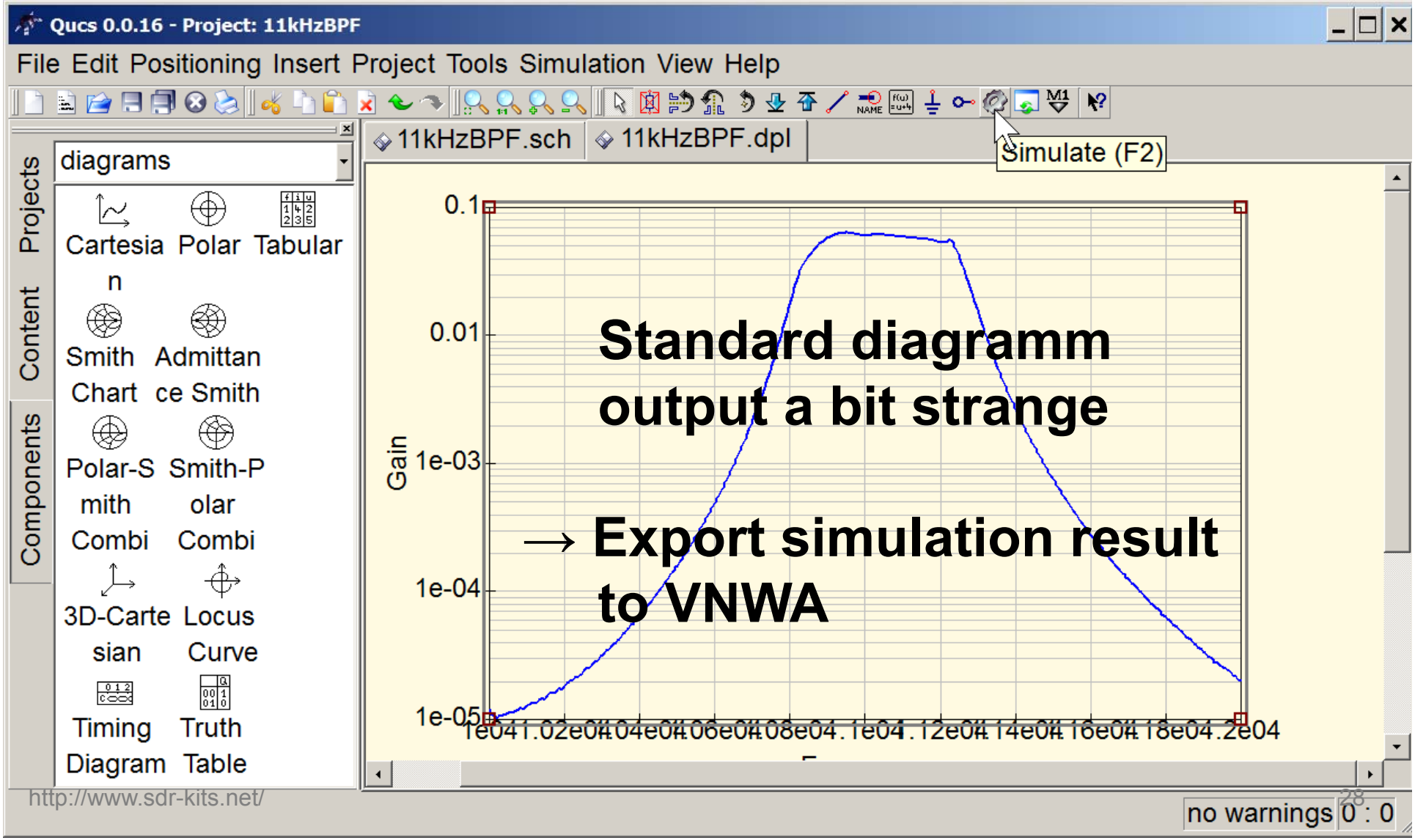
Quite Universal Circuit Simulator

- http://qucs.sourceforge.net/
- **Universal circuit simulator**
- **Free**
- **No restrictions**
- **Easy to use**
- **Grafics and data export needs brush up**

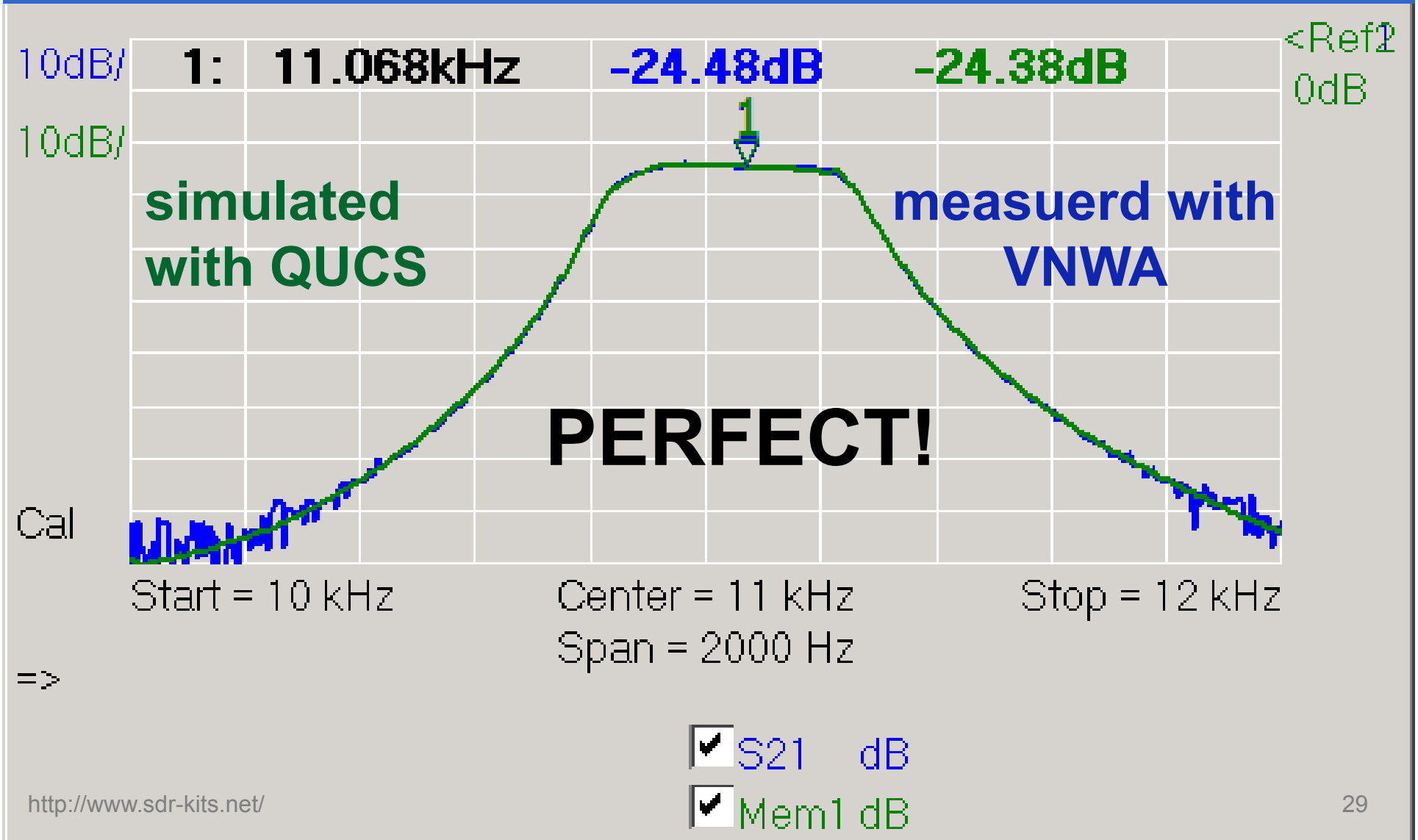
Measured S-Parameters in QUCS



Matching Simulation in QUCS



Comparison QUCS-Simulation vs. Measurement



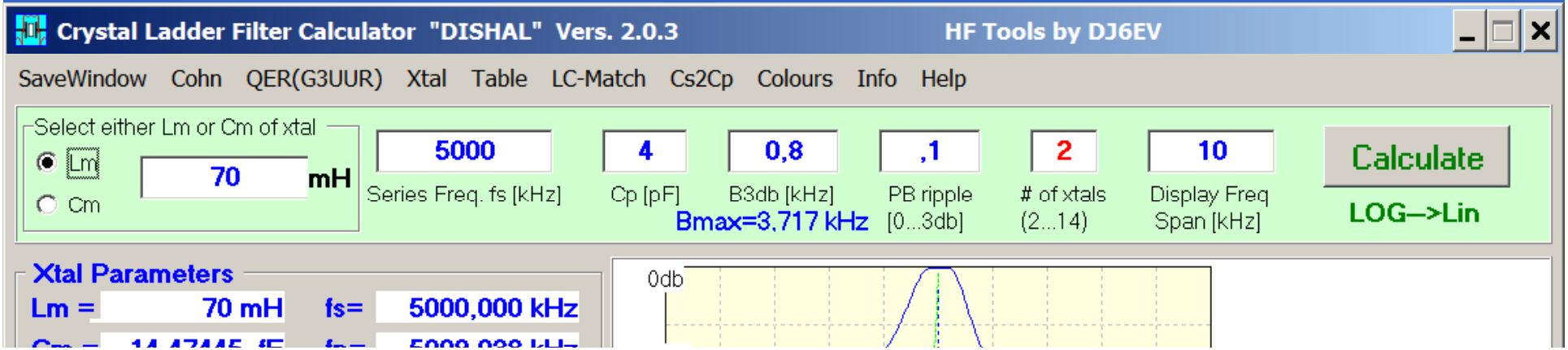
Free Filter Design Software (1): Elsie – for LC-Filters

This is the Student Edition of

Elsie

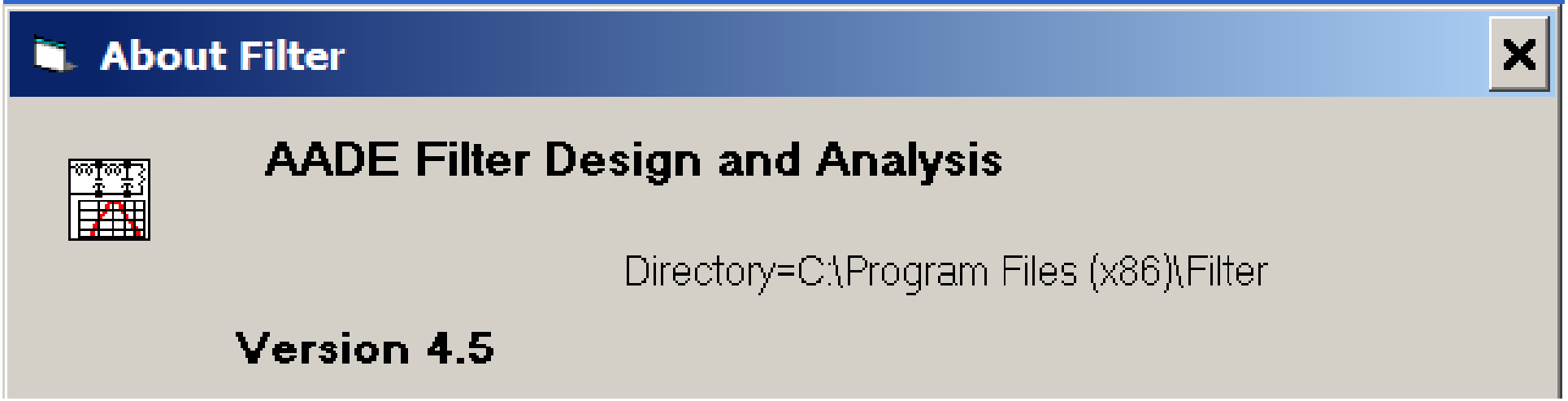
- http://tonnesoftware.com/elsiedownload.html
- **LC-Filter Designer and Analyzer**
- **Student version restricted to 7 dipols**
- **Numerical simulation results export easily to s2p-file!**

Free Filter Design Software (2): Dishal – for Crystal Filters



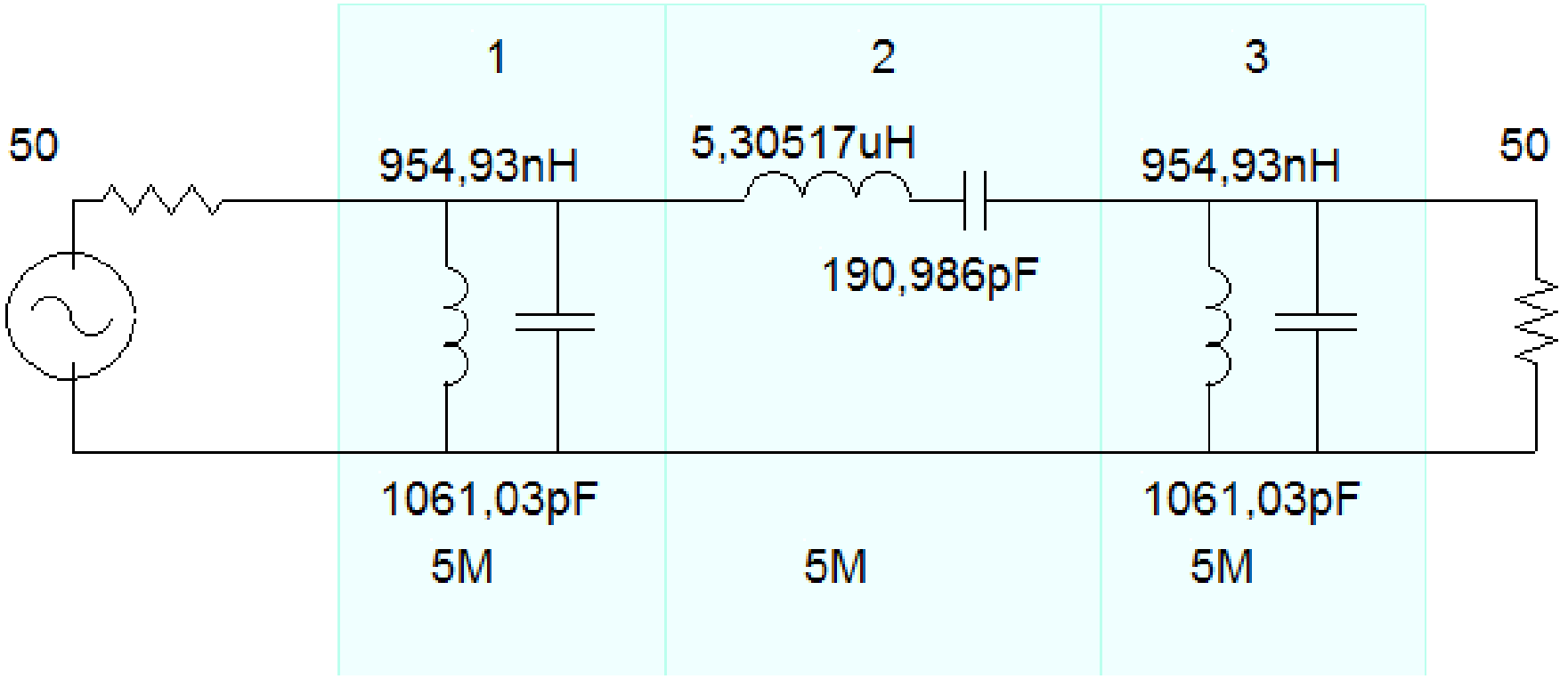
- http://www.bartelsos.de/dk7jb.php/quarzfilter-horst-dj6ev
- **Crystal filter designer and analyzer**
- **Simulates without crystal losses**
- **S_{21}-simulation results can be exported**

Free Filter Design Software (3): AADE Filter Design - for all filters



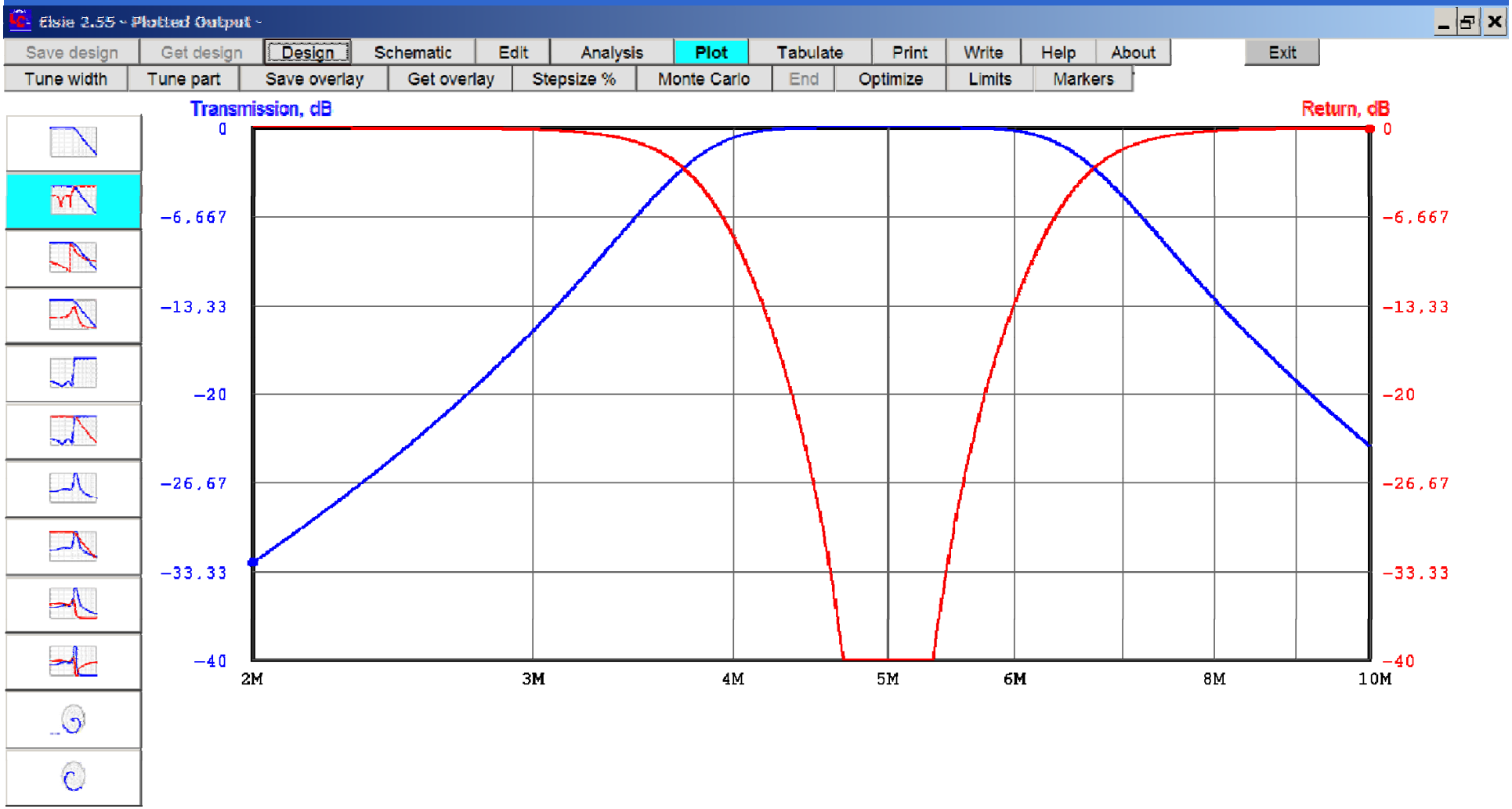
- http://aade.com/filter32/download.htm
- Univeral filter designer and analyzer
- Free, but with nag screen
- Easy to use
- Numerical simulation results cannot be exported

Design 3 Pole Butterworth π-Band Pass for 5 MHz with 3 MHz Bandwidth at 50 Ω



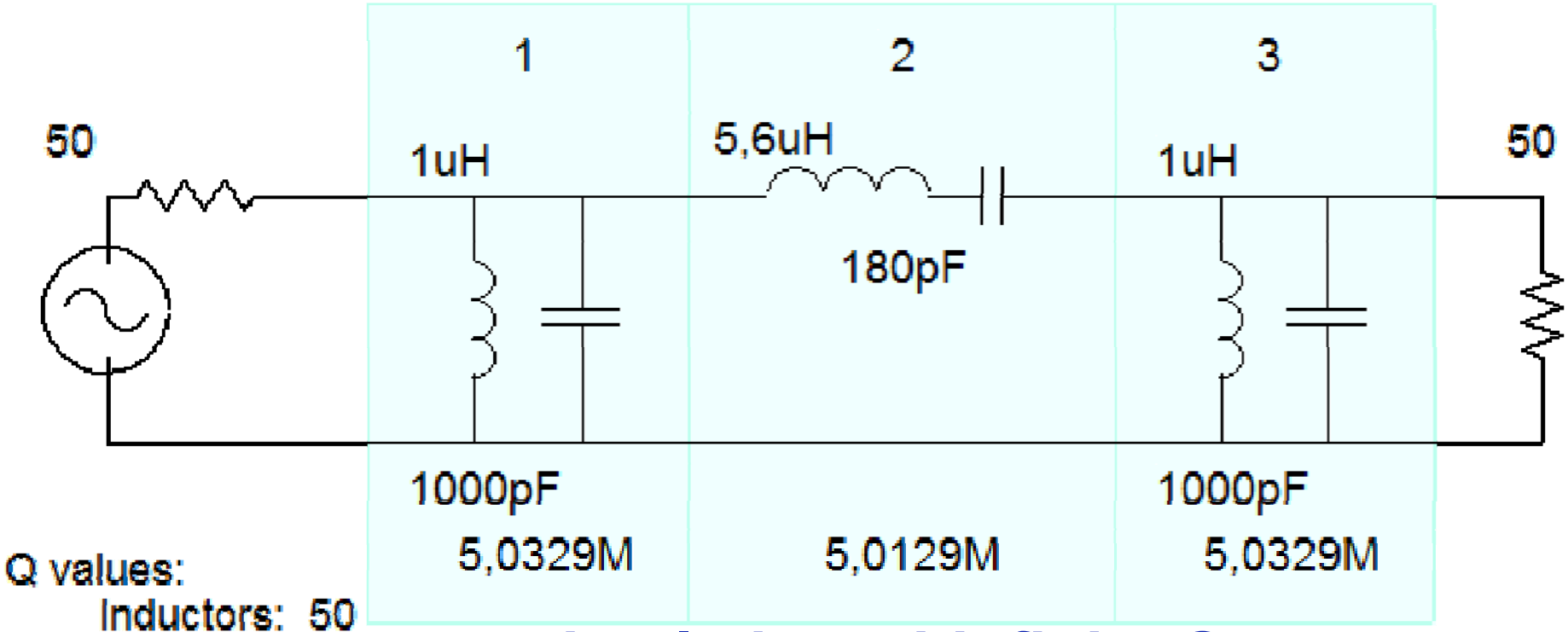
Filter Design with Elsie

Elsie Simulation Result



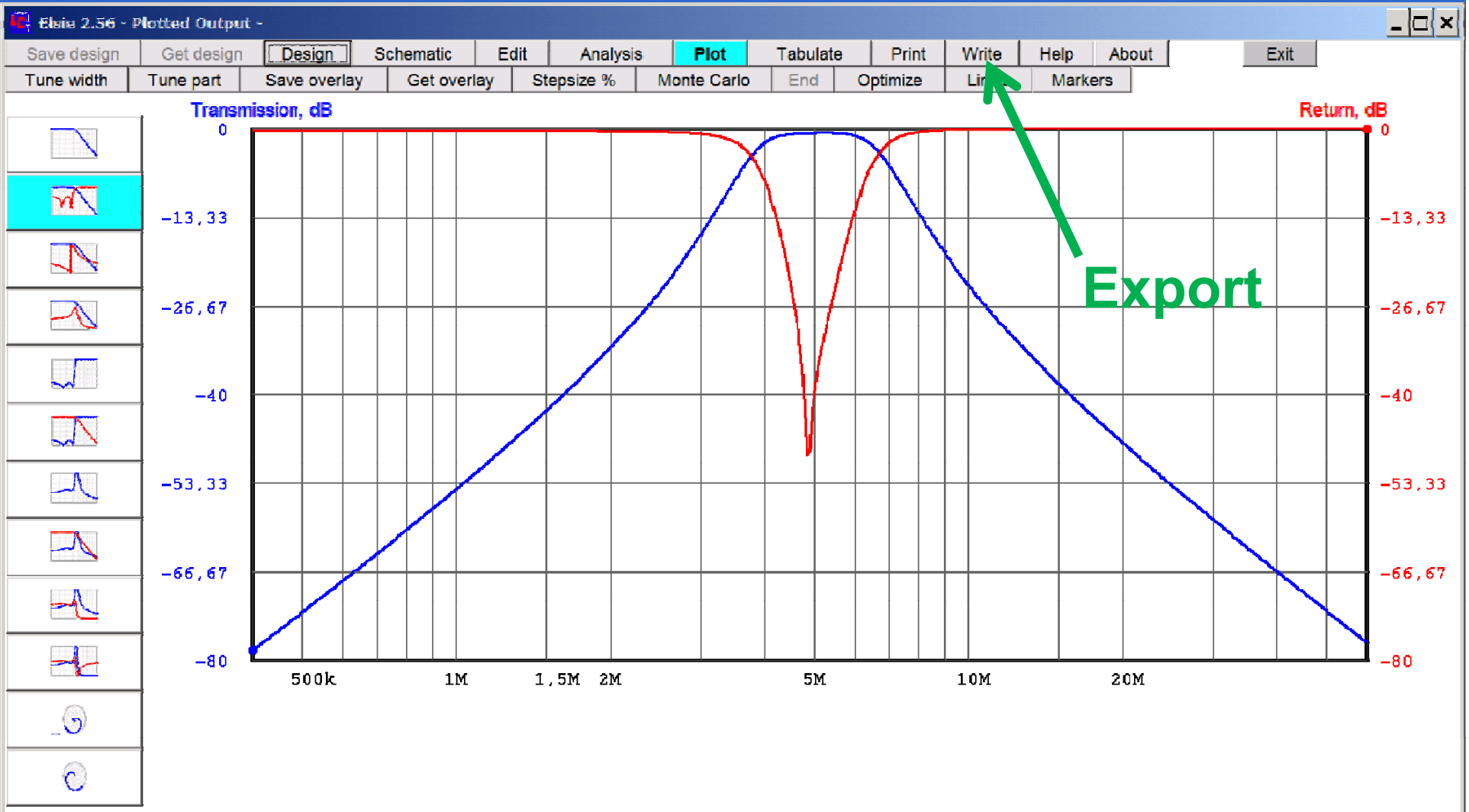
Modify Components to standard Values and finite Q …

Schematic | **Edit** | Analysis | Plot | Tabulate | Print

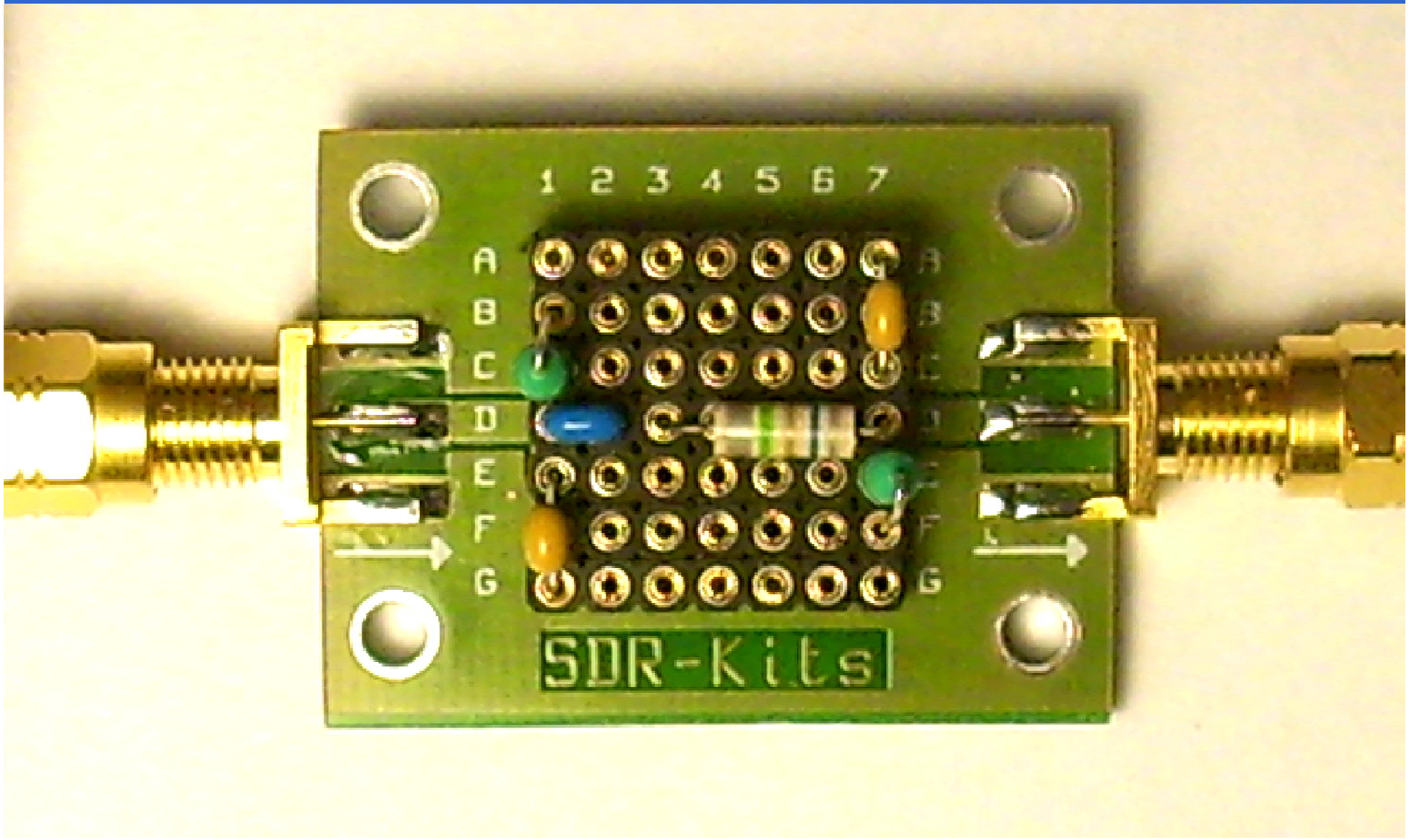


simulation with finite Q

…and export Simulation into s2p-file for Comparison with Measurement.

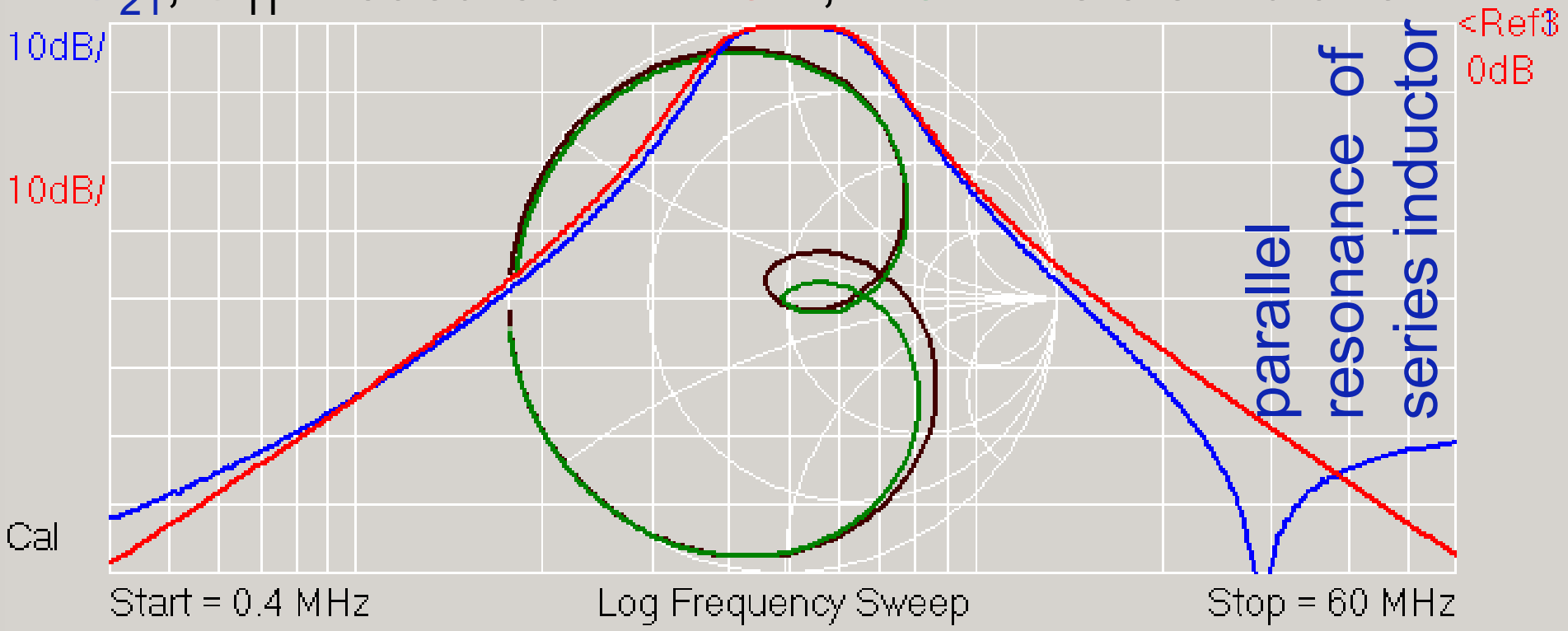


Filter Hardware



Comparison
Measurement vs. Elsie Simulation

S_{21}, S_{11} measured - Plot1, Plot2 Elsie simulation



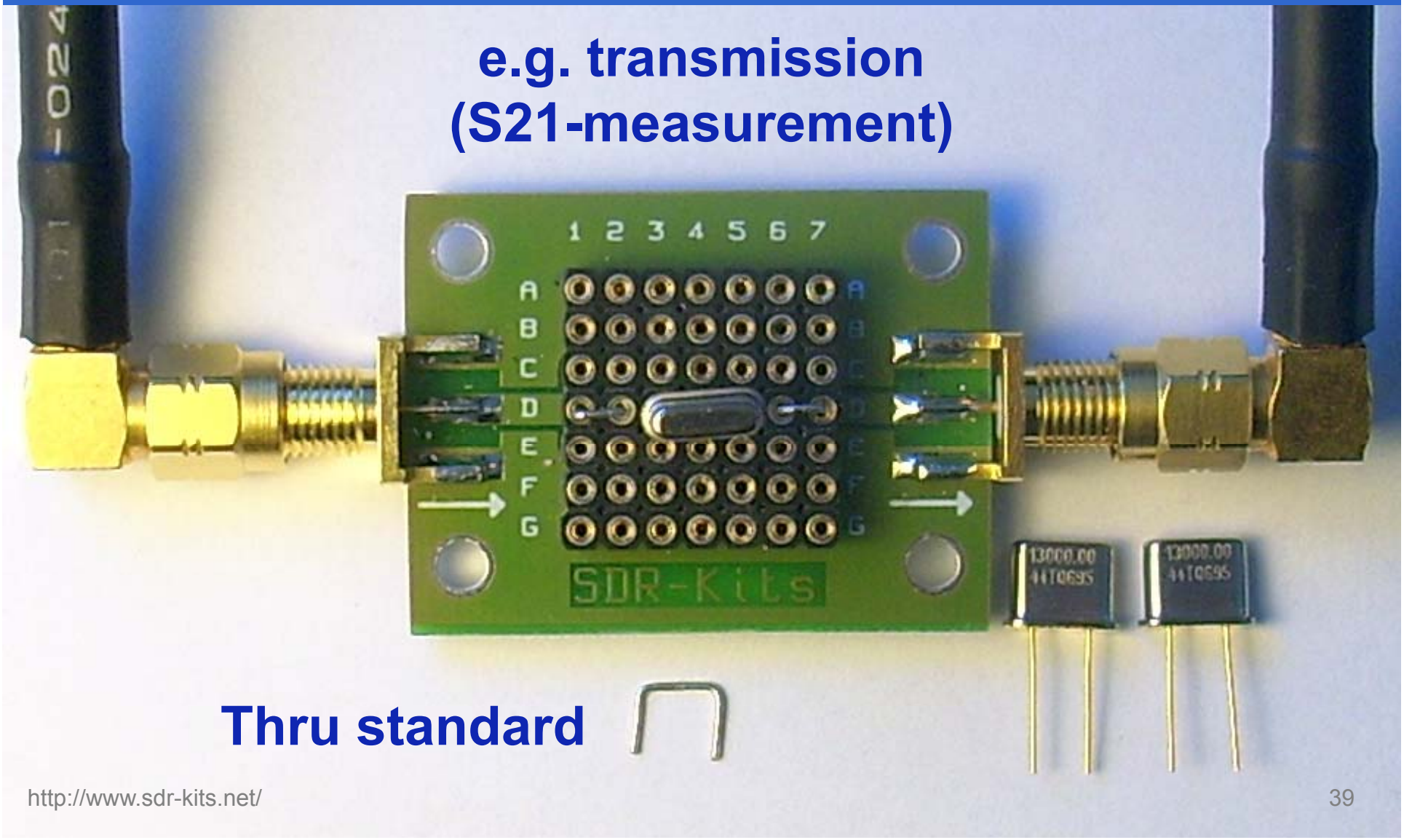
=>
TX Att. = 0 dB

S21 => Mem 1

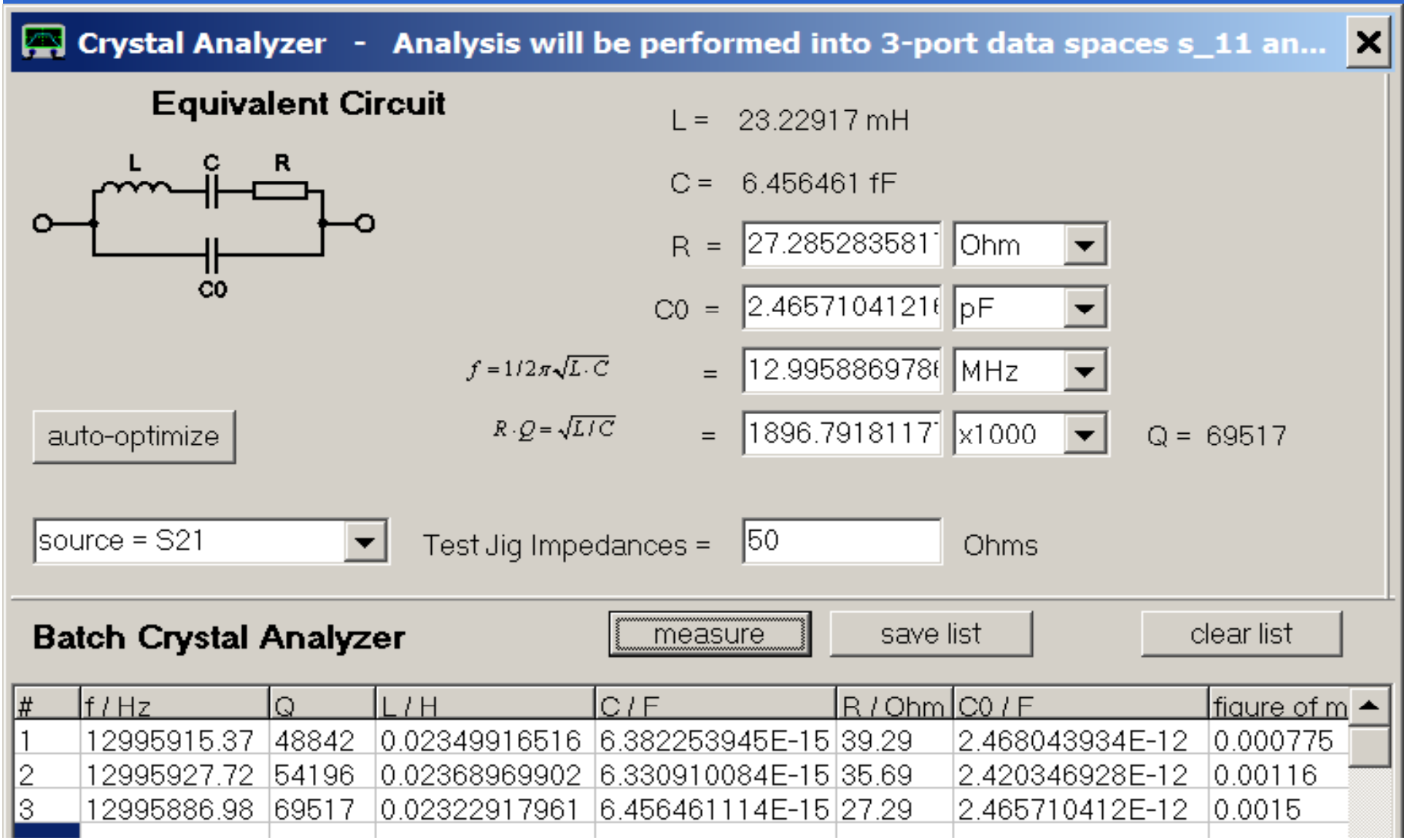
S21 dB
S11 Smith
Plot1 dB
Plot2 Smith

Continuous
Single Sweep

Measuring / Selecting Crystals: VNWA Crystal Analyzer

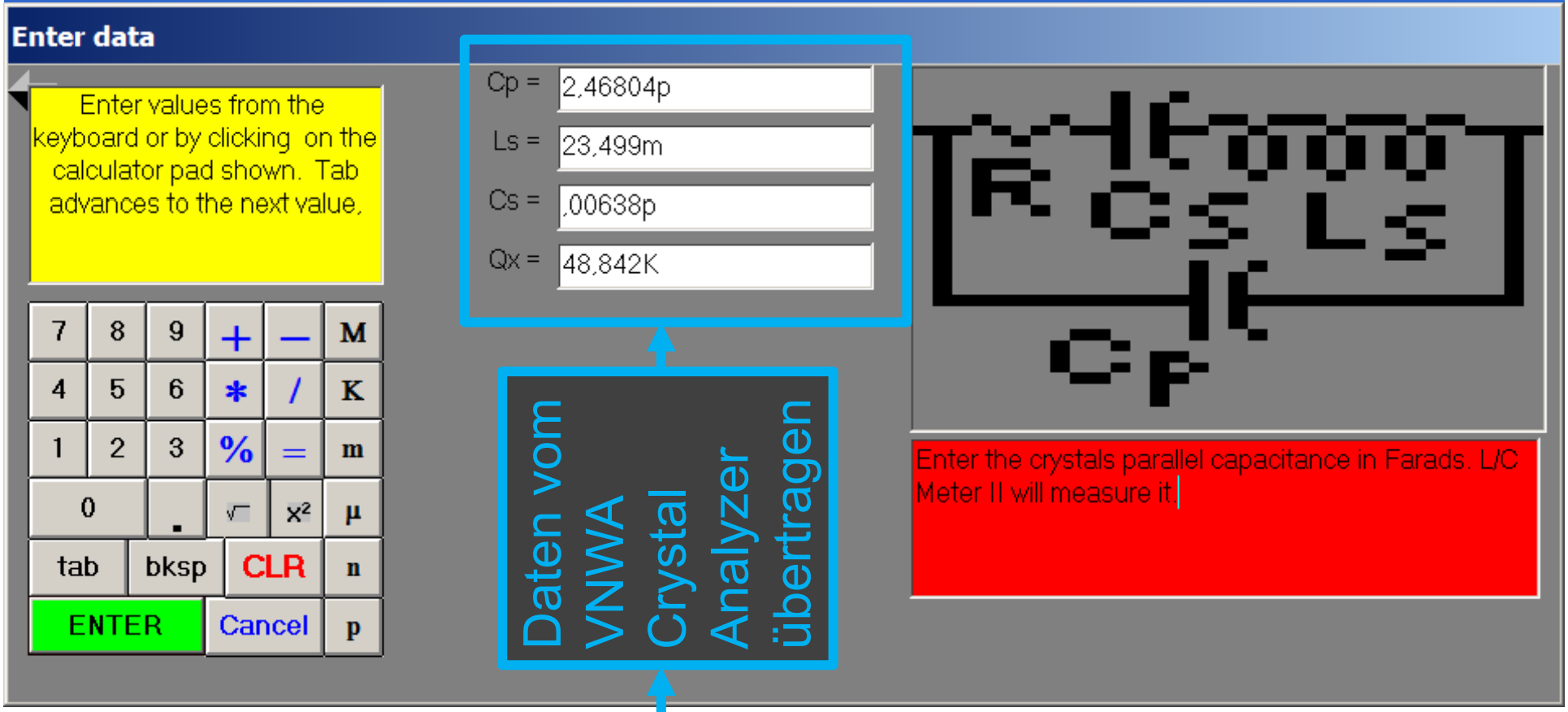


The VNWA Crystal Analyzer Tool: Find 3 similar Crystals…



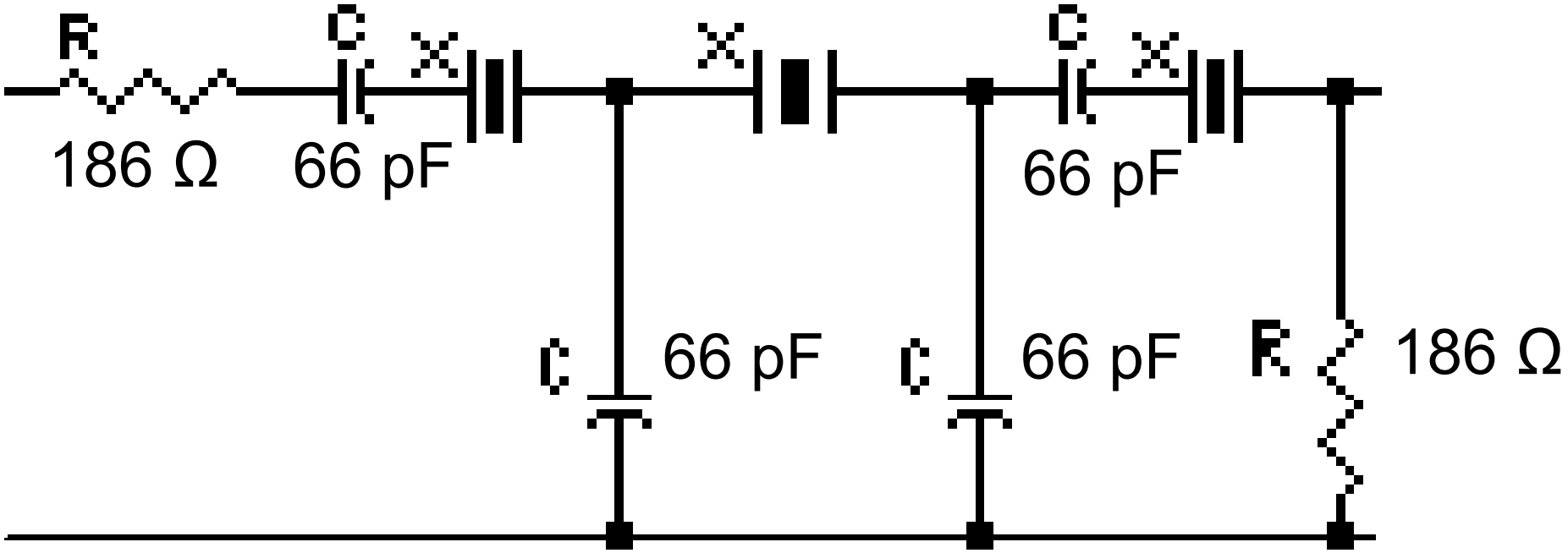
#	f / Hz	Q	L / H	C / F	R / Ohm	C0 / F	figure of m
1	12995915.37	48842	0.02349916516	6.382253945E-15	39.29	2.468043934E-12	0.000775
2	12995927.72	54196	0.02368969902	6.330910084E-15	35.69	2.420346928E-12	0.00116
3	12995886.98	69517	0.02322917961	6.456461114E-15	27.29	2.465710412E-12	0.0015

With these we want to build a Crystal Filter
→ Enter Crystal Parameters into AADE

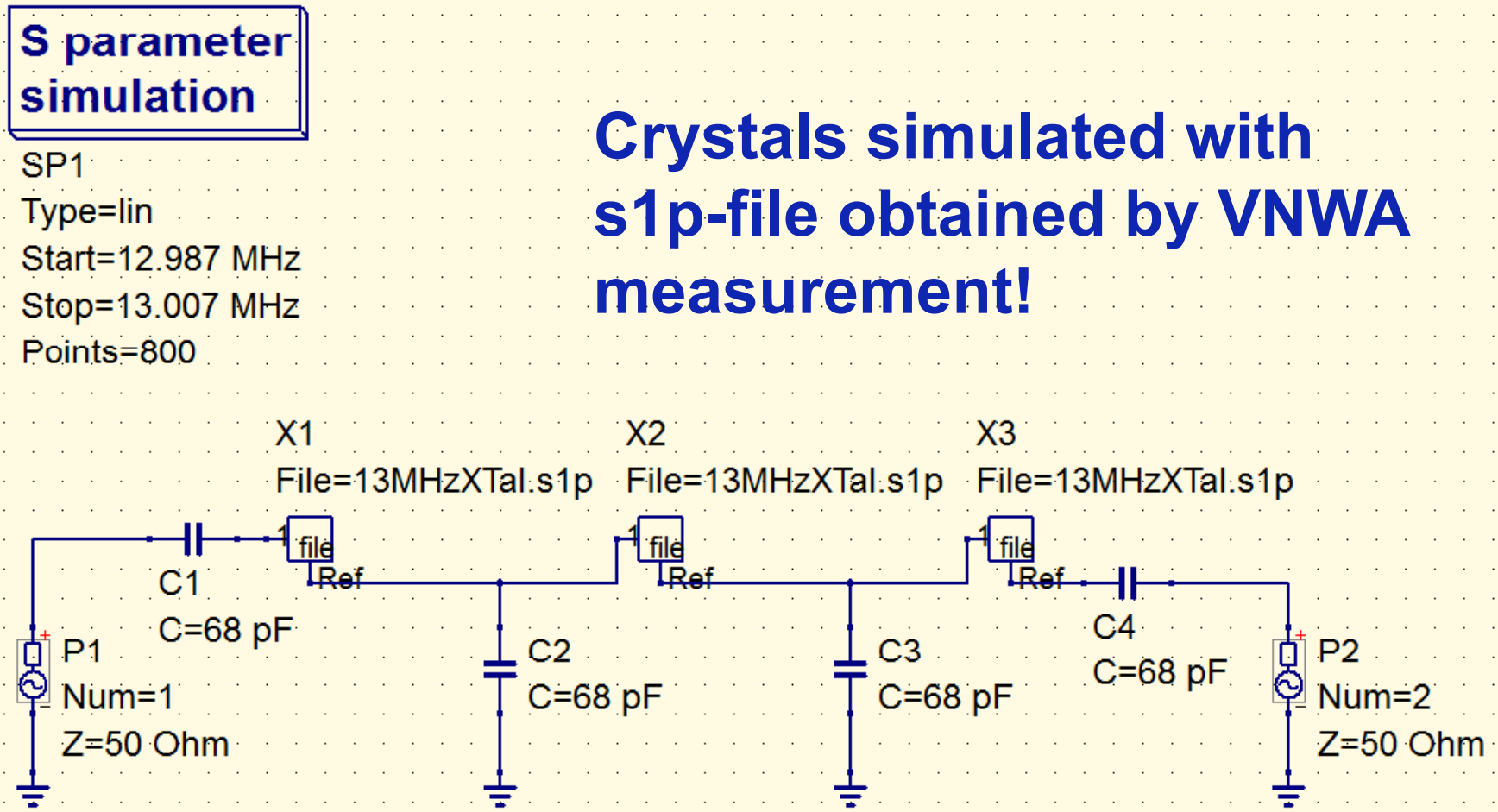


#	f / Hz	Q	L / H	C / F	R / Ohm	C0 / F	figure of m
1	12995915.37	48842	0.02349916516	6.382253945E-15	39.29	2.468043934E-12	0.000775

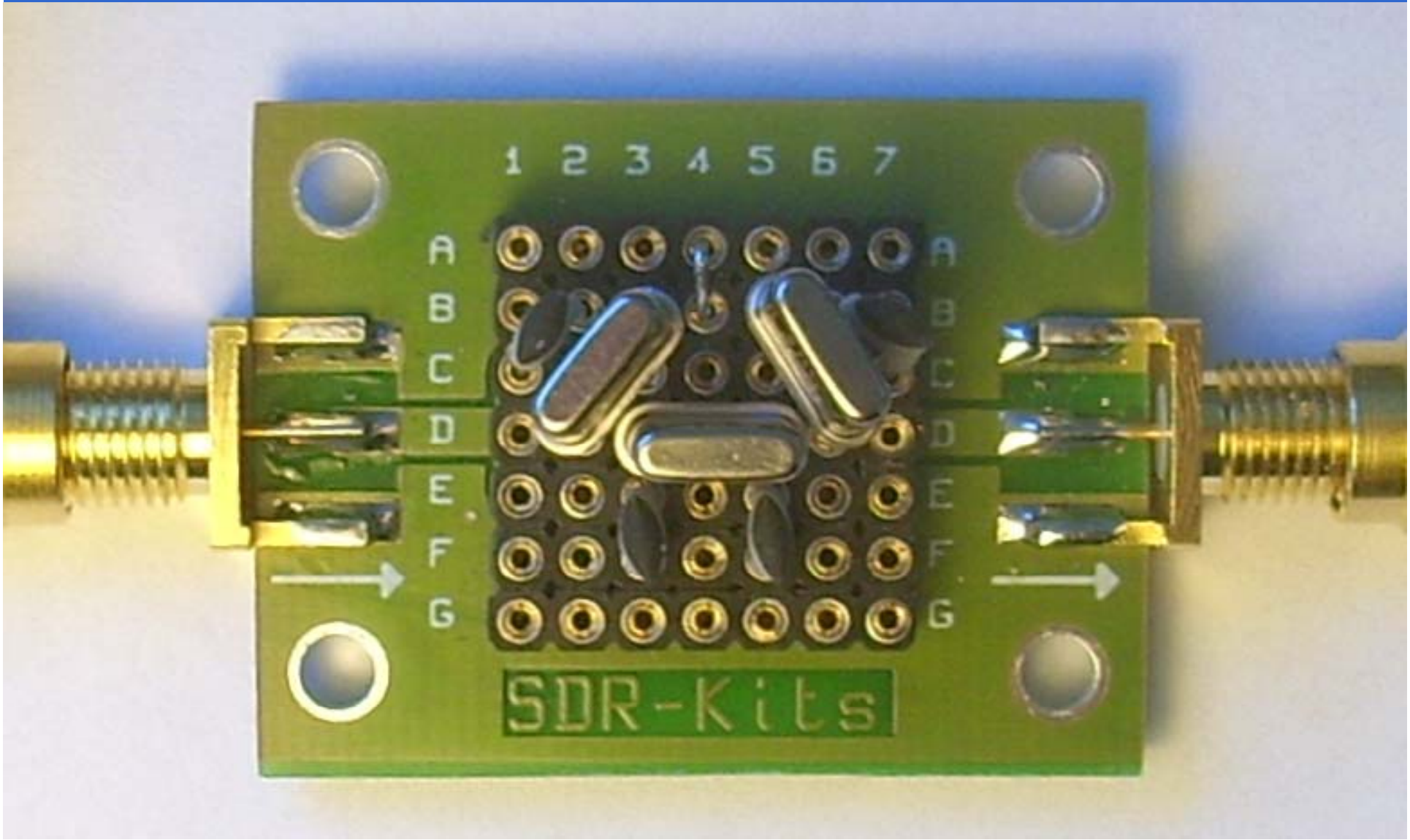
AADE Minimum Loss (Cohn) Design



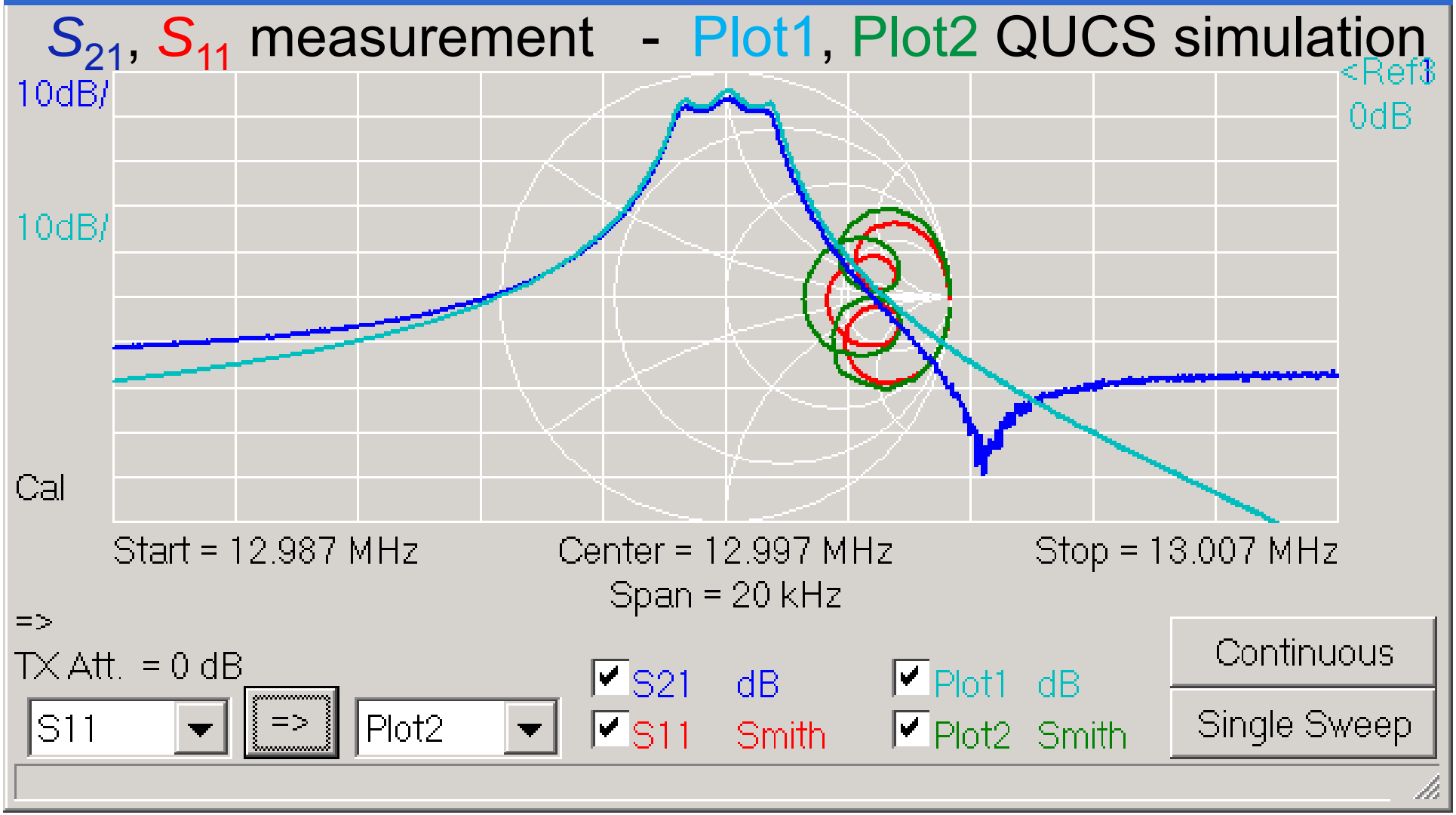
Simulation in QUCS at 50 Ω using standard Component Values



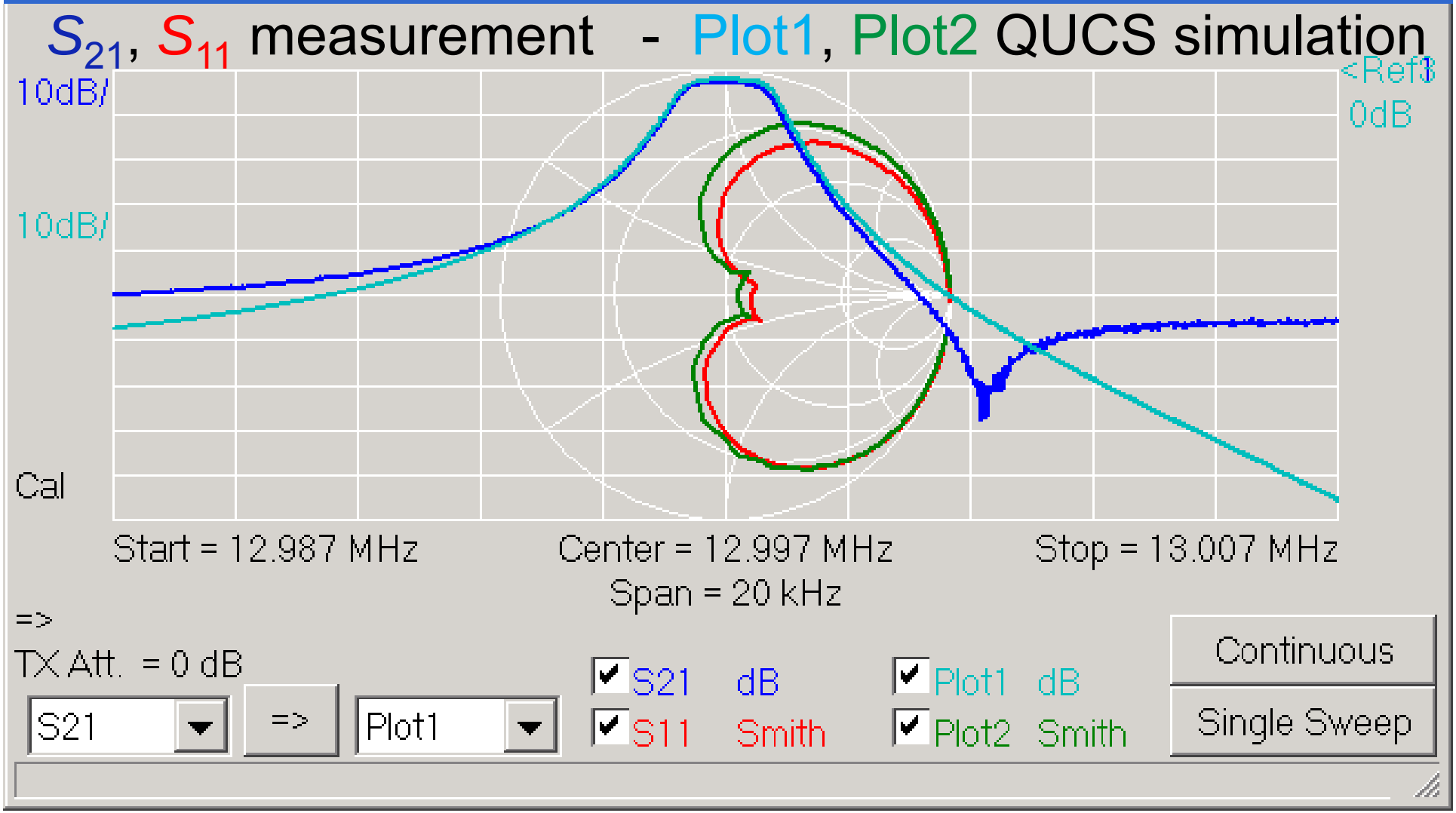
Crystal Filter Hardware



Crystal Filter: Measurement vs. Simulation at 50 Ω



Crystal Filter: Measurement vs. Simulation at 186 Ω



Now, we are able to…

- **Measure components**
- **Design filters**
- **Simulate filters**
- **Measure filters**

Try it for yourself!