

DG8SAQ VNWA Tutorial

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

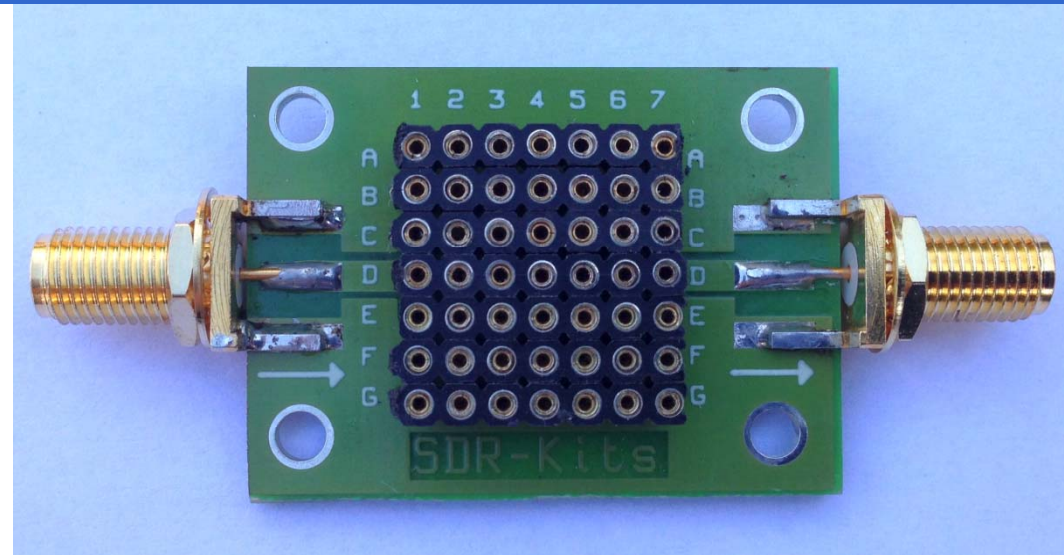
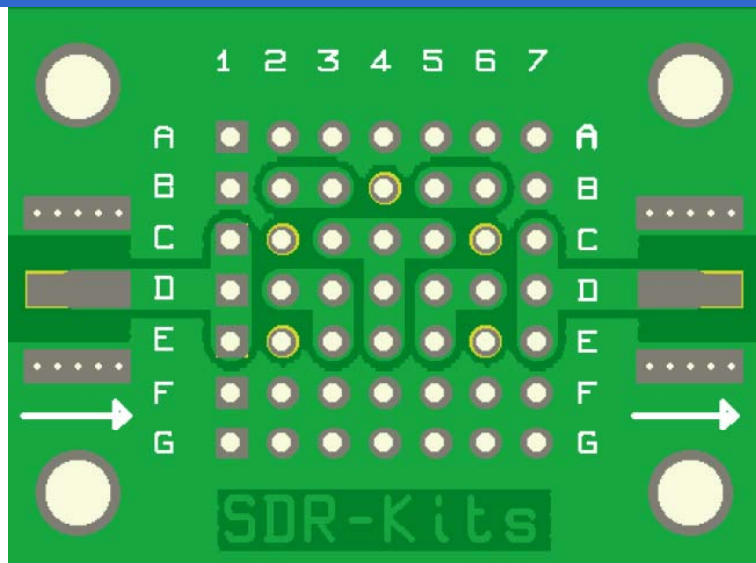
Tom BAIER

DG8SAQ

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

SDR-Kits

Test Board for HF Experiments



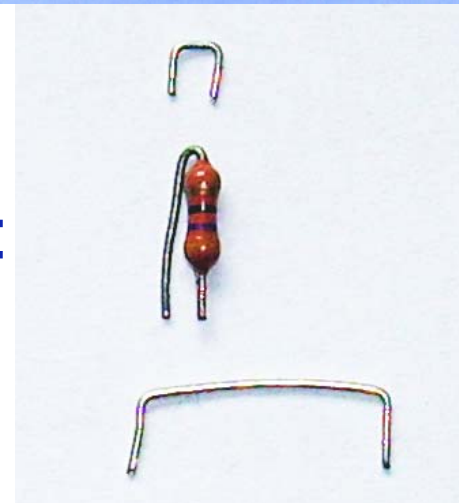
**Calibration
Standards:**

Open = n.c.

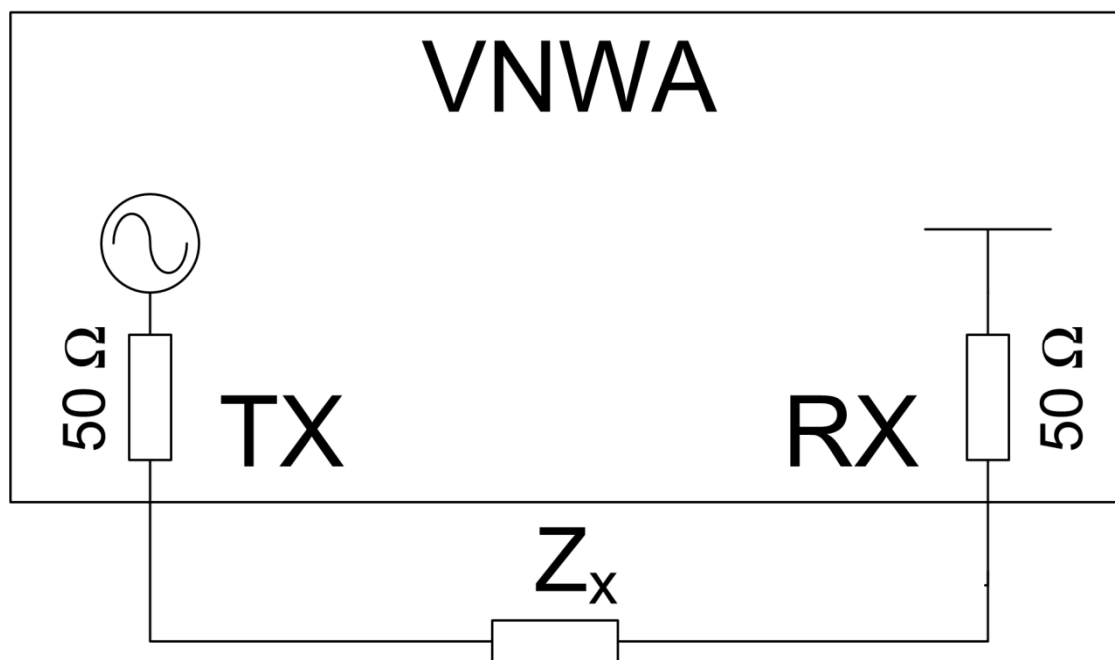
Short:

Load = 47Ω :

Thru:



Measuring „Load“-Resistor without SOL-Calibration?

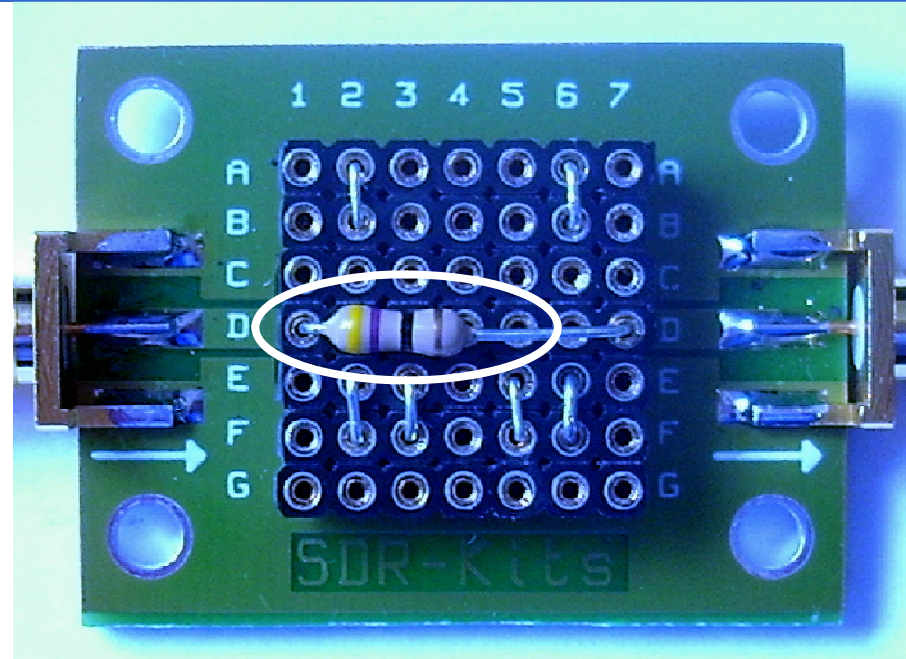
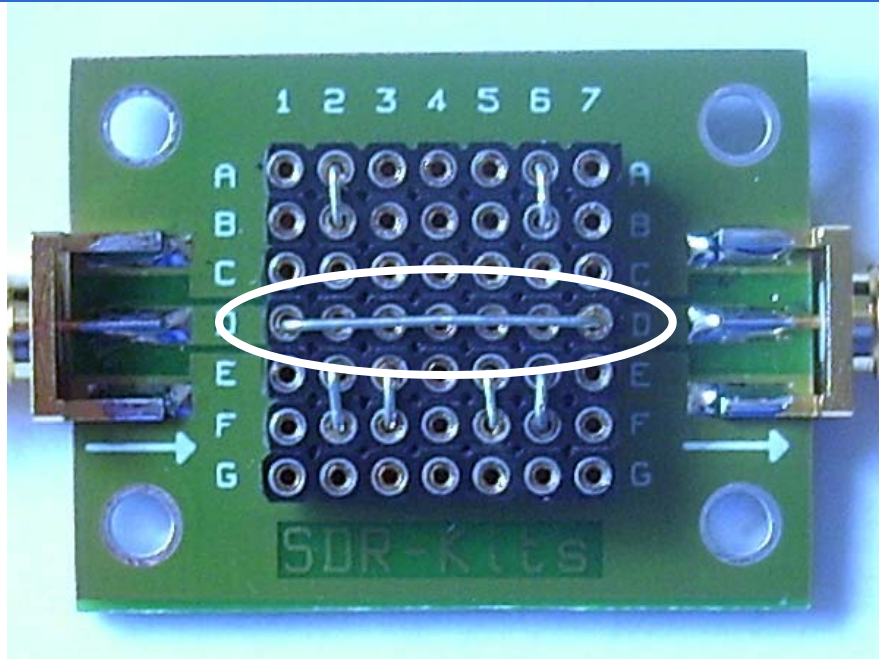


$Z_x = 47\ \Omega$ yield $\approx 3,4$ dB insertion loss.

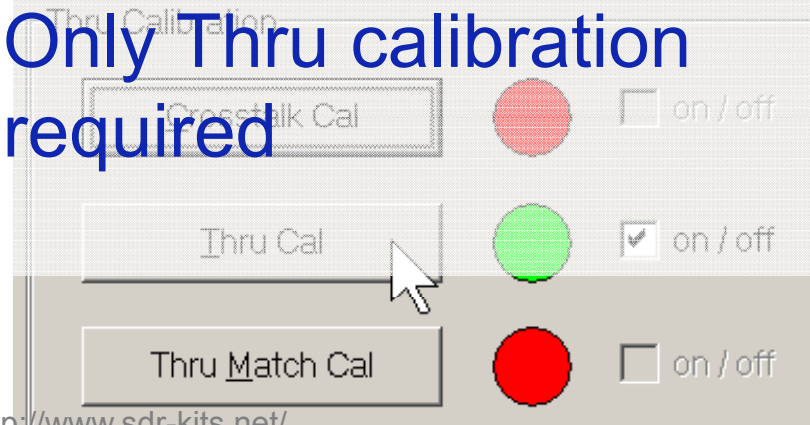
Works, because VNWA TX and RX port impedances are exactly $50\ \Omega$.

➤ only Thru calibration required!

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



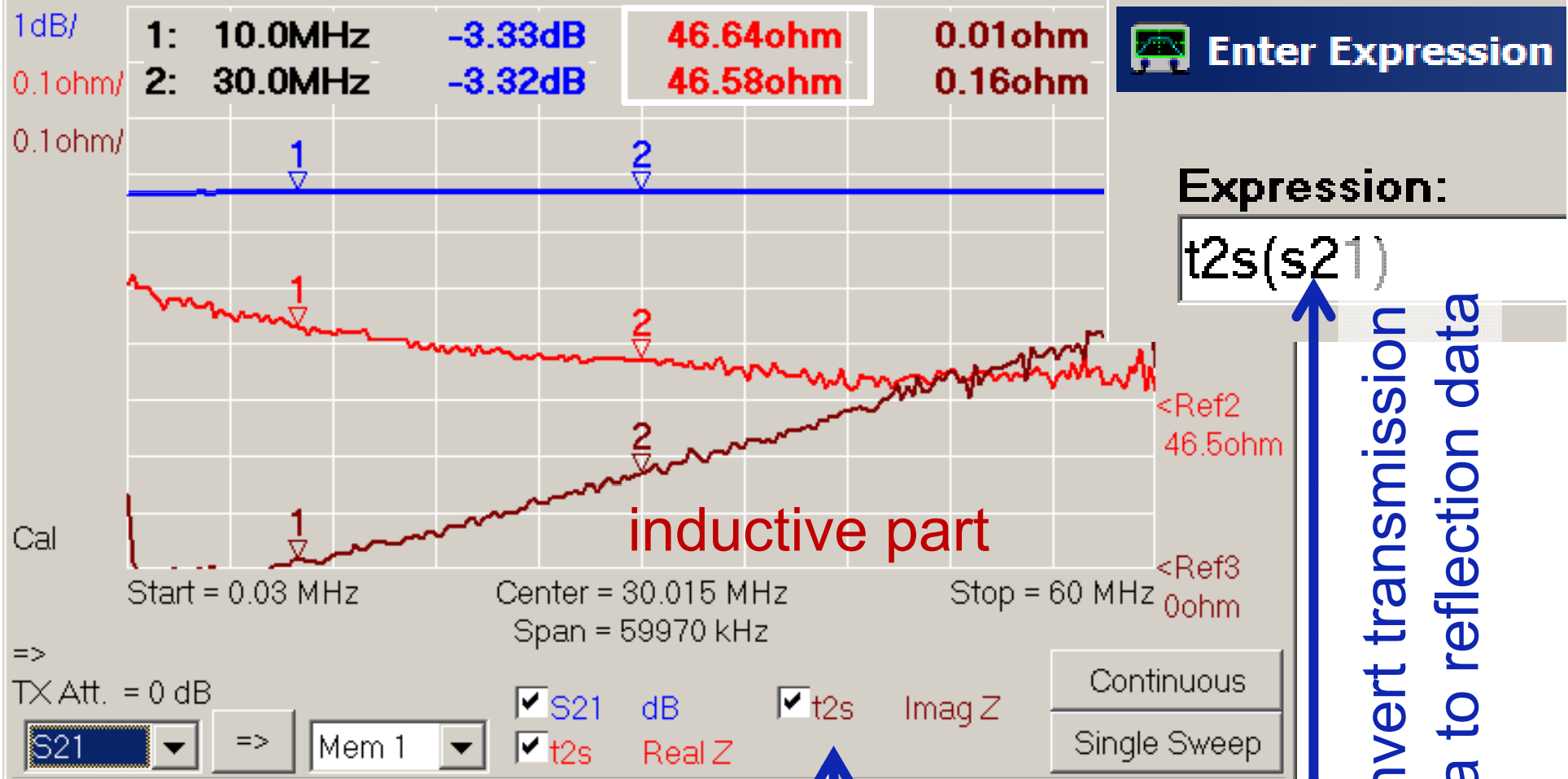
Only Thru calibration
required



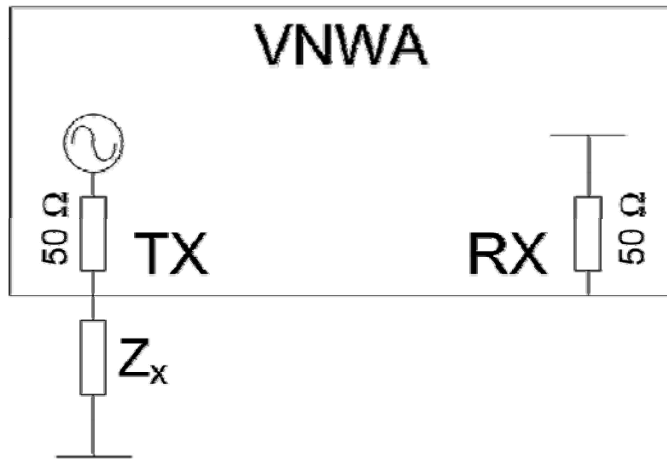
Measurement:
Resistor between
TX and RX

Measuring „Load“-Resistor

Result = 46,6 Ω

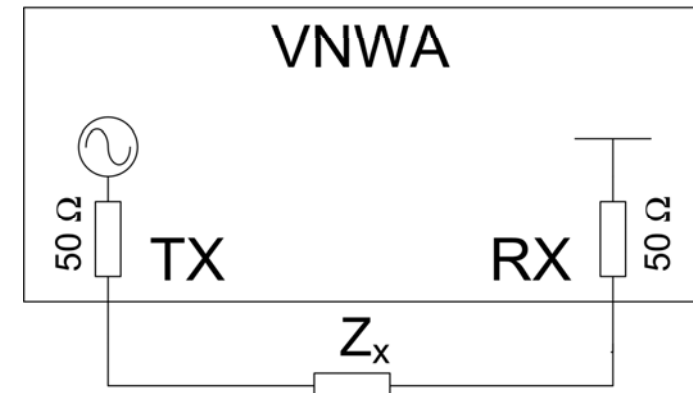


Reflection Data vs. Transmission Data



normalized impedance:

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



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

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

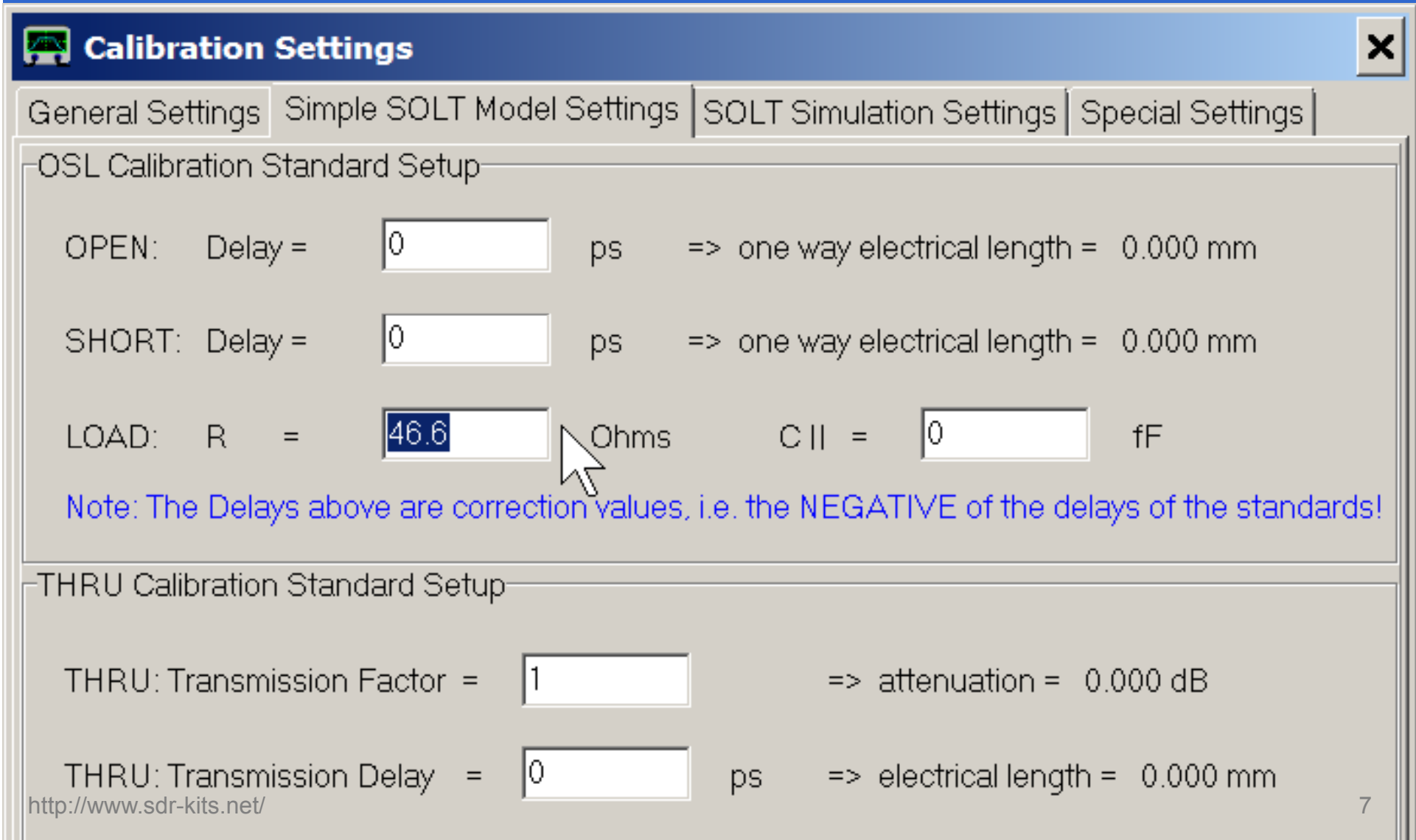


$$S_{11} = t2s(S_{21})$$

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

These conversions can be performed with VNWA Custom traces.

Simple Calibration Standard Model: Only measured Load-Resistance



The image shows a software dialog box titled "Calibration Settings" with a close button (X) in the top right corner. The dialog has four tabs: "General Settings", "Simple SOLT Model Settings", "SOLT Simulation Settings", and "Special Settings". The "Simple SOLT Model Settings" tab is selected. The dialog is divided into two sections: "OSL Calibration Standard Setup" and "THRU Calibration Standard Setup".

OSL Calibration Standard Setup

OPEN: Delay = ps => one way electrical length = 0.000 mm

SHORT: Delay = ps => one way electrical length = 0.000 mm

LOAD: R = Ohms C || = fF

Note: The Delays above are correction values, i.e. the NEGATIVE of the delays of the standards!

THRU Calibration Standard Setup

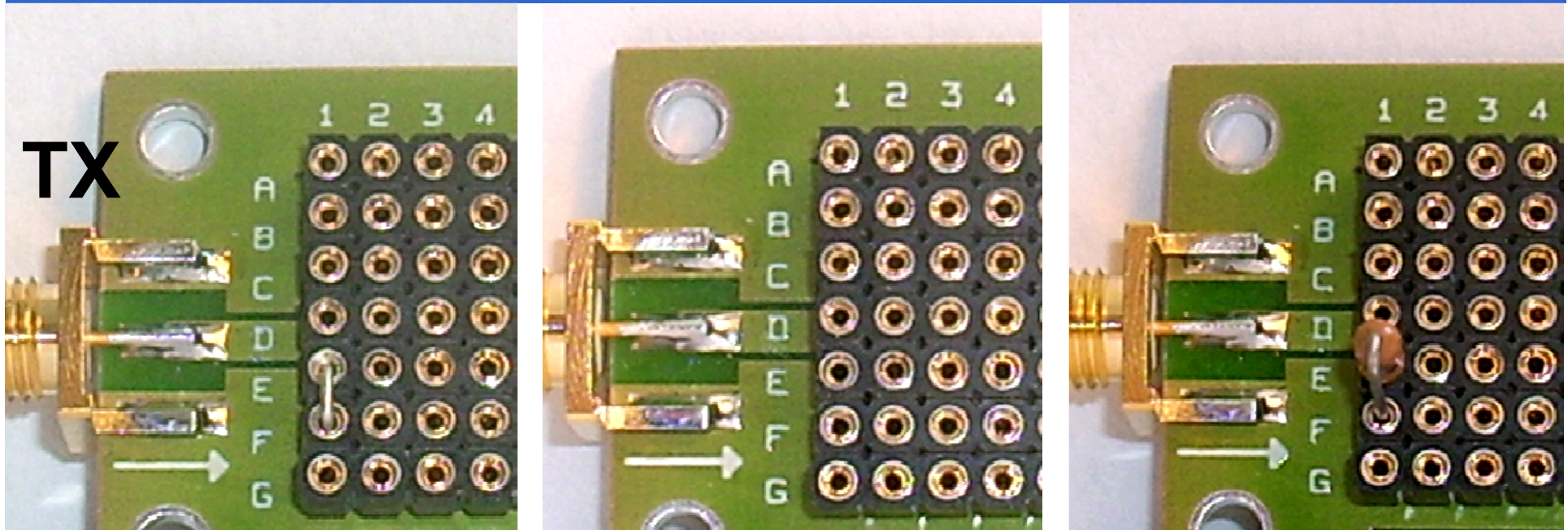
THRU: Transmission Factor = => attenuation = 0.000 dB

THRU: Transmission Delay = ps => electrical length = 0.000 mm


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


7


SOL-Calibration for S_{11} -Measurement




Reflect Calibration

Short **Short** 


Open 


Load 


Cal 

<http://www.edron.it/soft/>

Thru Calibration

Crosstalk Cal  on / off

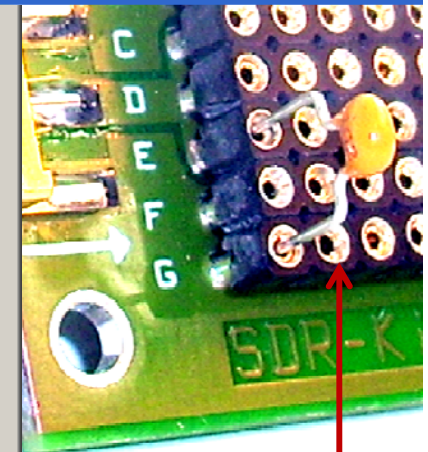
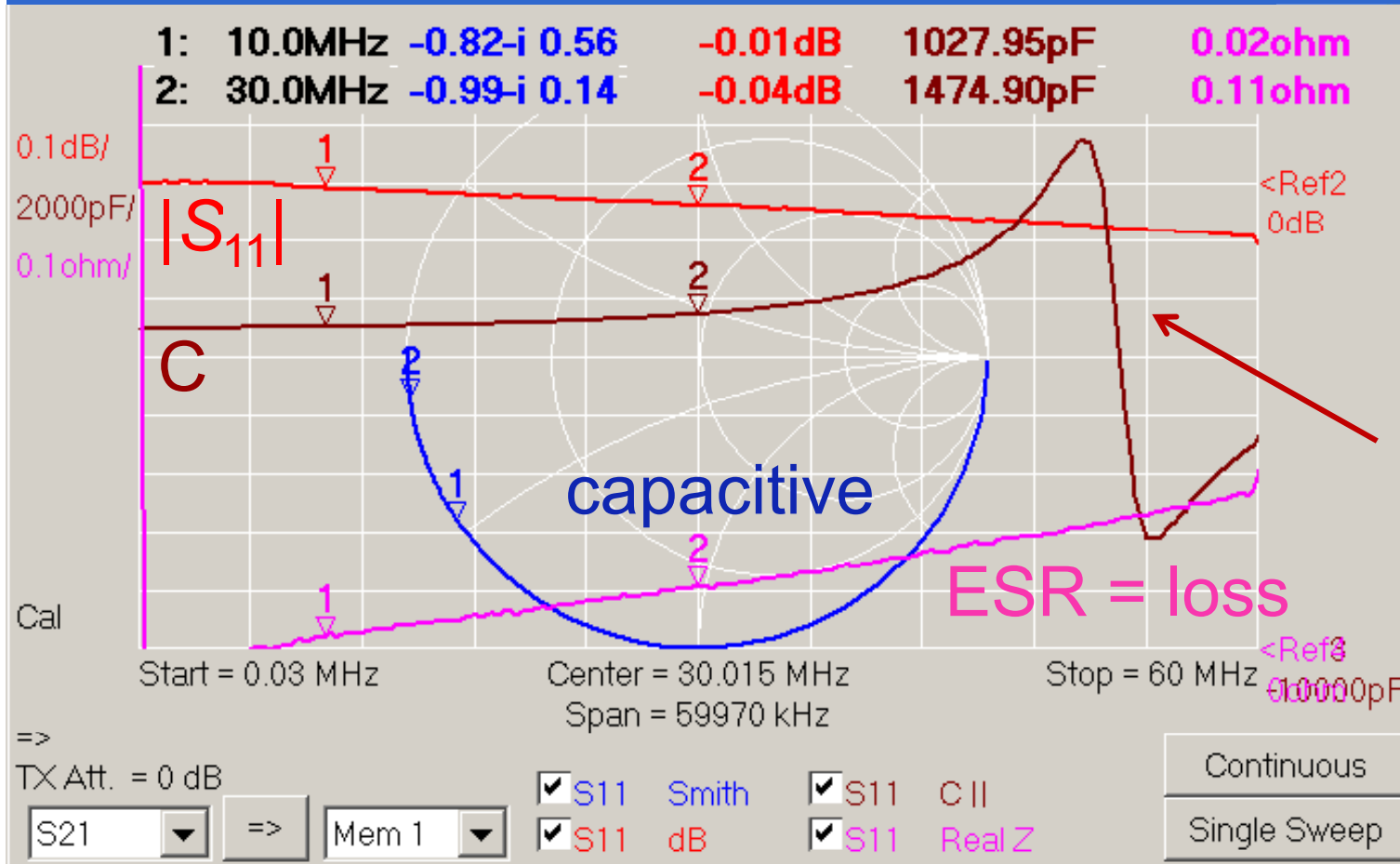
Thru Cal  on / off

Thru Match Cal  on / off

Invalidate All Thru Calibrations

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

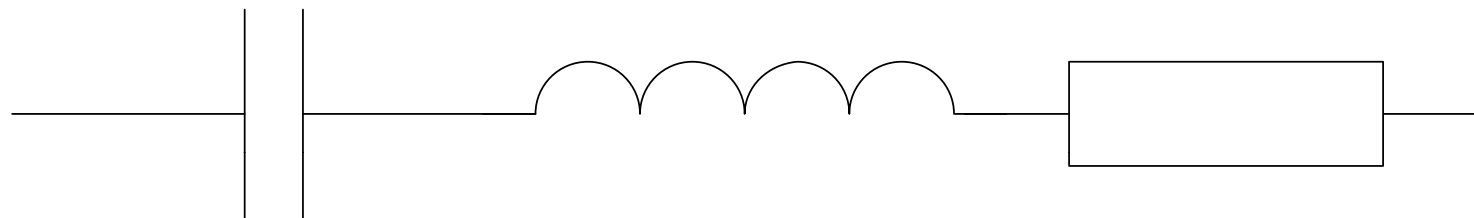


Enter Expression 2 for trace 2:

Expression:

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

Impedance to Reflecion coefficient



0,984 nF

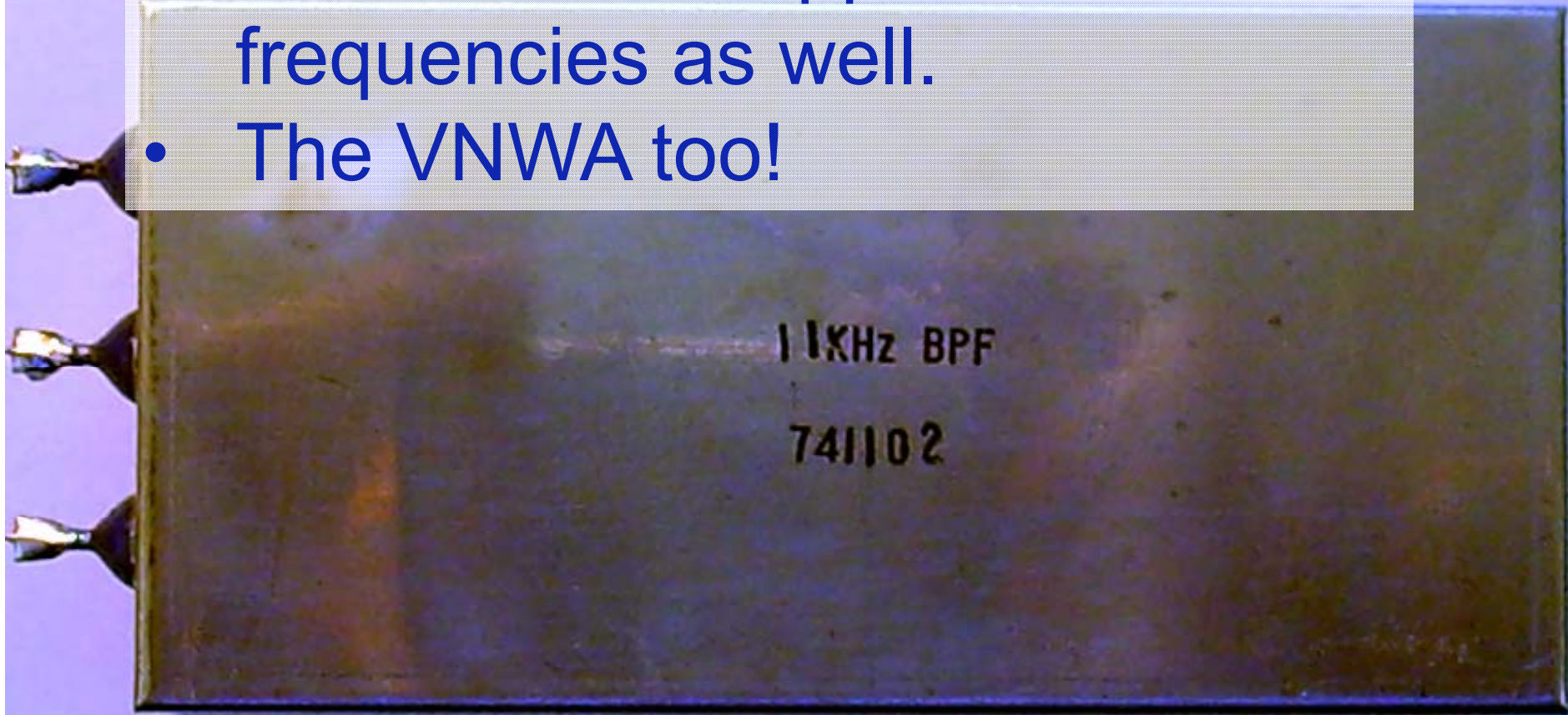
9,3 nH

0,22 Ω

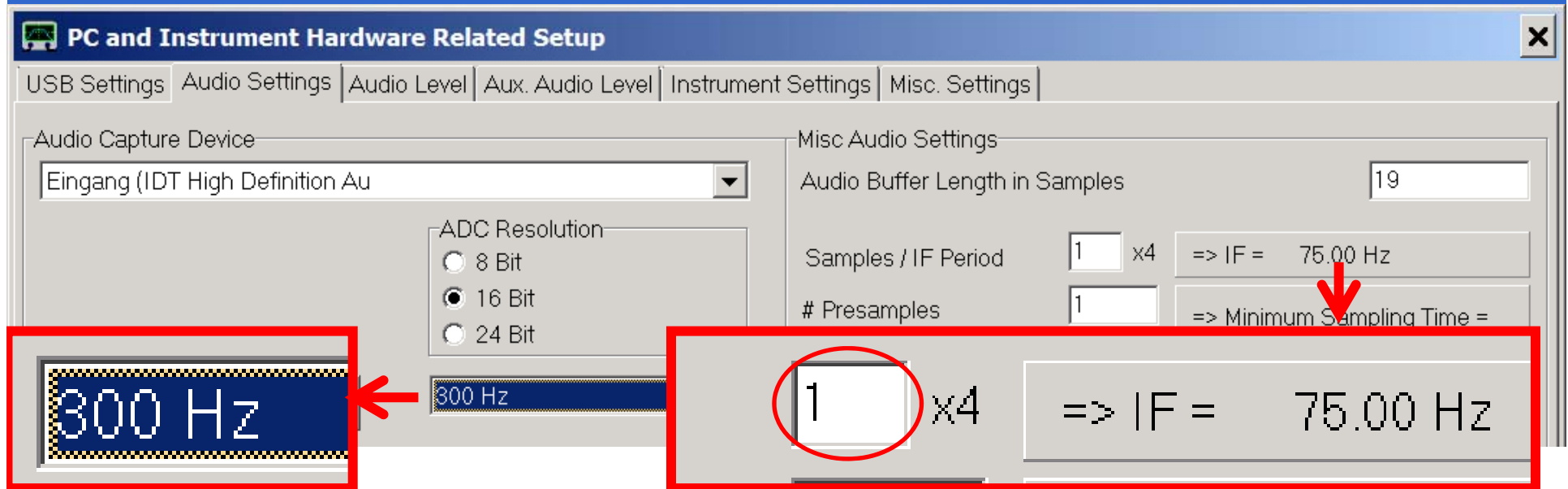
einfaches Modell

Two Port Measurement of a 12 kHz Band Pass Filter

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

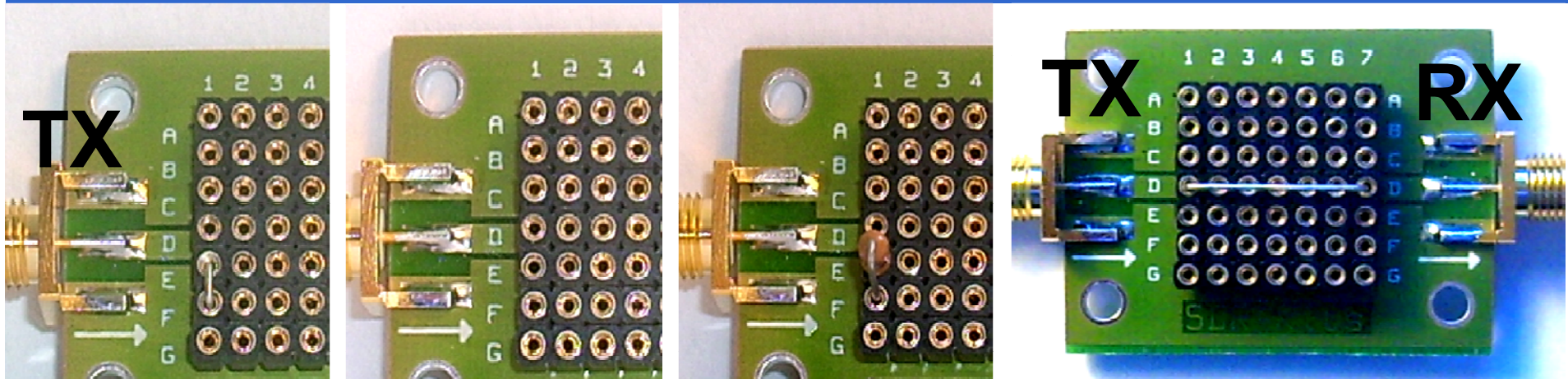









Special VNWA Settings for low Frequencies



Lowest sample rate 300 Hz **IF must be within Codec**
→ **Nyquist limit 150 Hz** **frequency range**
→ **Measurements down to** **(20 Hz...16kHz)**
 ≈150 Hz possible

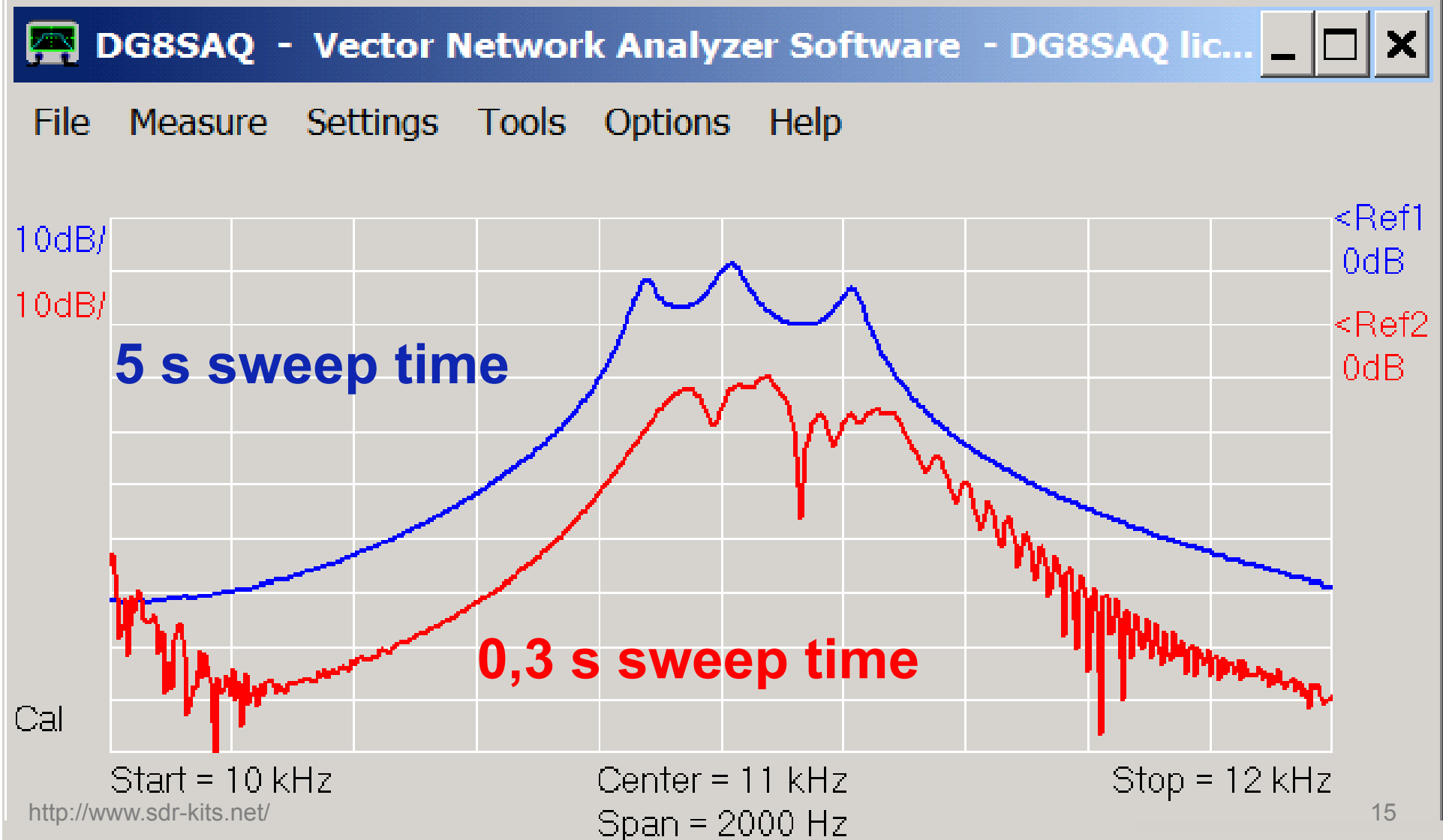
SOLT-Calibration for 2-Port Measurements



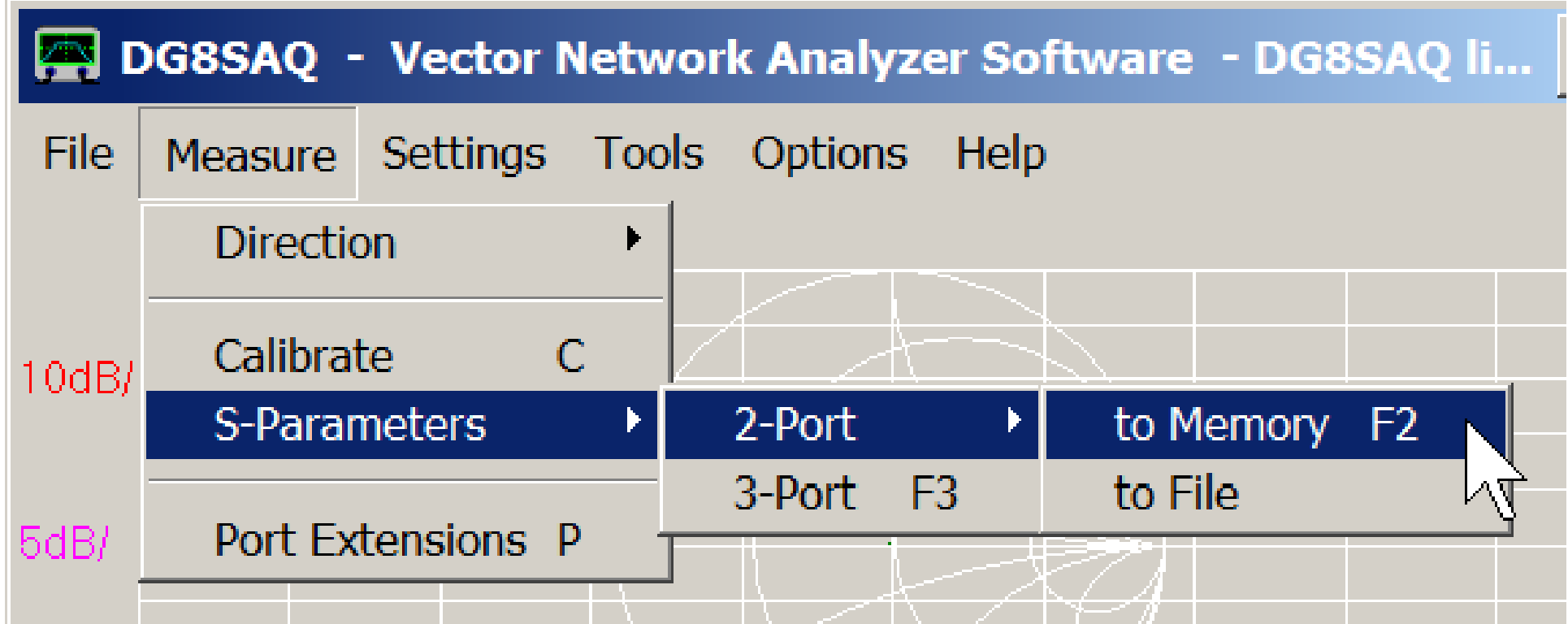
Reflect Calibration		Thru Calibration	
Short	Open	Load	Thru
Short		Crosstalk Cal	 <input type="checkbox"/> on / off
Open		Thru Cal	 <input checked="" type="checkbox"/> on / off
Load		Thru Match Cal	 <input checked="" type="checkbox"/> on / off
Cal <input checked="" type="checkbox"/> on / off		Invalidate All Thru Calibrations	

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

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

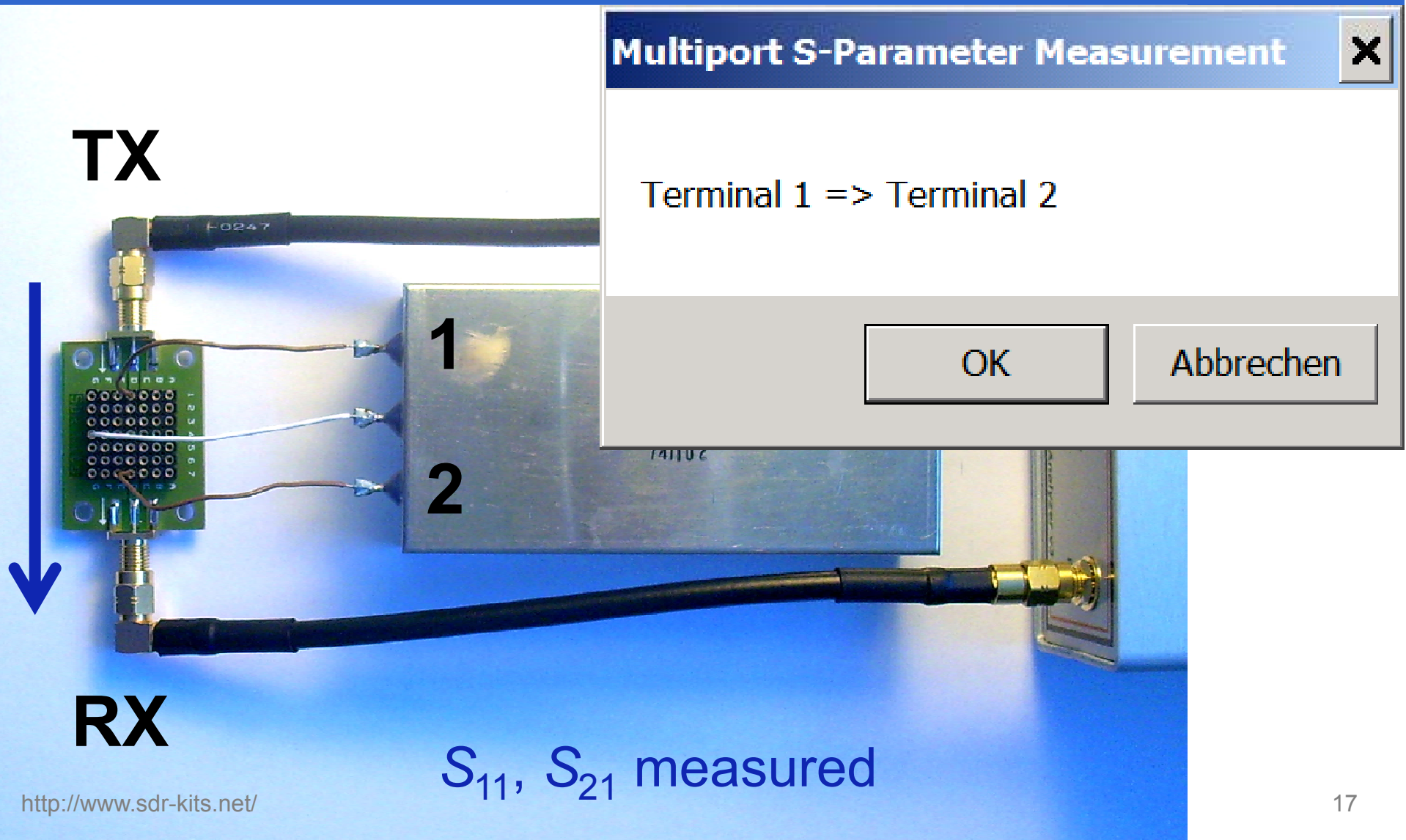


Two Port Measurement of a 12 kHz Band Pass Filter



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

Multipoint S-Parameter Me

Terminal 2 => Terminal 1

OK

2

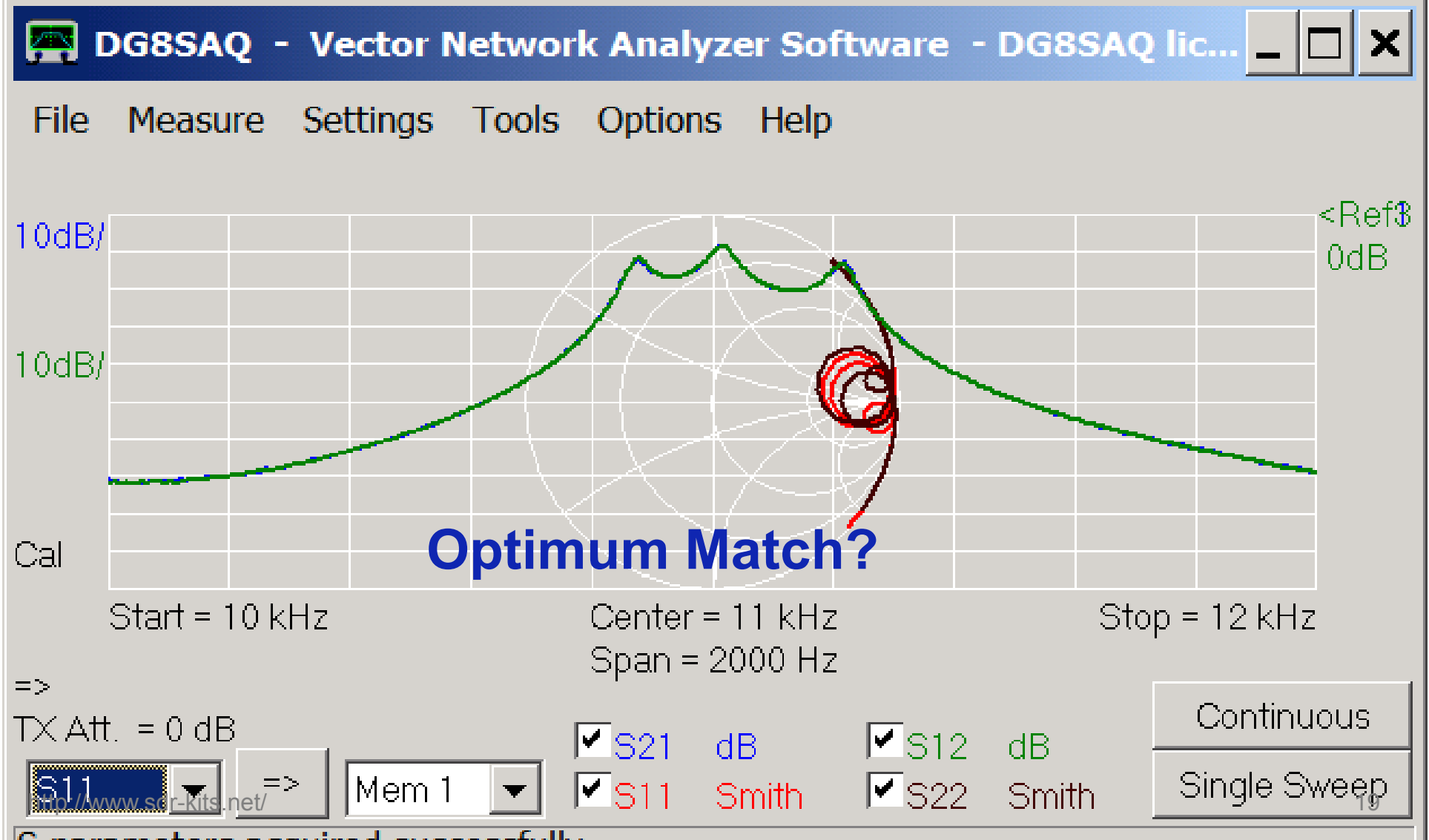
1

TX

RX

S_{12} , S_{22} measured

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

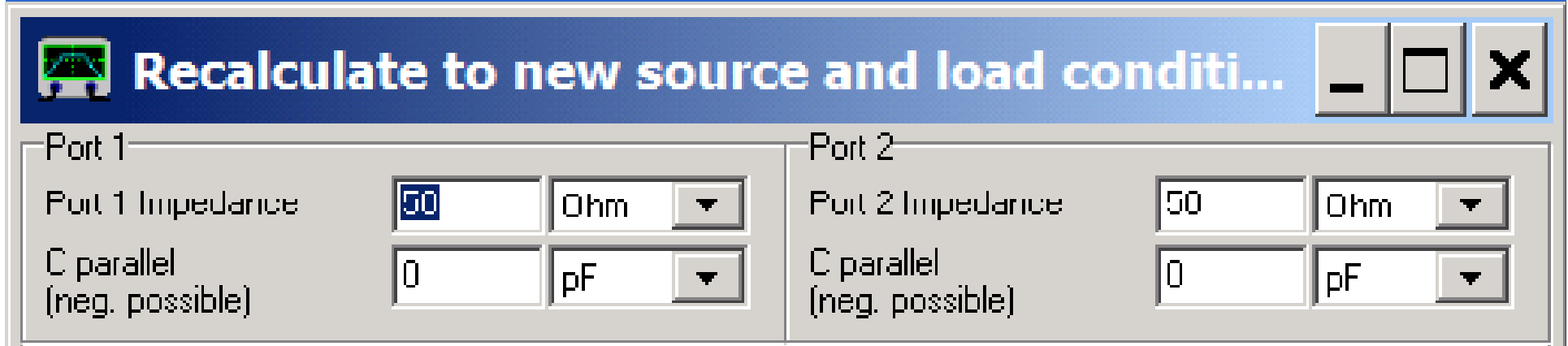


VNWA Matching Tool (1)

The screenshot shows the DG8SAQ software interface. The title bar reads "DG8SAQ - Vector Network Analyzer Software". The menu bar includes "File", "Measure", "Settings", "Tools", "Options", and "Help". The "Tools" menu is open, showing "Matching Tool" (with a keyboard shortcut "M") and "Directors Unmatched". A mouse cursor is hovering over "Matching Tool". A large white text box with a black border is overlaid on the interface, containing the text: "Allows to recalculate 2-port S-parameters to source and load impedances different from 50 Ohms!". The background shows a plot area with a green line, a vertical axis labeled "MC", and a horizontal axis with "Start = 10 kHz" and "End = 12 kHz". A "Configure Tools" button with the shortcut "Alt+T" is visible at the bottom.

Allows to recalculate 2-port S-parameters to source and load impedances different from 50 Ohms!

VNWA Matching Tool (2)



Recalculate to new source and load conditi...

Port 1

Port 1 Impedance: 50 Ohm

C parallel (neg. possible): 0 pF

Port 2

Port 2 Impedance: 50 Ohm

C parallel (neg. possible): 0 pF

Complex conjugate of
source impedance

=

filter *input* impedance

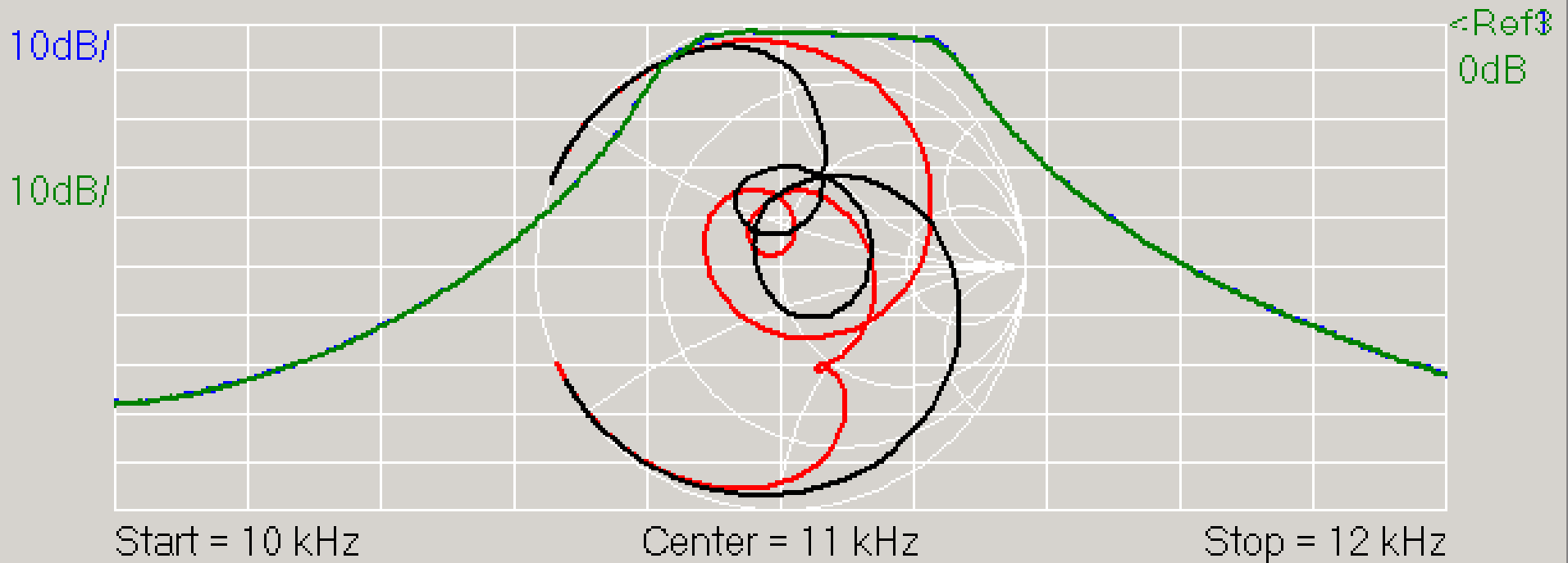
Complex conjugate of
load impedance

=

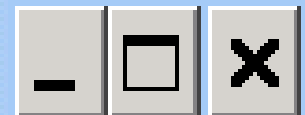
filter *output* impedance

Matching Analysis with VNWA Matching Tool

Optimum: $Z_{in} = Z_{out} = 610 \Omega$



Recalculate to new source and load conditi...



Port 1

Port 1 Impedance

610

Ohm



C parallel

(neg. possible)

0

pF



Port 2

Port 2 Impedance

610

Ohm



C parallel

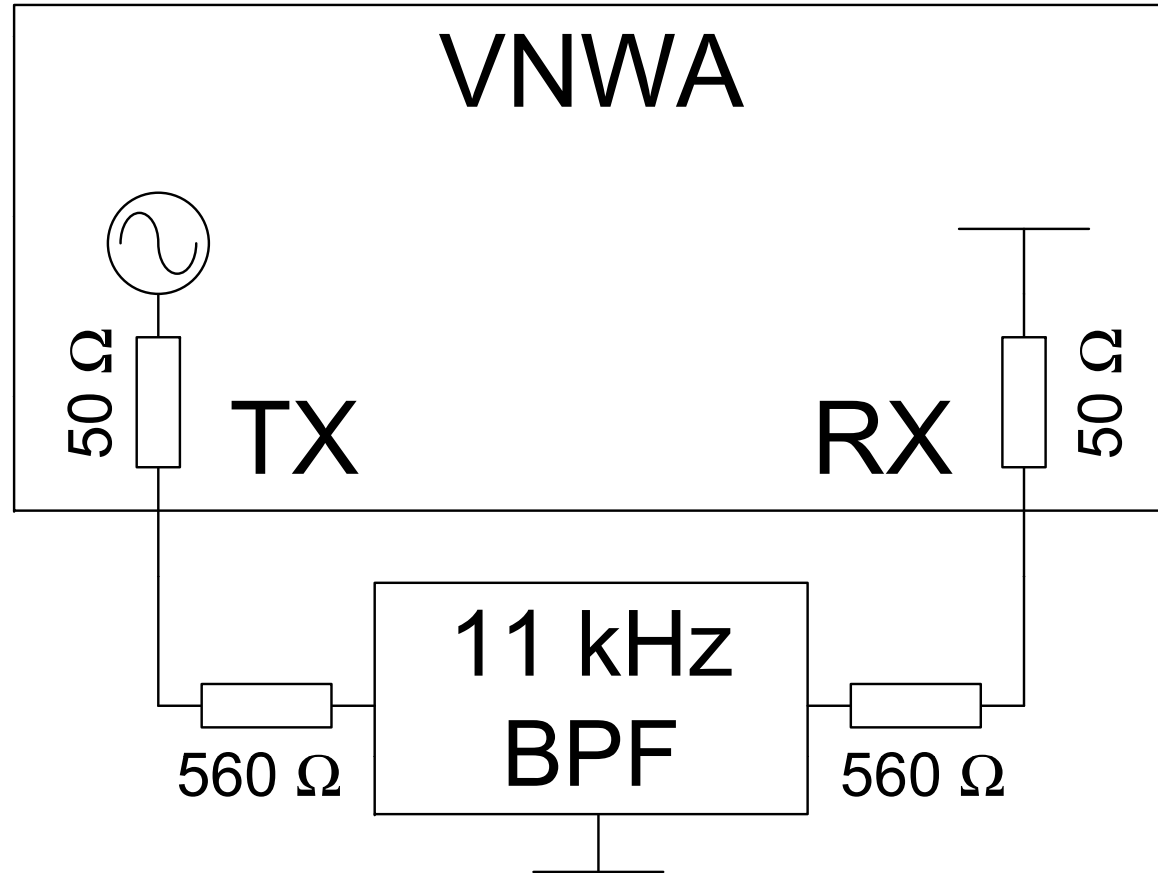
(neg. possible)

0

pF

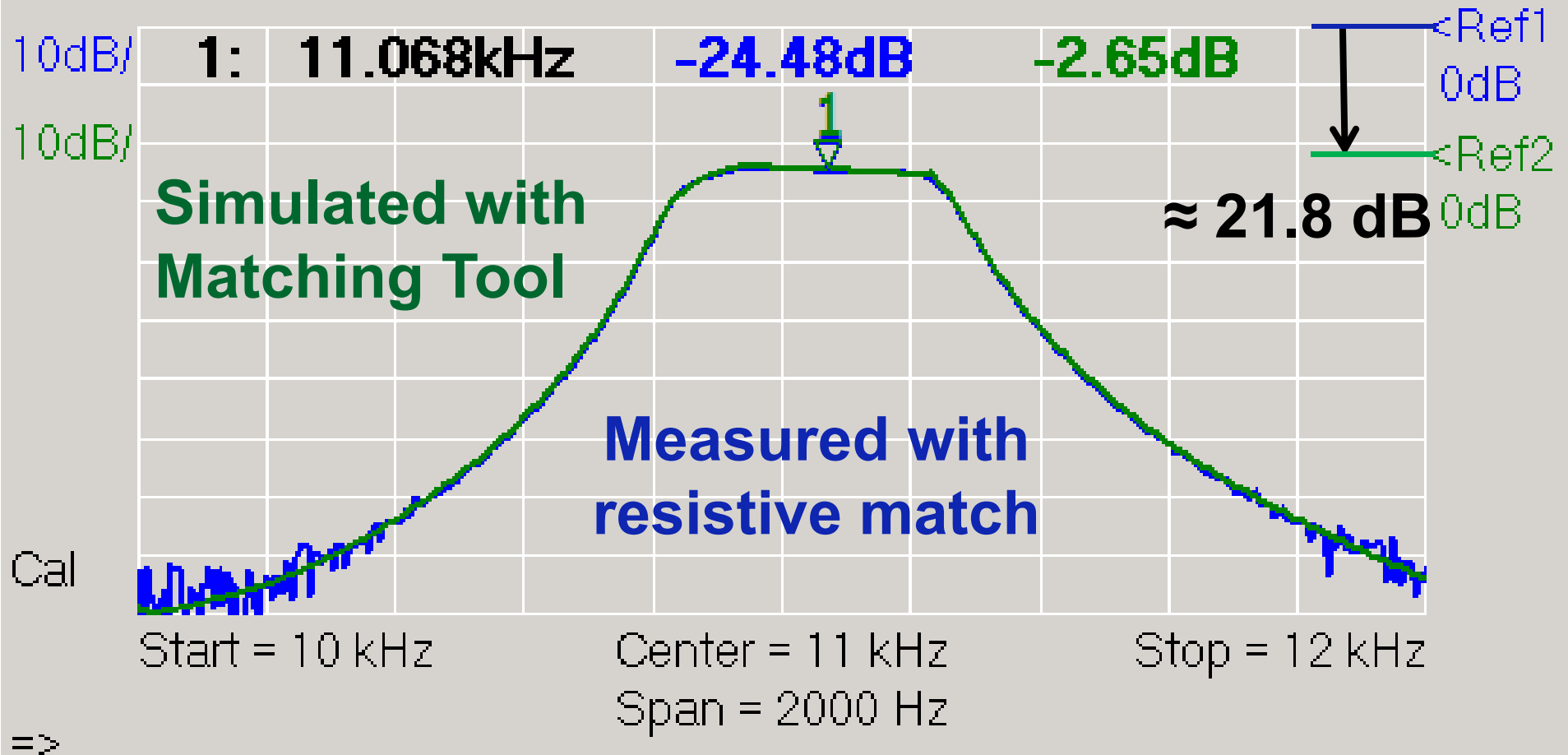


Forced Impedance Match using Resistors



$$50 \Omega + 560 \Omega = 610 \Omega$$

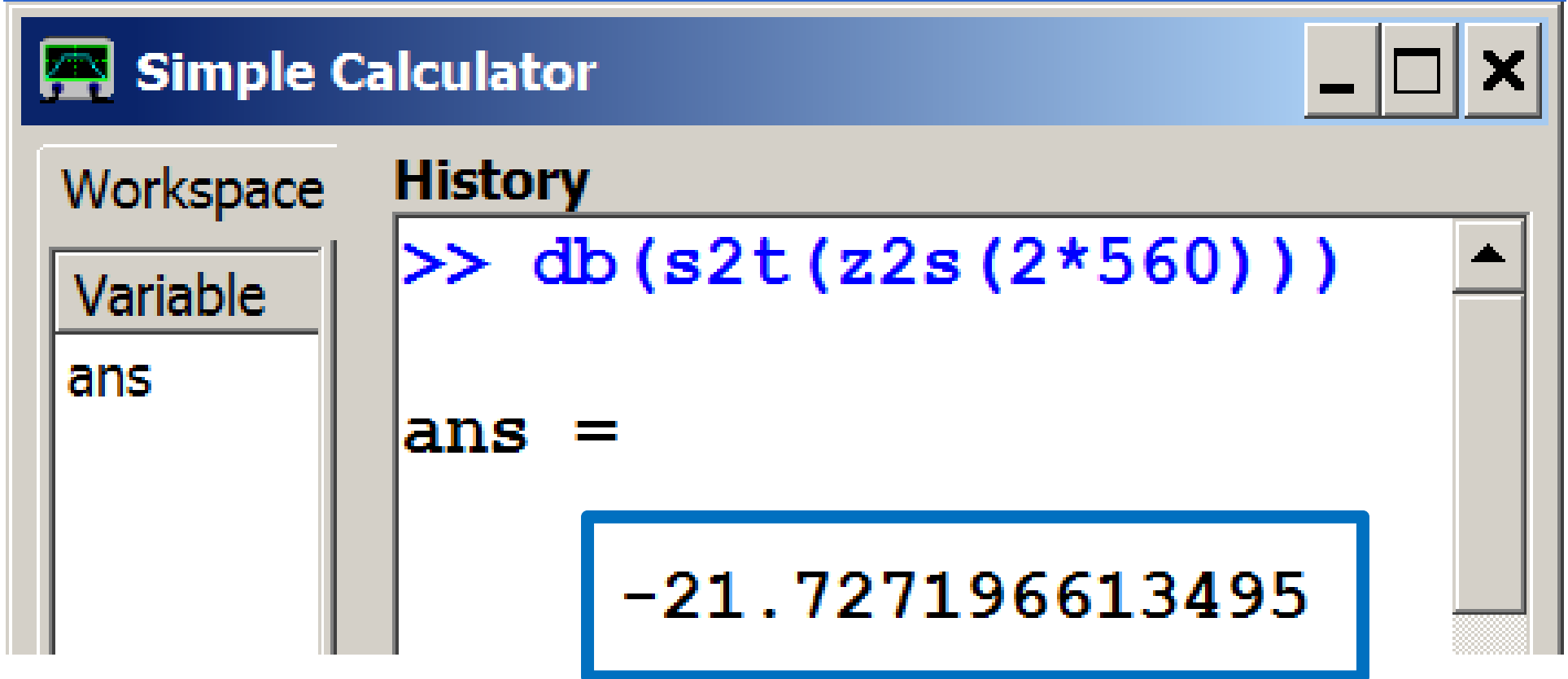
Match works except for increased Loss



S21 dB

Mem1 dB

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



The screenshot shows a window titled "Simple Calculator". On the left, there is a "Workspace" pane with a "Variable" section containing the variable "ans". The main "History" pane shows the command `>> db (s2t (z2s (2*560)))` and the result `ans =` followed by the value `-21.727196613495`, which is enclosed in a blue rectangular box.

21,7 dB additional attenuation ✓

This can also be „properly“ simulated!

Simulation Tool QUCS



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

Measured S-Parameters in QUCS

Qucs 0.0.16 - Project: 11kHzBPF

File Edit Positioning Insert Project Tools Simulation View Help

11kHzBPF.sch 11kHzBPF.dpl

S parameter simulation

SP1
Type=lin
Start=10 kHz
Stop=12 kHz
Points=400

measured S-parameters from s2p-file

X1
File=11kHz_BPF.s2p

P1 Num=1 Z=50 Ohm

R1 R=560 Ohm

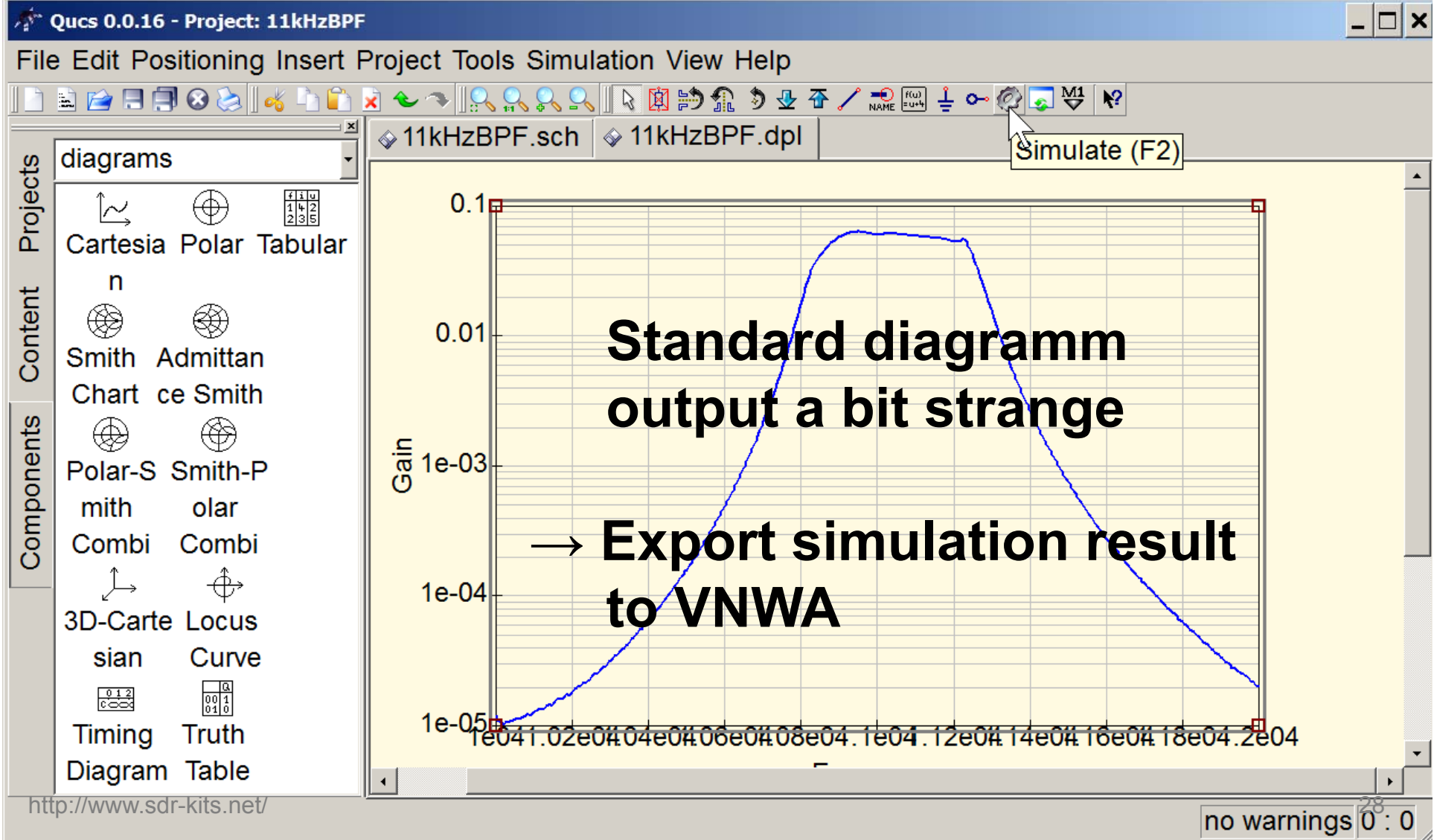
R2 R=560 Ohm

P2 Num=2 Z=50 Ohm

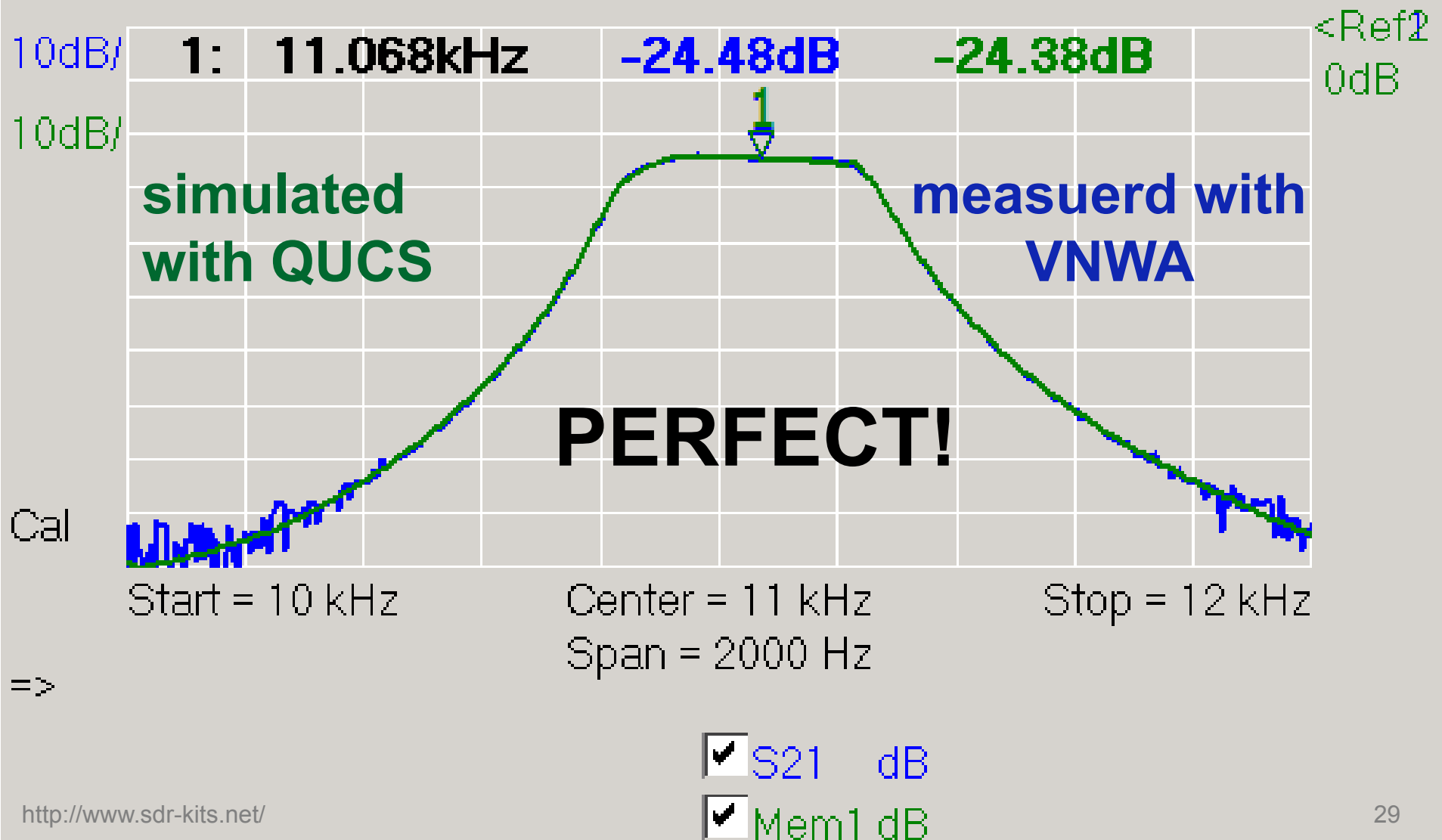
no warnings 0 : 0

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


Matching Simulation in QUCS



Comparison QUCS-Simulation vs. Measurement



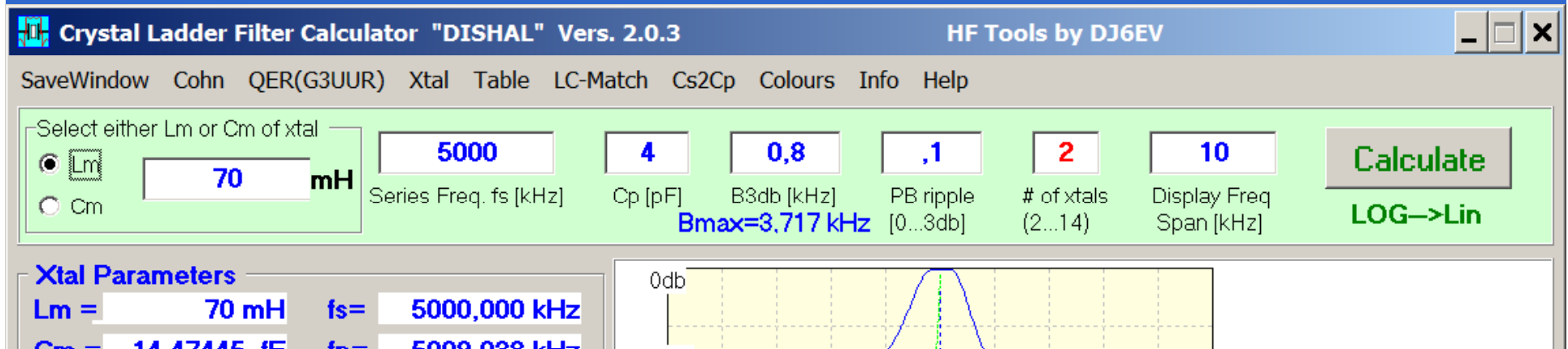
Free Filter Design Software (1): Elsie – for LC-Filters

 Elsie Student Edition - Welcome !

This is the Student Edition of
Elsie

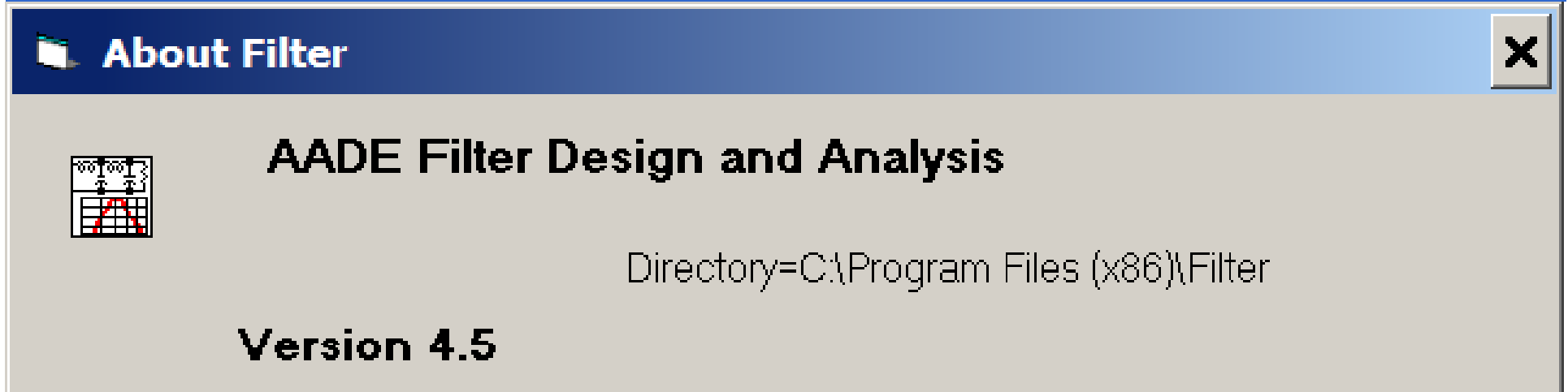
- <http://tonnesoftware.com/elsiedownload.html>
- **LC-Filter Designer and Analyzer**
- **Student version restricted to 7 dipols**
- **Numerical simulation results export easily to s2p-file!**

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



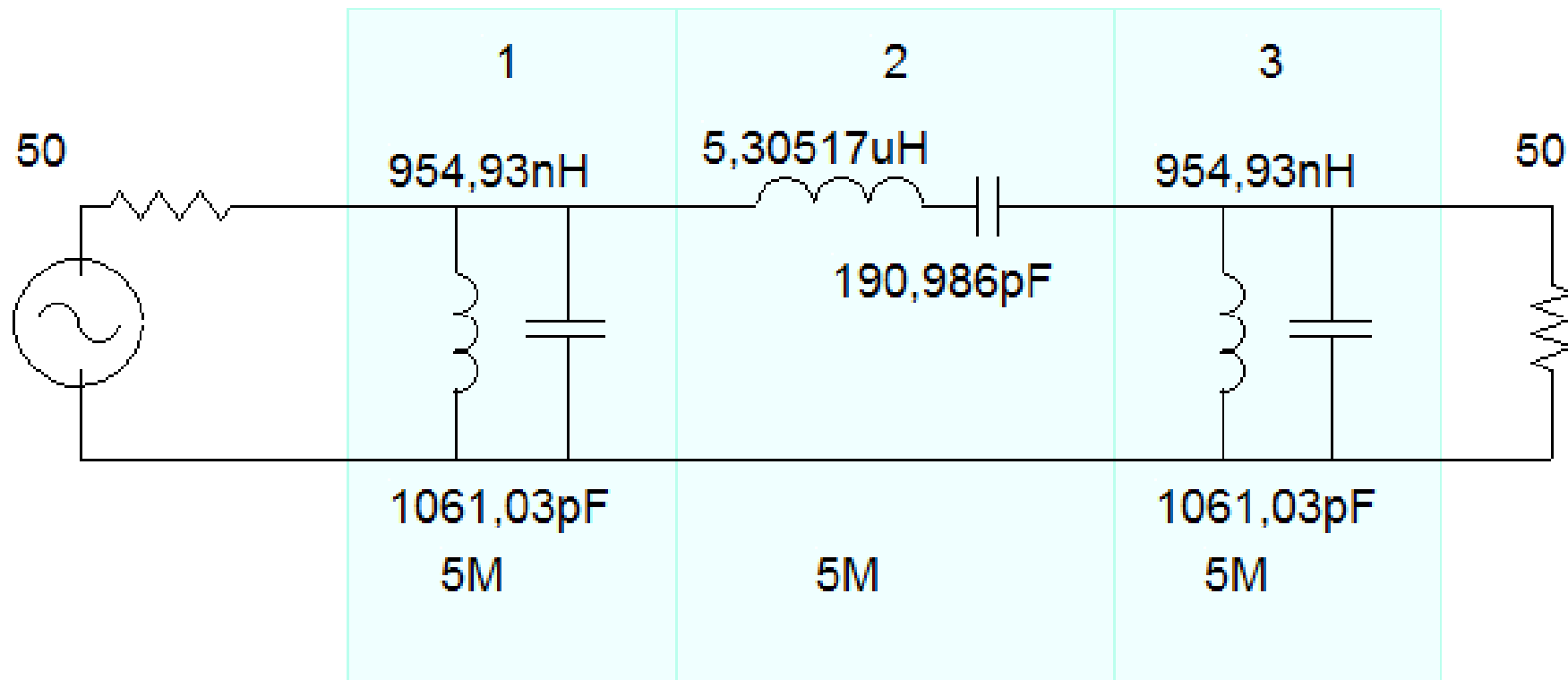
- <http://www.bartelsos.de/dk7jb.php/quarzfilter-horst-dj6ev>
- **Crystal filter designer and analyzer**
- **Simulates without crystal losses**
- **S_{21} -simulation results can be exported**

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



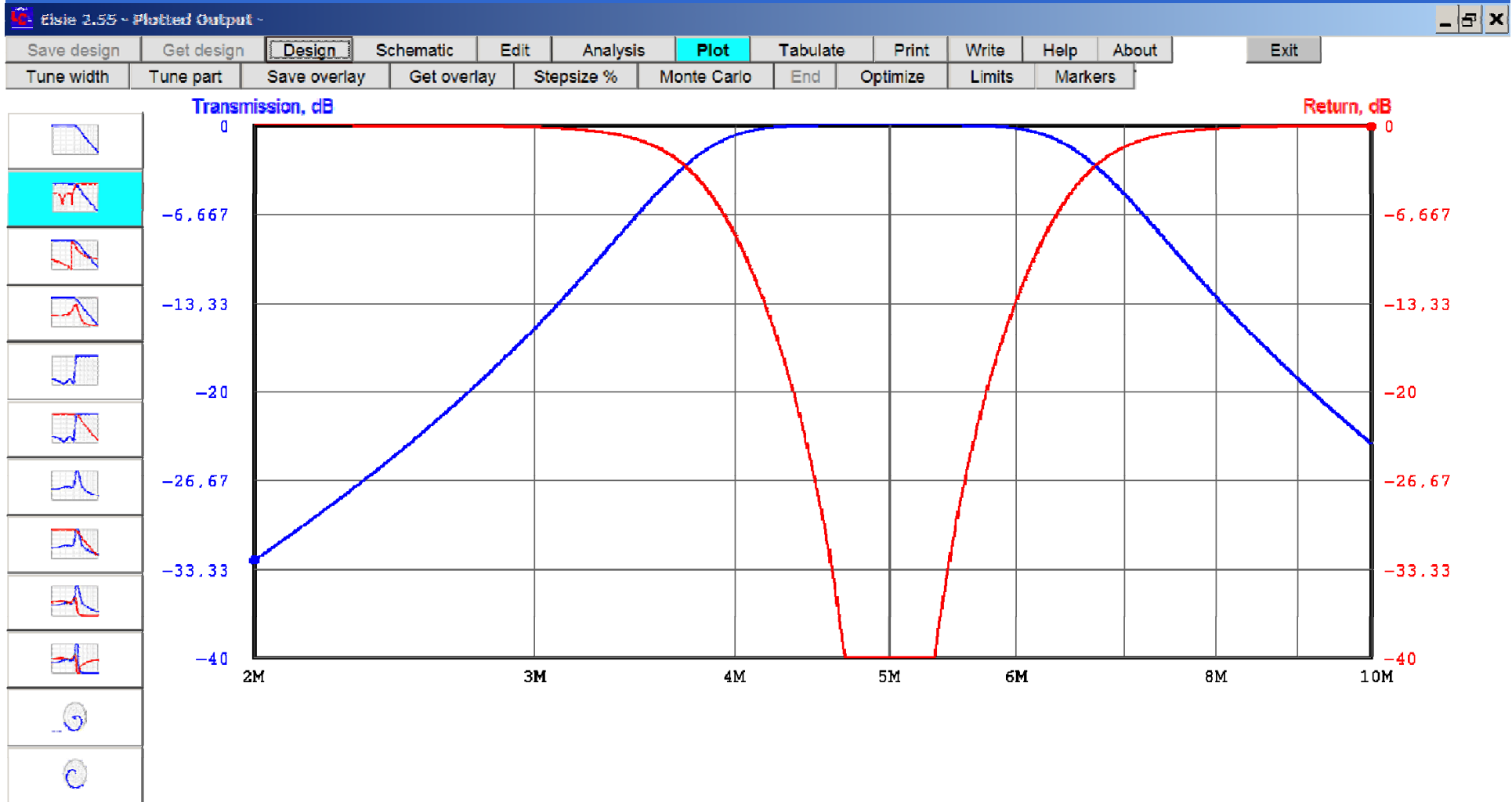
- <http://aade.com/filter32/download.htm>
- **Universal filter designer and analyzer**
- **Free, but with nag screen**
- **Easy to use**
- **Numerical simulation results cannot be exported**

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

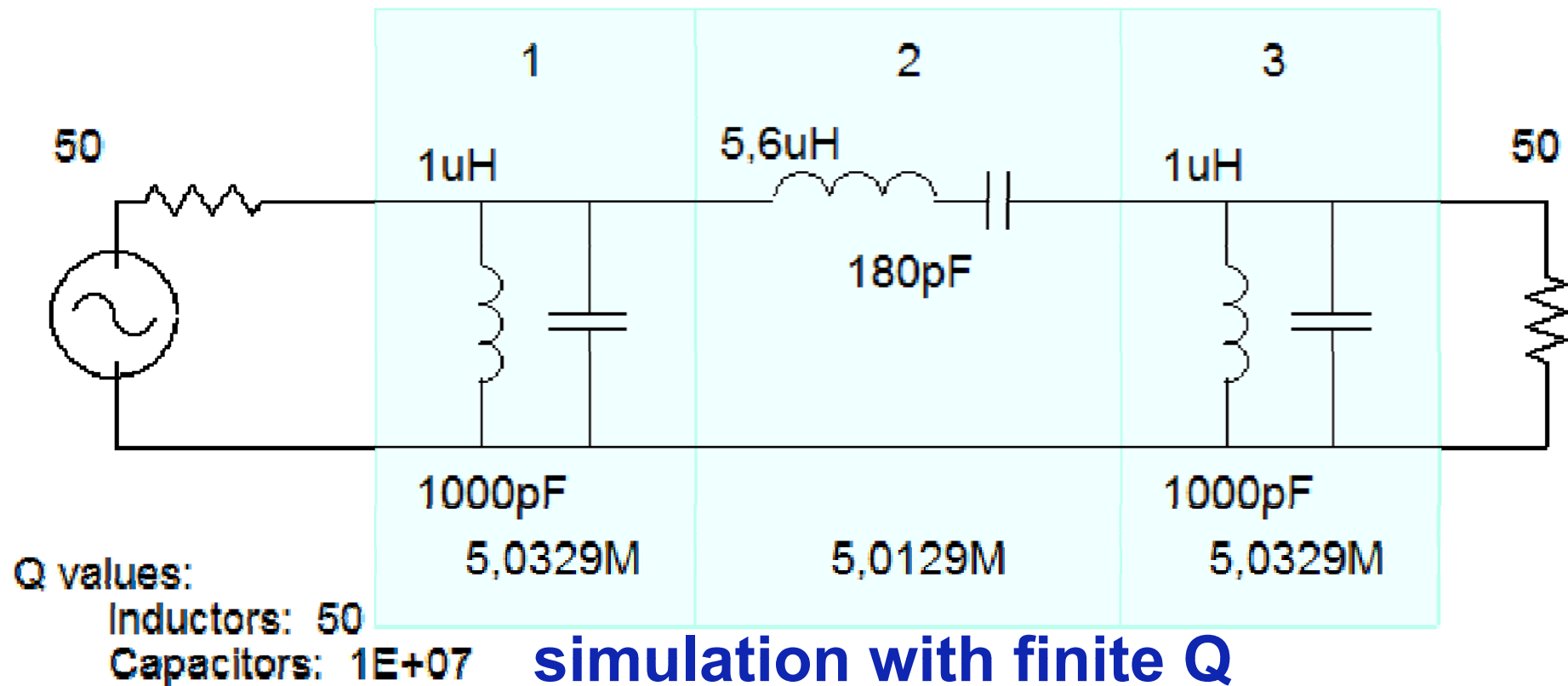
Edit

Analysis

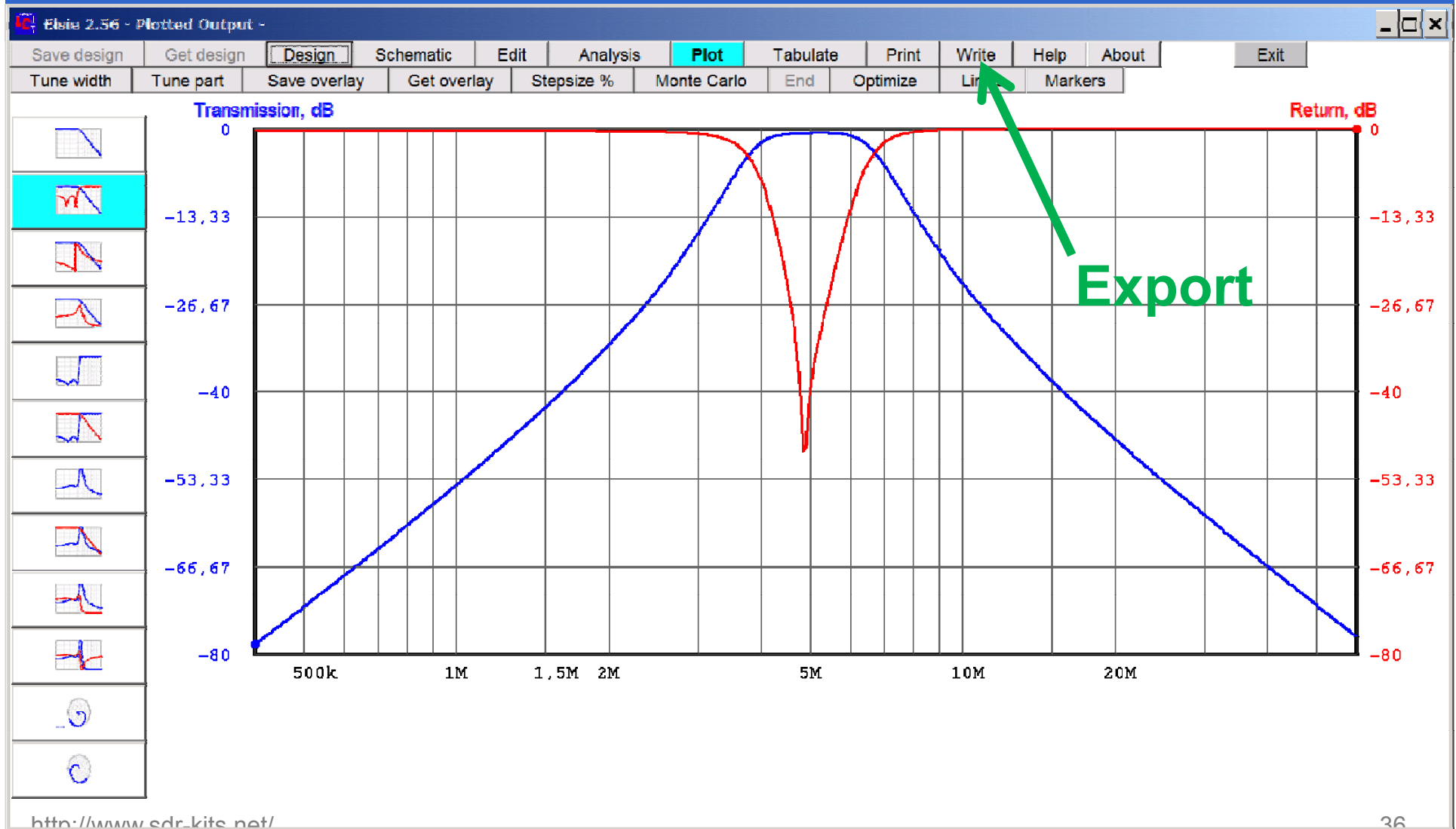
Plot

Tabulate

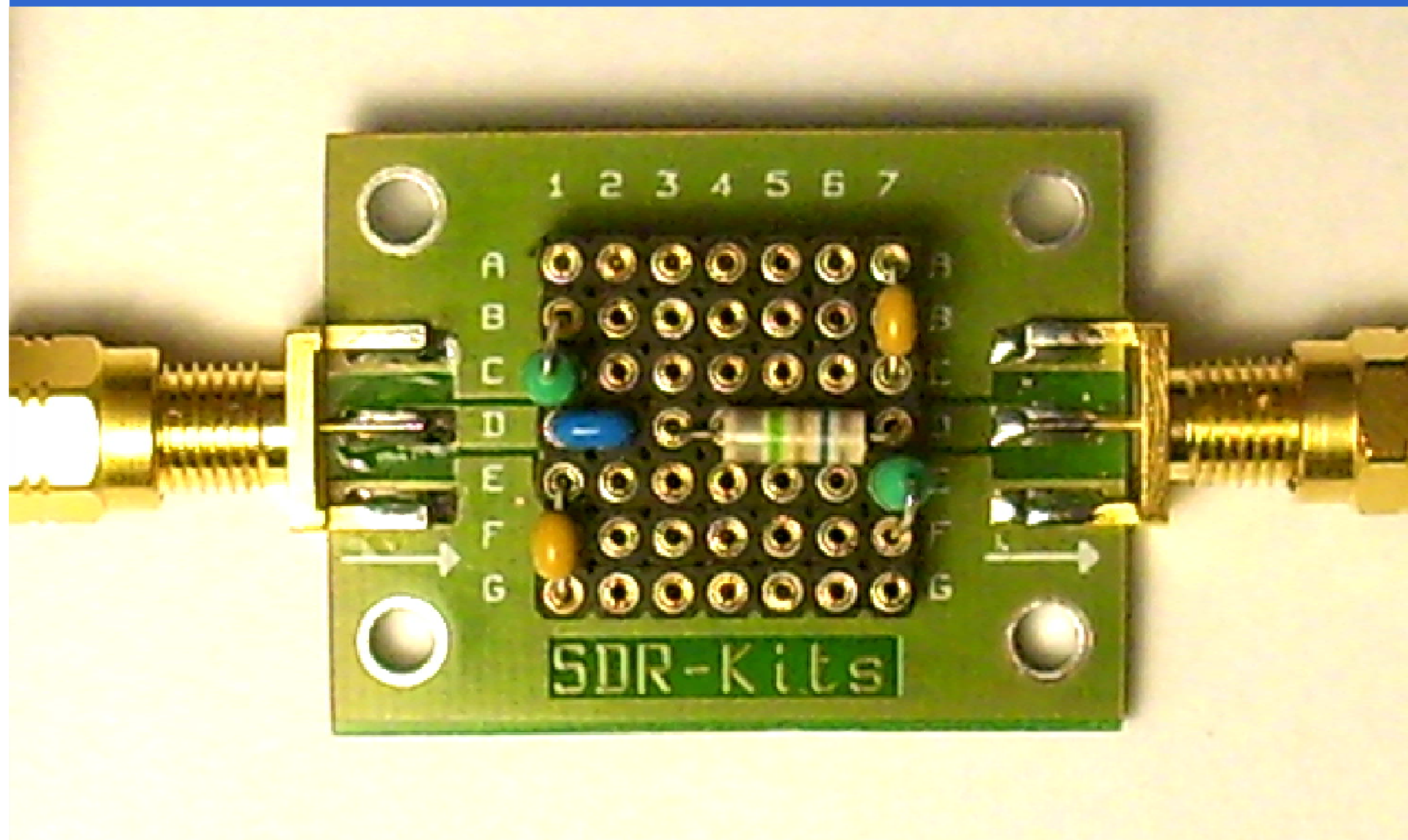
Print



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

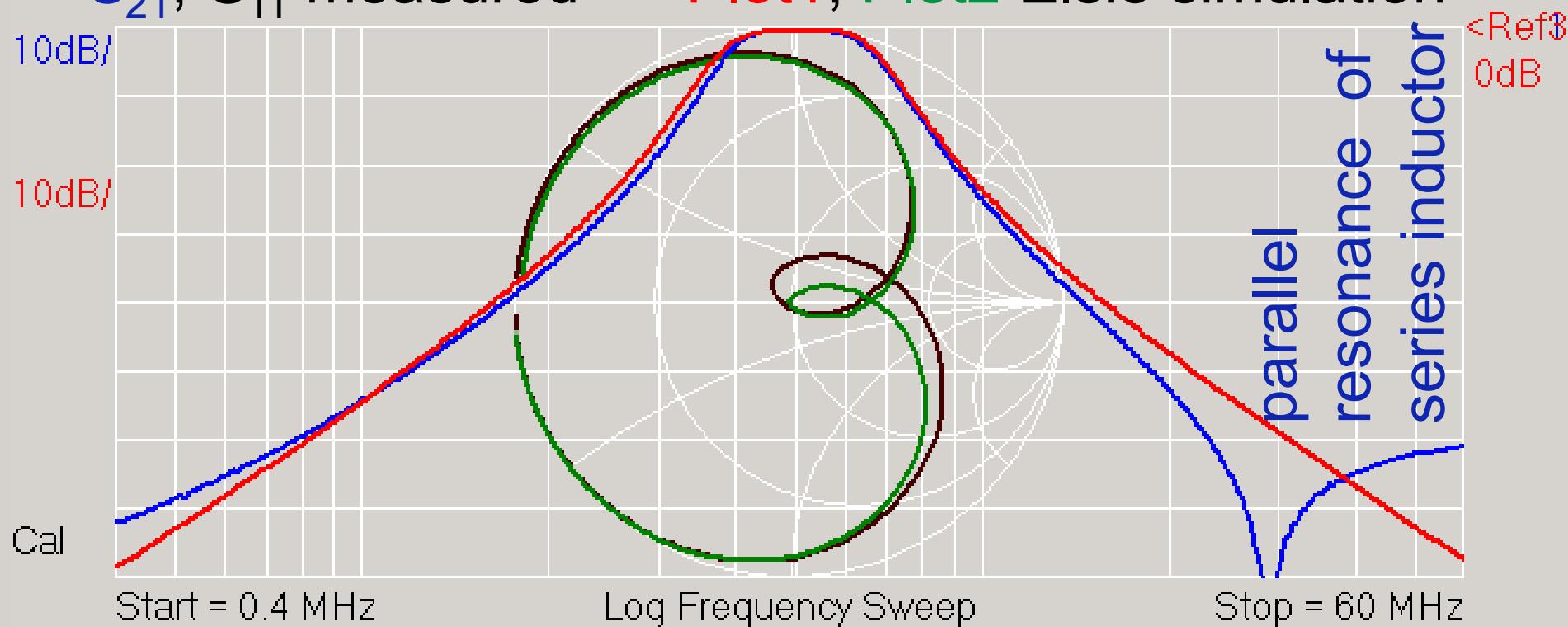


Filter Hardware



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

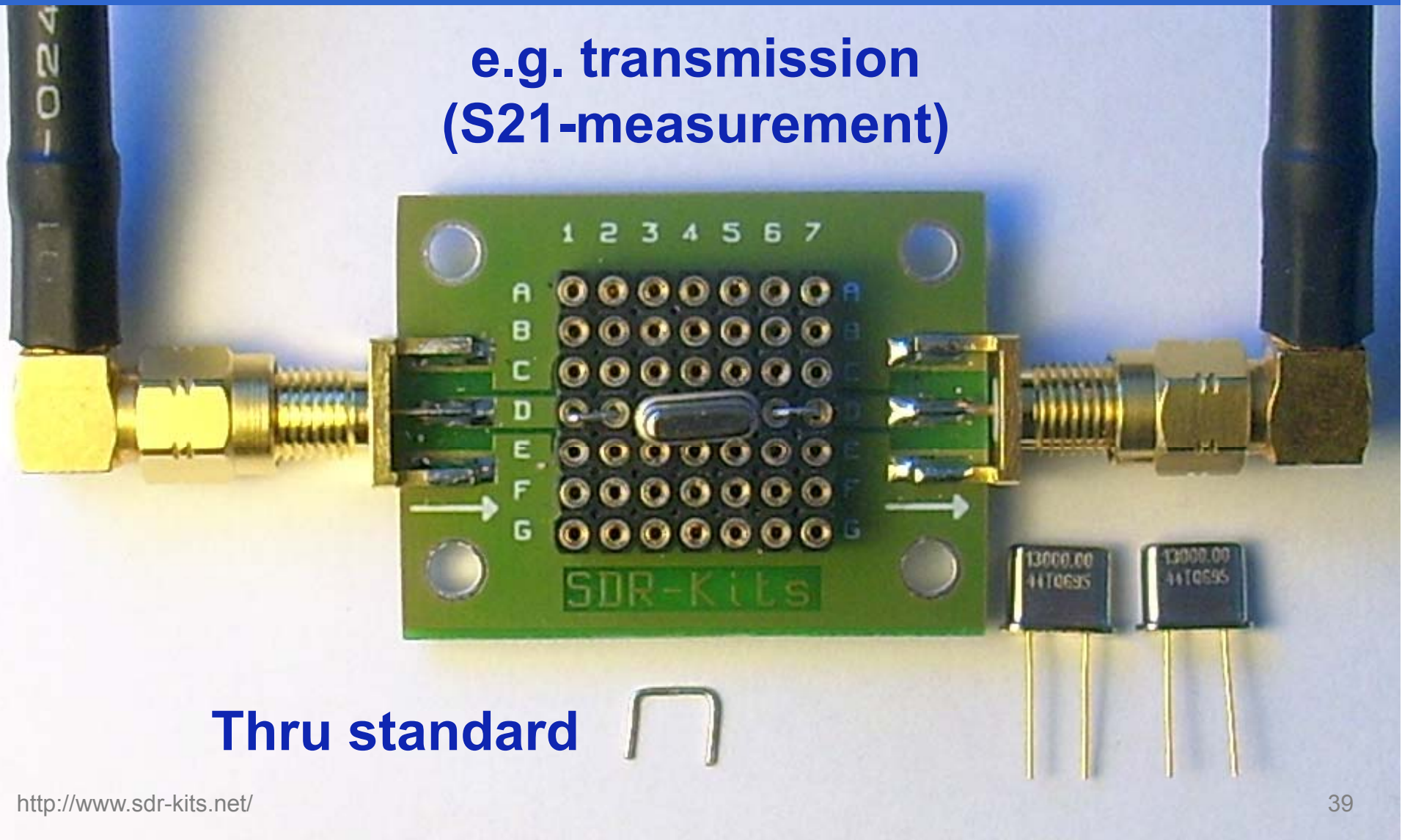
Continuous

Single Sweep

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

Measuring / Selecting Crystals: VNWA Crystal Analyzer

e.g. transmission
(S21-measurement)

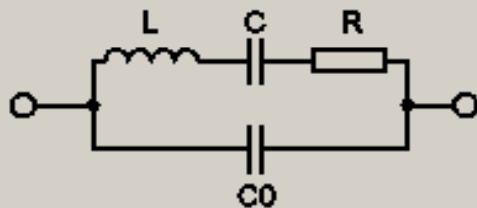


Thru standard

The VNWA Crystal Analyzer Tool: Find 3 similar Crystals...

Crystal Analyzer - Analysis will be performed into 3-port data spaces s_11 an... ✕

Equivalent Circuit



L = 23.22917 mH

C = 6.456461 fF

R = Ohm

C0 = pF

$f = 1/2\pi\sqrt{L \cdot C}$ = MHz

$R \cdot Q = \sqrt{L/C}$ = x1000

Q = 69517

source = S21

Test Jig Impedances = Ohms

Batch Crystal Analyzer

#	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

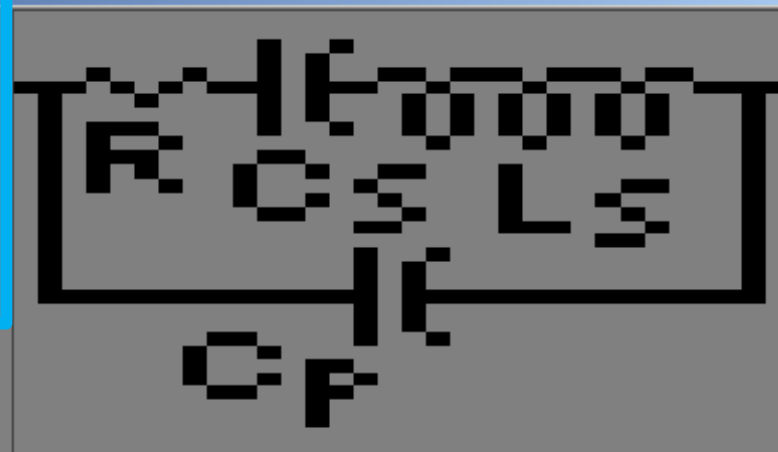
With these we want to build a Crystal Filter → Enter Crystal Parameters into AADE

Enter data

Enter values from the keyboard or by clicking on the calculator pad shown. Tab advances to the next value.

7	8	9	+	-	M
4	5	6	*	/	K
1	2	3	%	=	m
0	.	√	x ²	μ	
tab	bksp	CLR	n		
ENTER	Cancel	p			

Cp = 2,46804p
 Ls = 23,499m
 Cs = ,00638p
 Qx = 48,842K

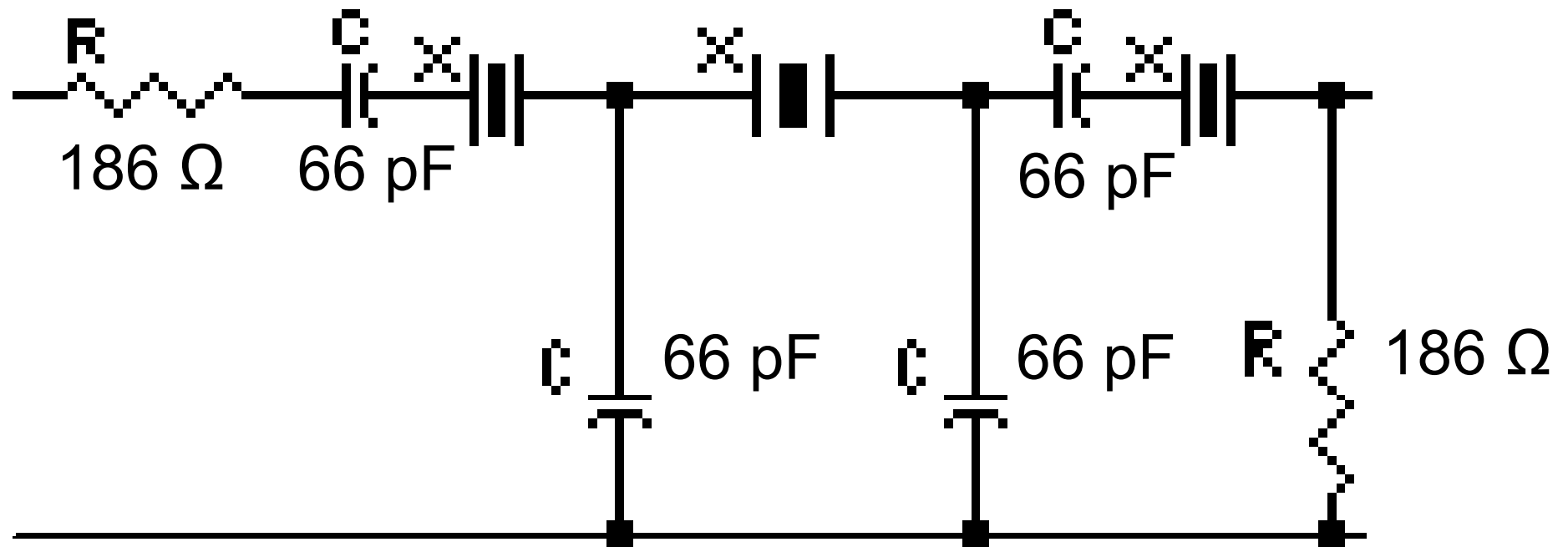


Daten vom
 VNWA
 Crystal
 Analyzer
 übertragen

Enter the crystals parallel capacitance in Farads. L/C Meter II will measure it.

#	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

S parameter simulation

SP1

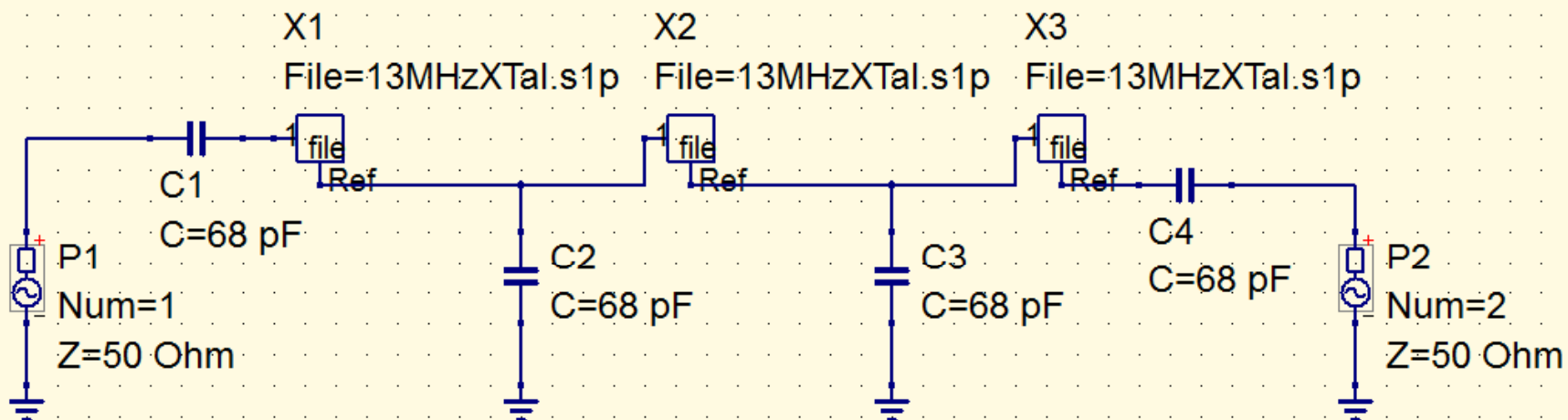
Type=lin

Start=12.987 MHz

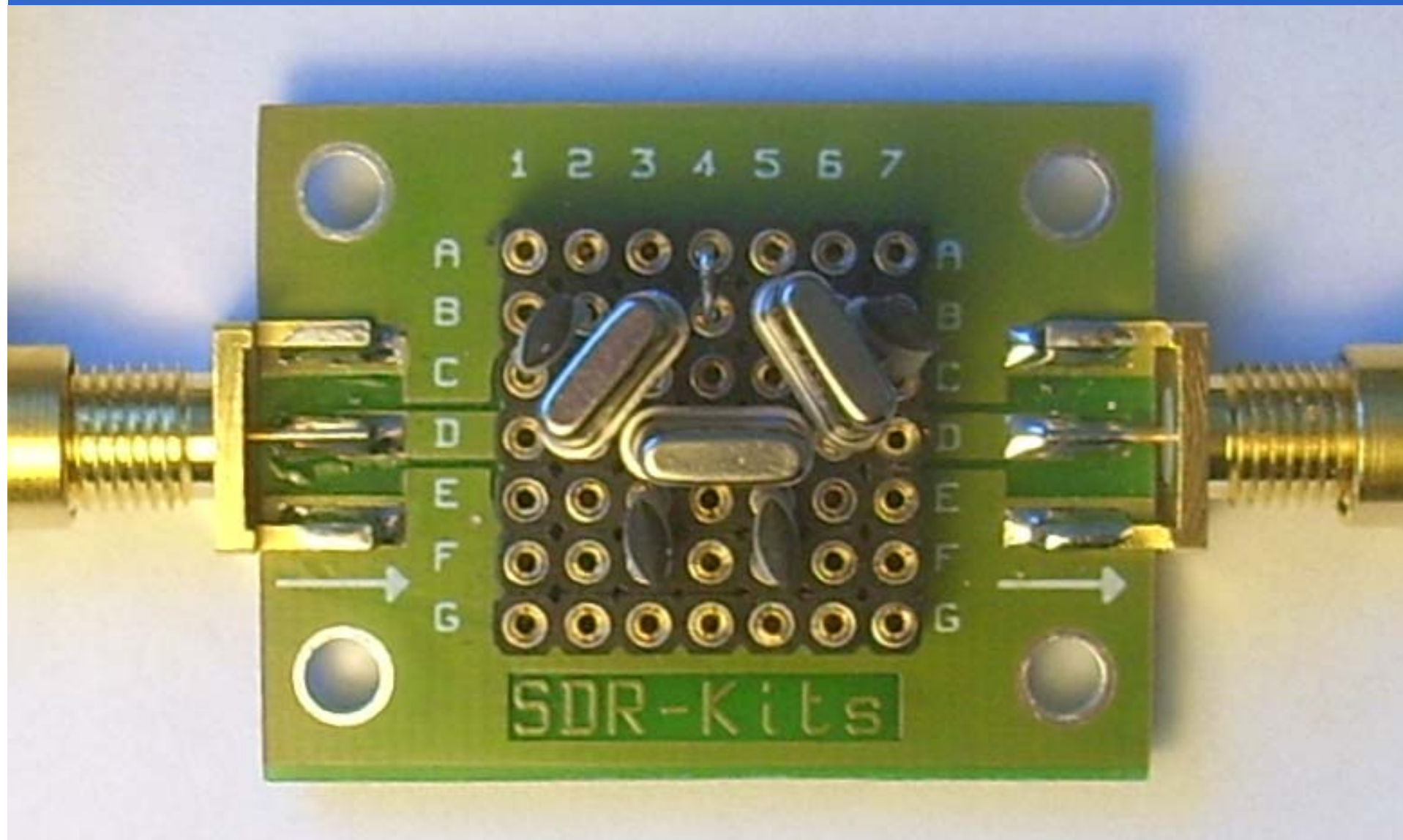
Stop=13.007 MHz

Points=800

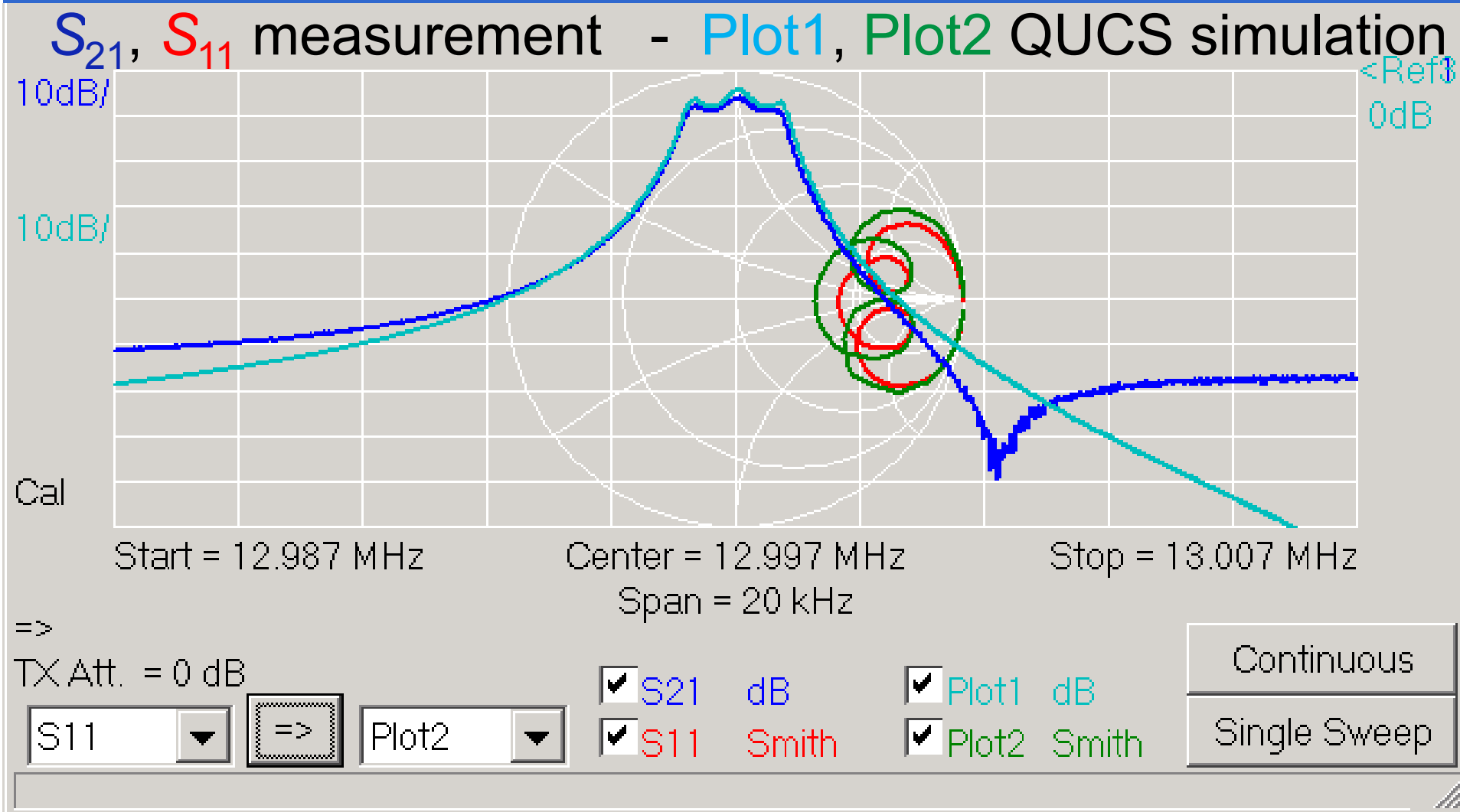
Crystals simulated with s1p-file obtained by VNWA measurement!



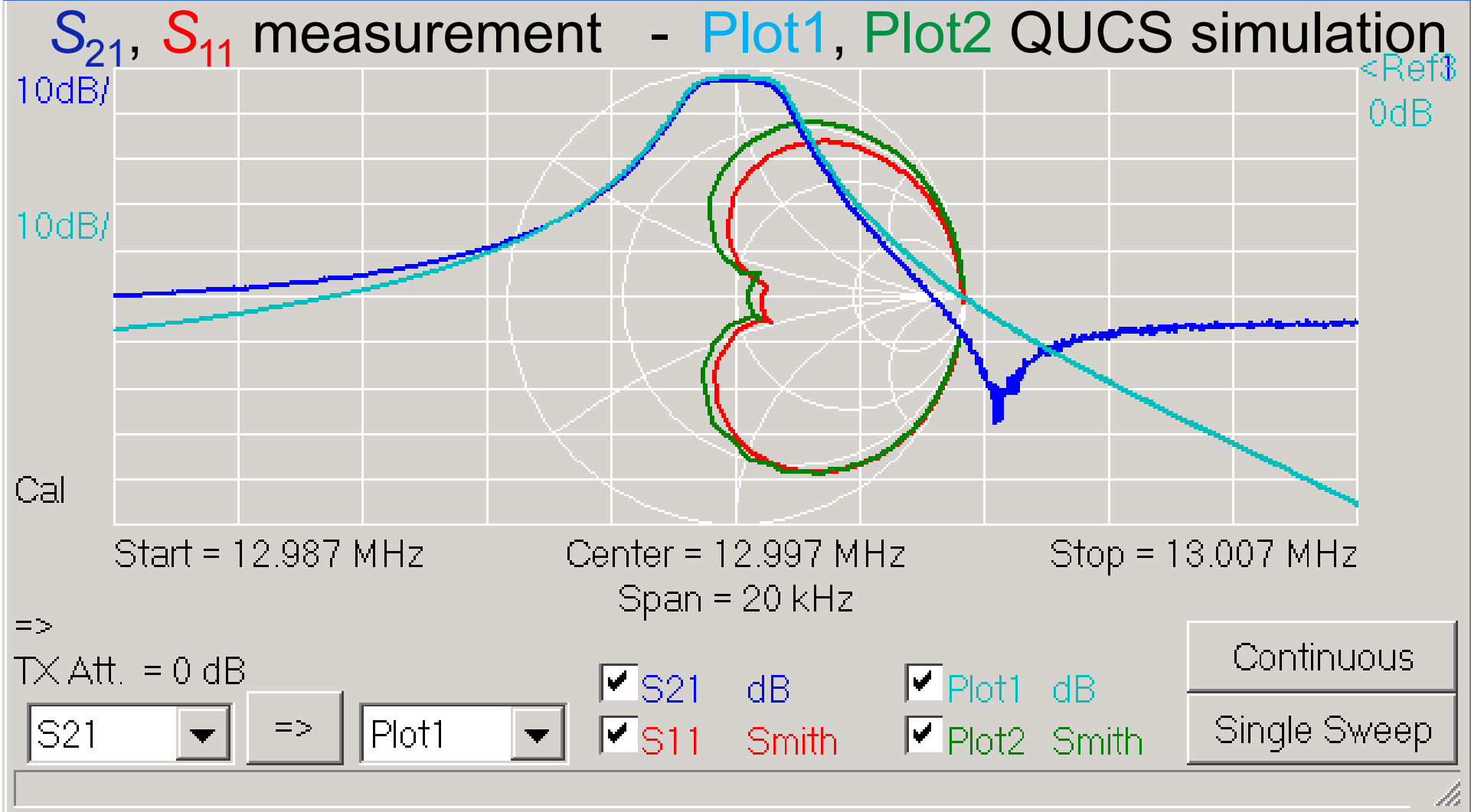
Crystal Filter Hardware



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!