HAM RADIO 2012

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FRIEDRICHSHAFEN

Evolution of the DG8SAQ Vector Network Analyzer:

New VNWA3 Features & Applications

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DG8SAQ

Hochschule Ulm

Prittwitzstrasse 10

89075 Ulm

English version by
Jan Verduyn G0BBL and Kurt Poulsen OZ7OU

Technik
Informatik & Medien
Hochschule Ulm
University of
Applied Sciences

VNWA Presentation - Contents

- **What are S-parameters?**
- **How does the VNWA function and how was it born?**
- **New features**
- **Some novel measurement examples**

Dank an:
- *Eric Hecker*
- *Giuseppe Gristina*
- *Fred Schneider*
- *Mario Armando Natali*

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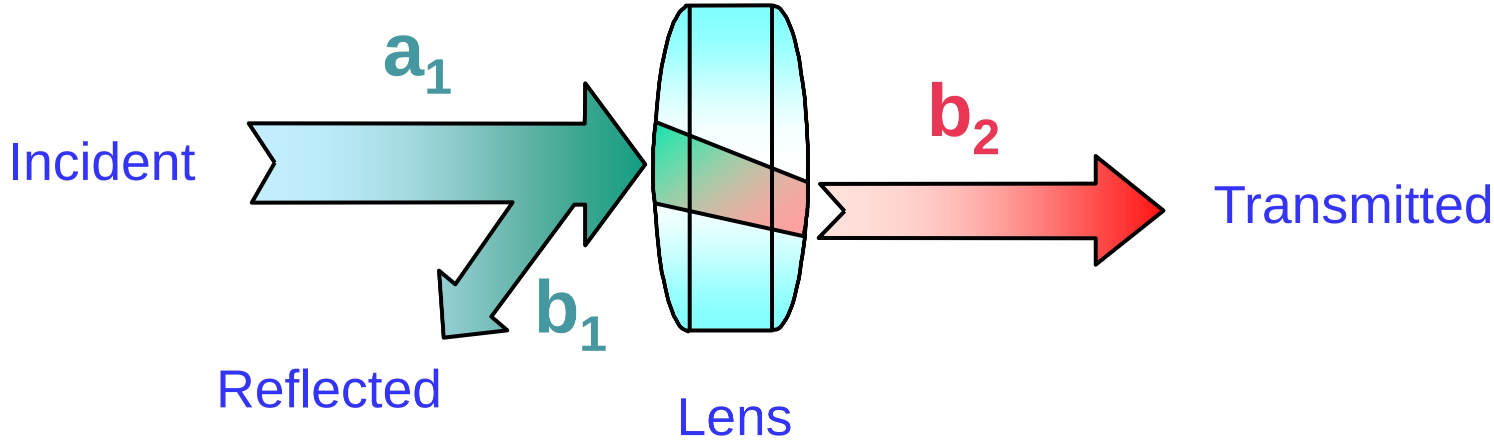
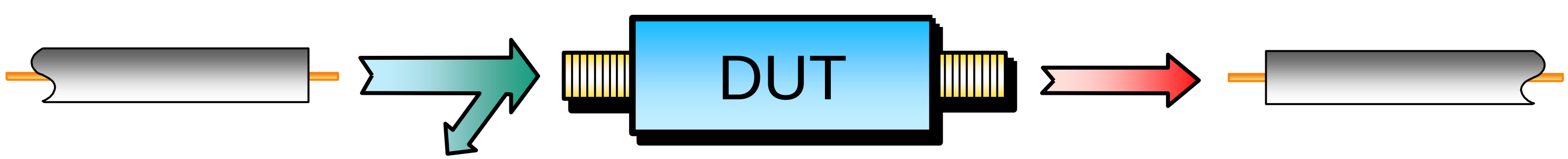
It is all about scattering of Waves

Optic



Electrical



DUT : DEVICE UNDER TEST

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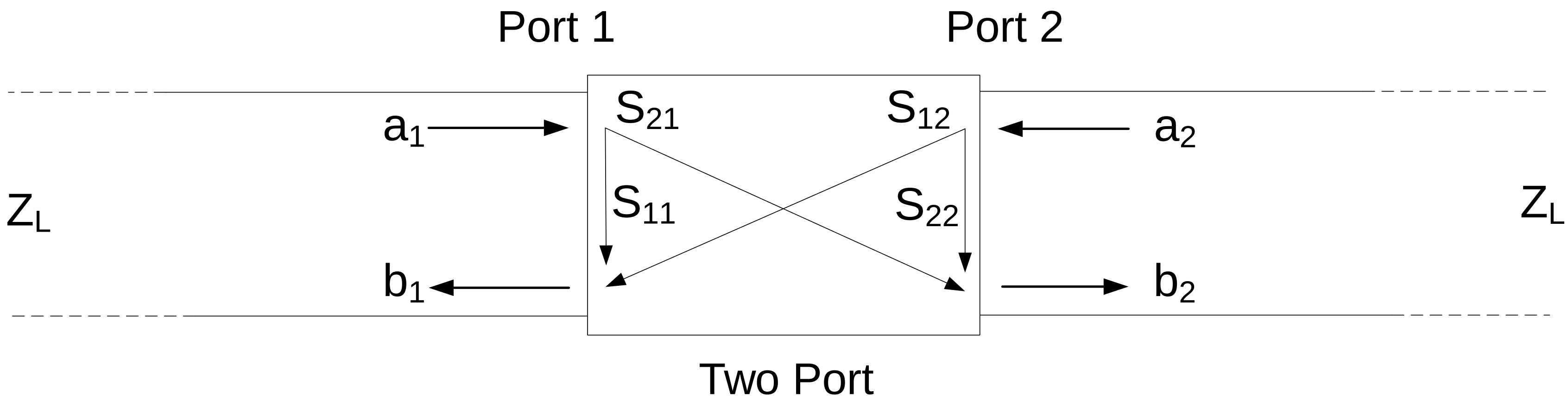
S-Parameter = Scattering Parameter S_{ik}



- Complex S-parameters: $S_{ik} = b_i / a_k$
- $\boldsymbol{S_{ik}}$ are complex numbers consisting of ***Magnitude*** and ***Phase***!

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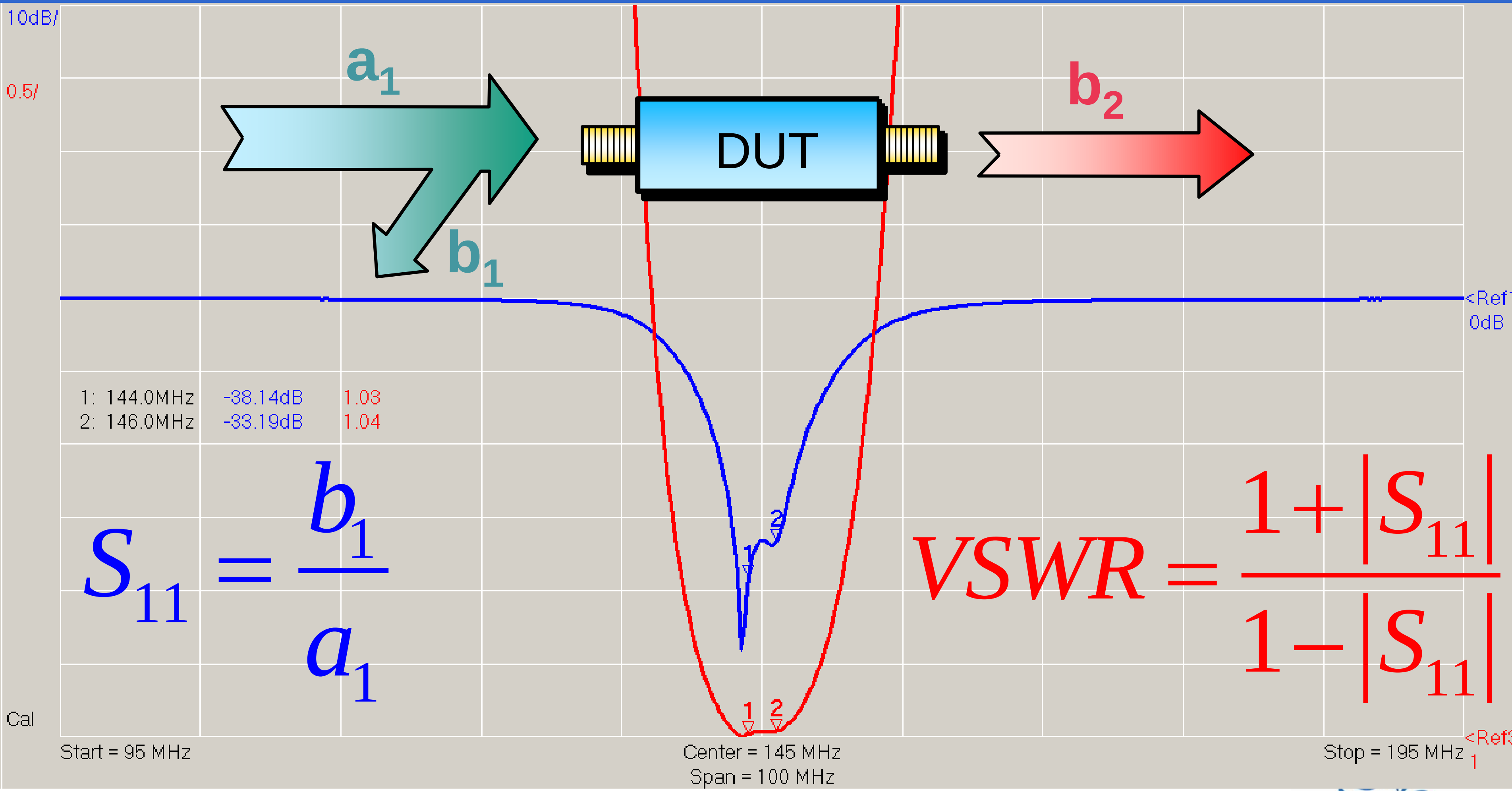
S-Parameter S_{11}

$|S_{11}|$ = Input Return Loss

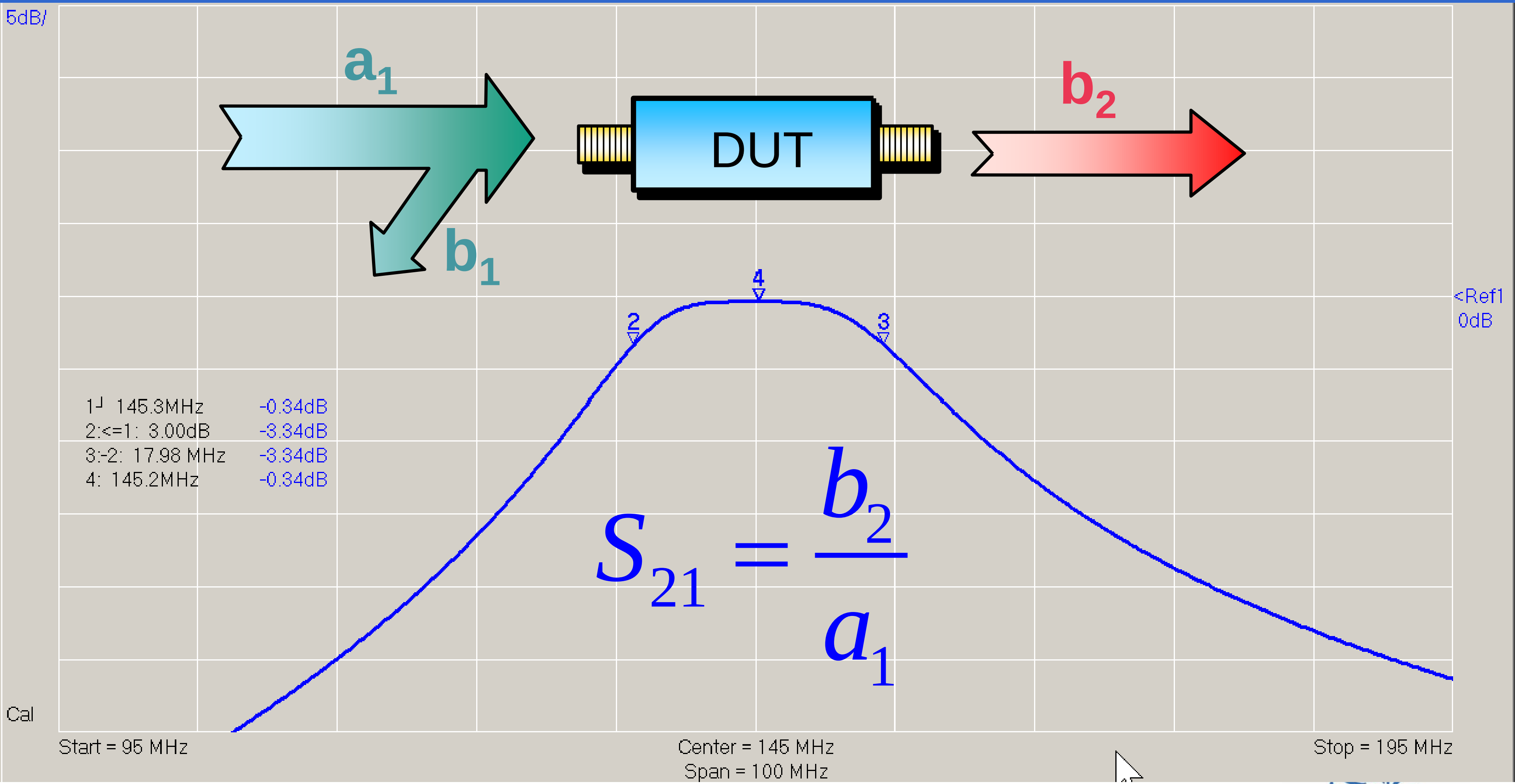


$$S_{11} = \frac{b_1}{a_1}$$

$$VSWR = \frac{1+|S_{11}|}{1-|S_{11}|}$$

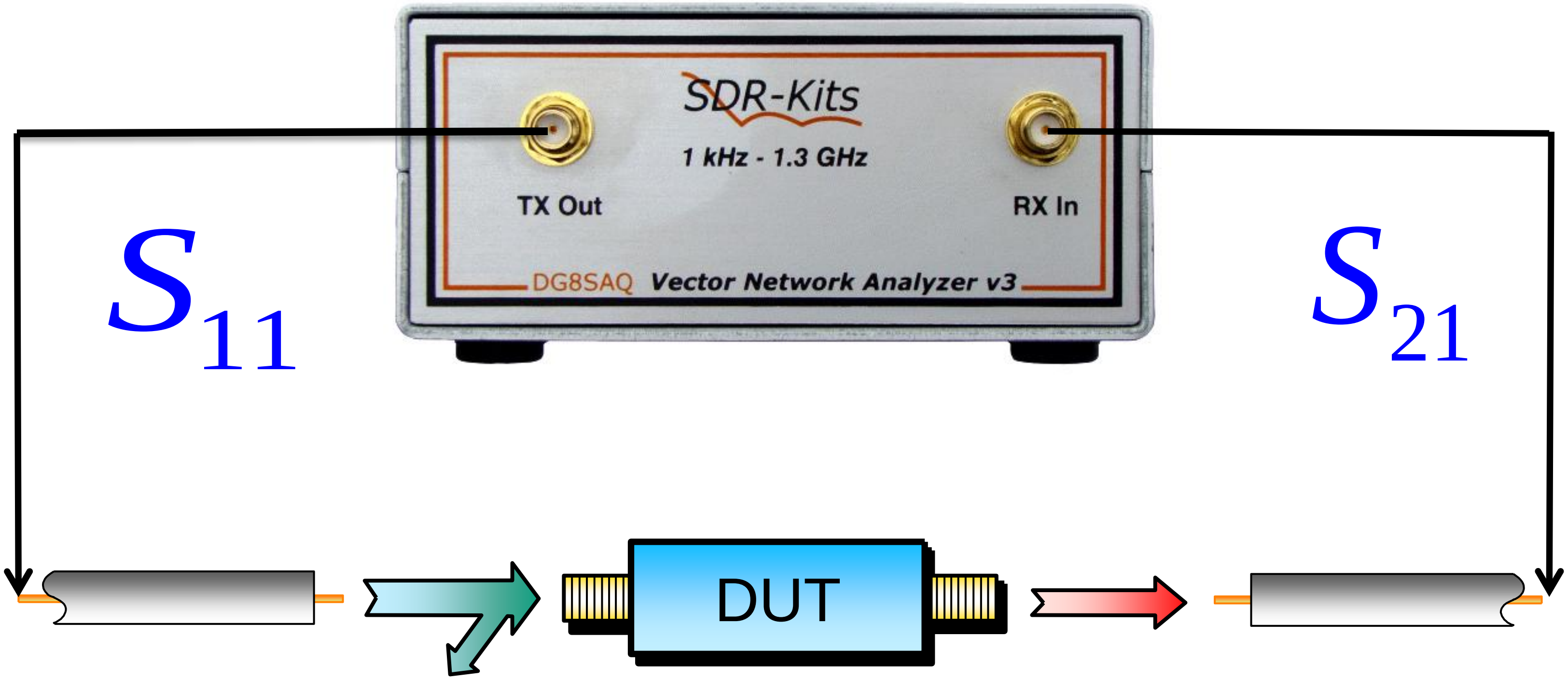
S-Parameter S_{21}

$|S_{21}|$ = Transmission Loss



$$S_{21} = \frac{b_2}{a_1}$$

The VNWA can measure these S-Parameters!



DUT : DEVICE UNDER TEST

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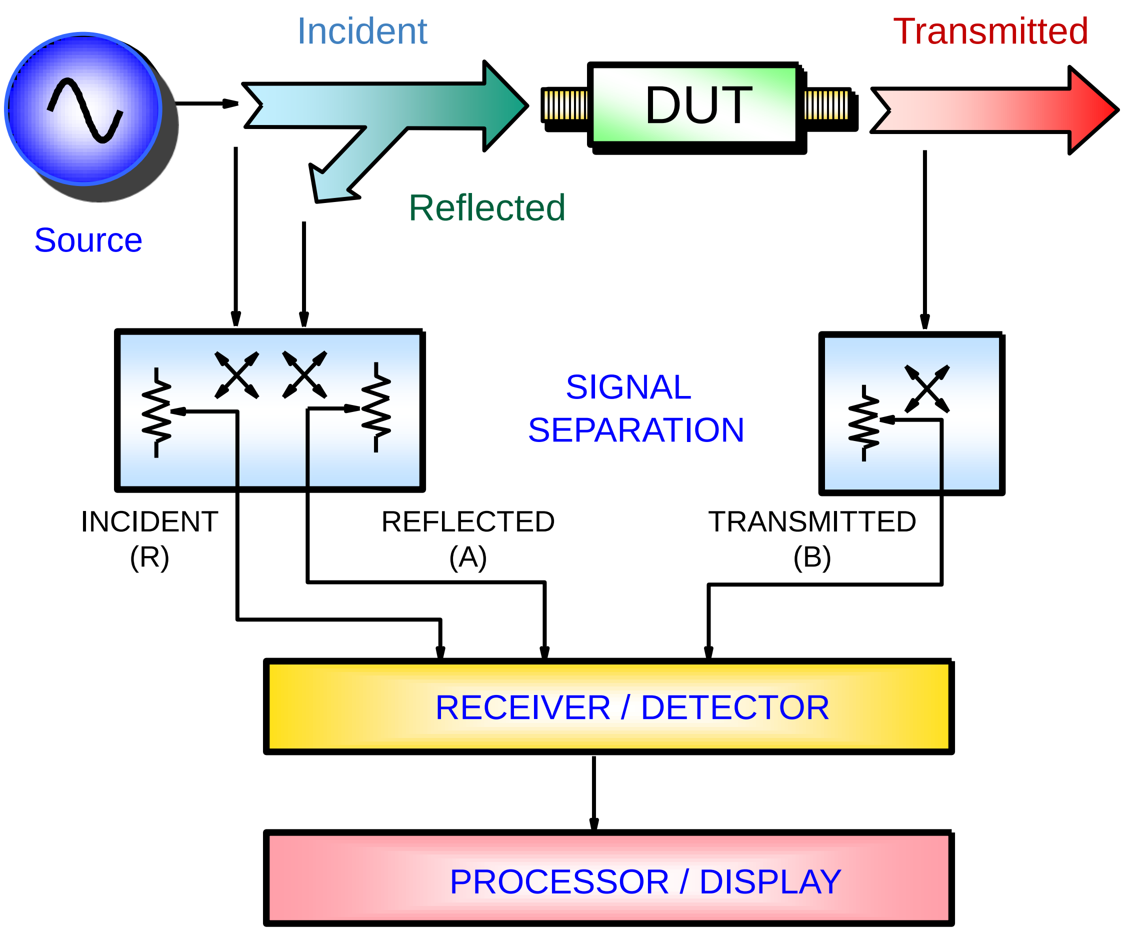
Evolution and Principle of Operation (1)
VNWA Basics



- Tunable
  Signal Source
- 3 Coherent
  Receivers
- Device Control
- Data Processing
  and Graphics

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Evolution and Principle of Operation (2) Functional Diagram

Direct Digital Synthesizer (DDS)

- Tuneable Signal Source

3 Gilbert-Cell Mixers + DDS
+ PC Sound Card (IF)

- 3 Coherent Receivers

- Device Control
- Dataprocessing and Graphics

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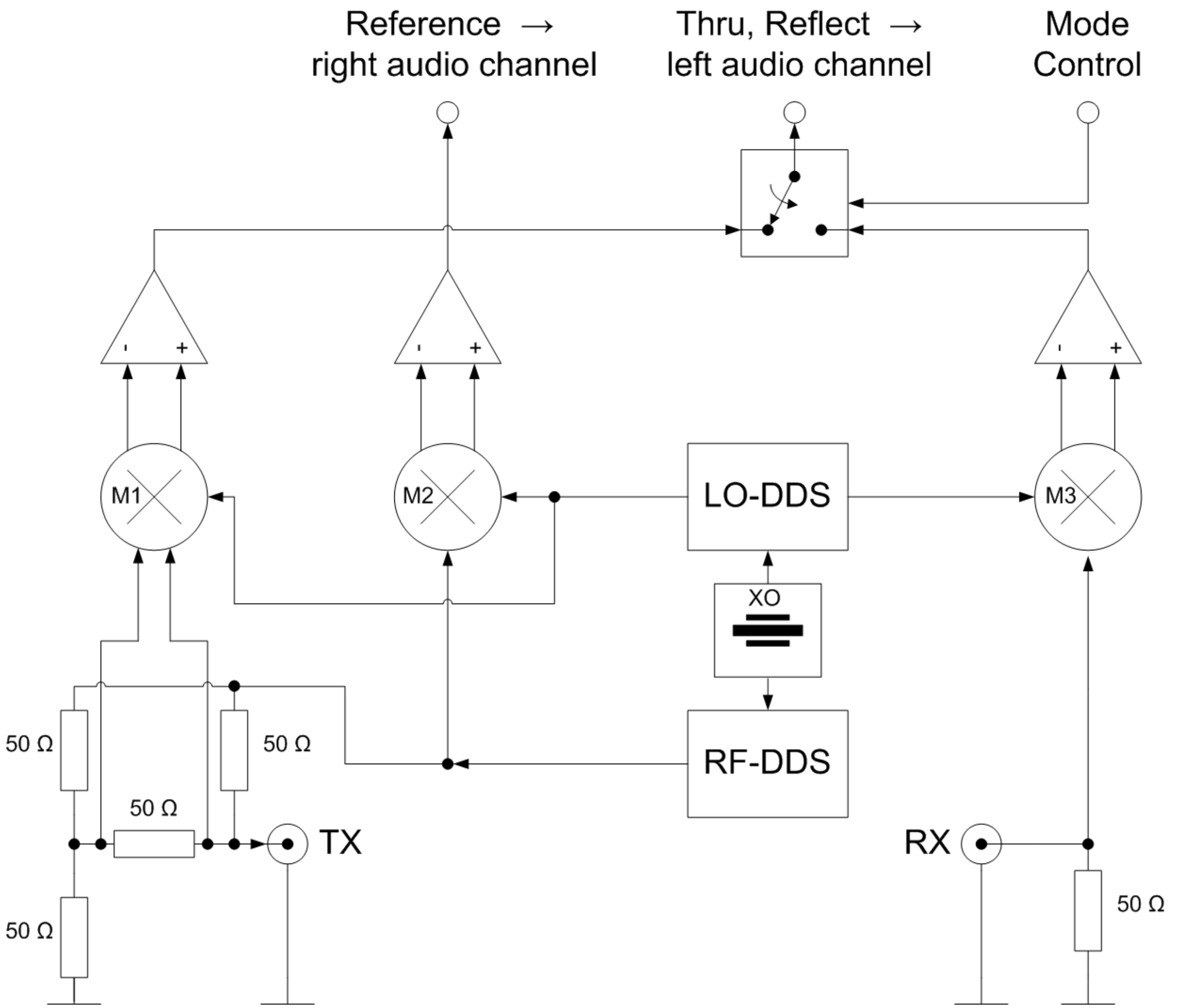
Evolution and Principle of Operation (3)
Functional Block Diagram



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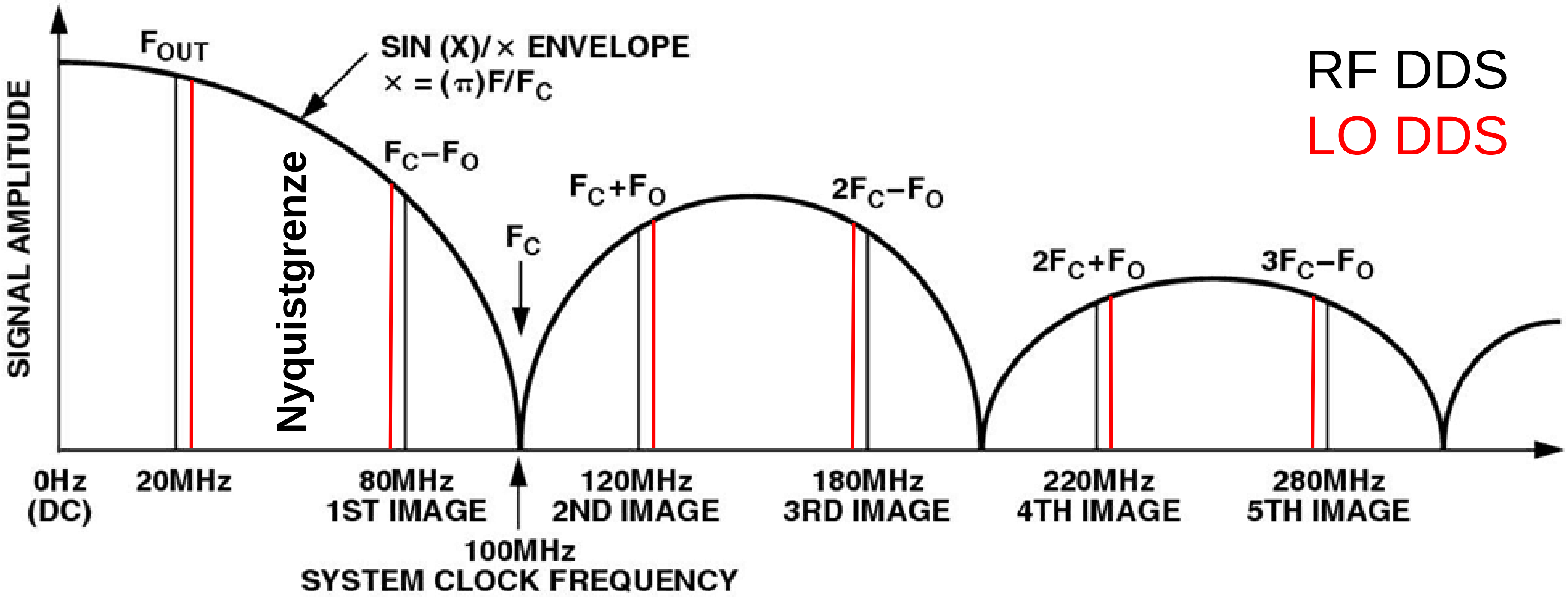
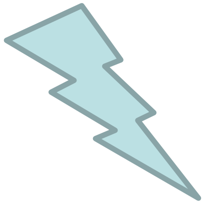
Evolution and Principle of Operation (4)
Problem: DDS Alias Frequencies





All Alias-Frequencies mix down
to the same Intermediate Frequency
→ either use Low Pass filter, or…

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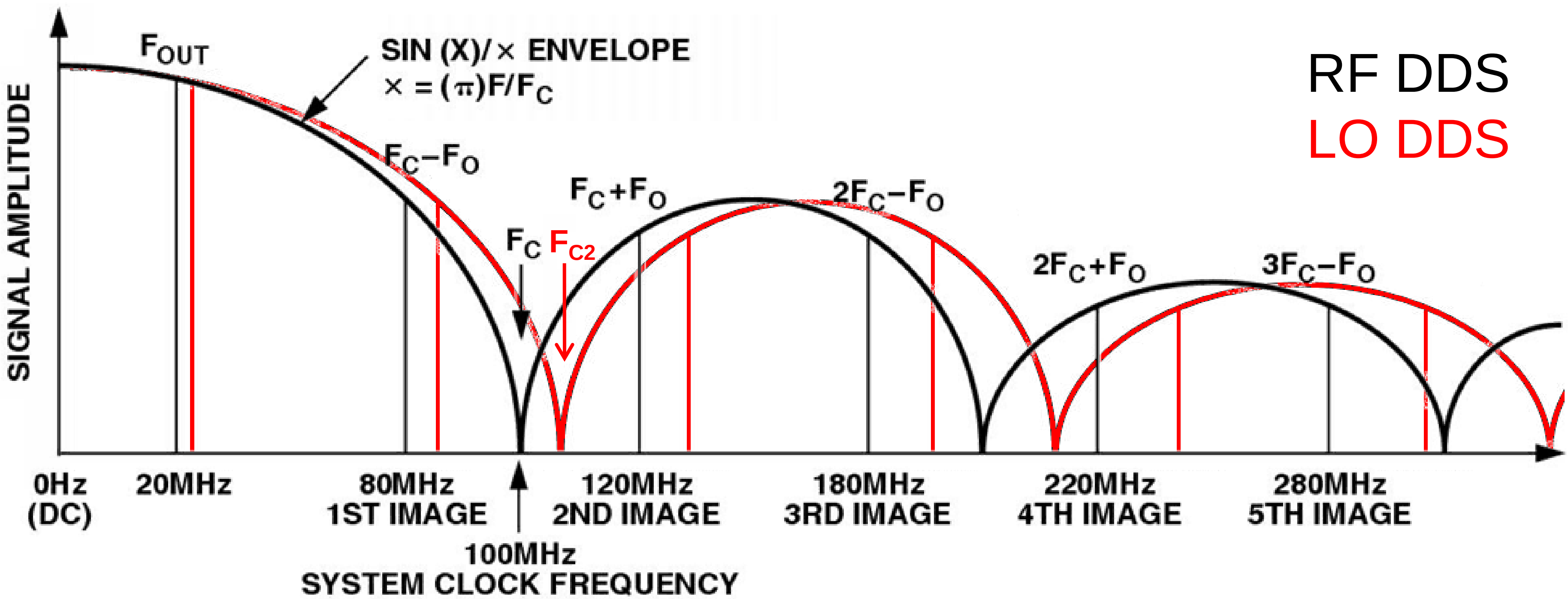
Evolution and Principle of Operation (5)
… use LO DDS with Clock Frequency Offset



all Alias-Frequencies can now be used to extend the VNWA Frequency Range

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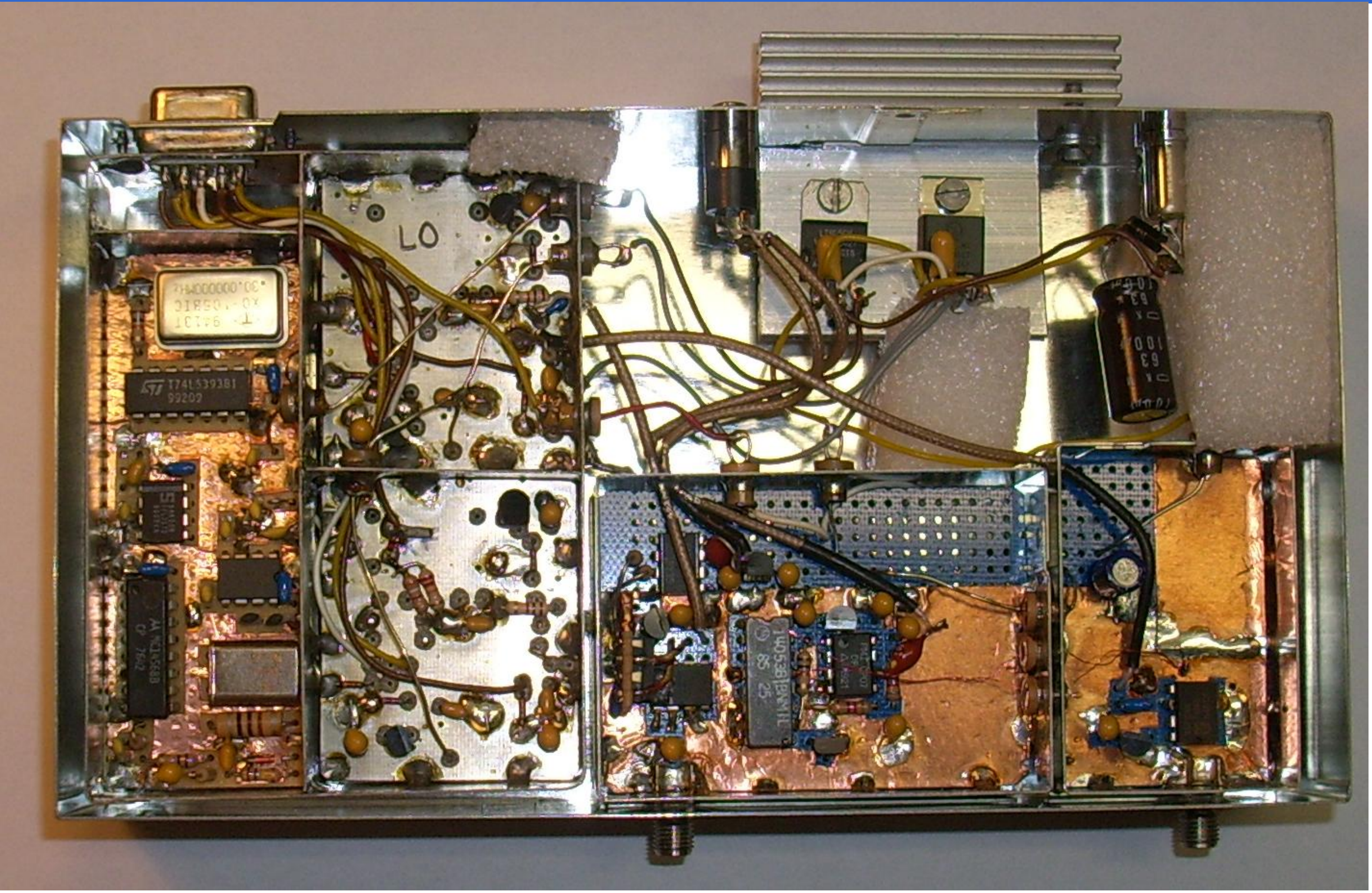
Evolution and Principle of Operation (6)
Result: VNWA1



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Evolution and Principle of Operation (7)
VNWA1 First Practical Use

Evolution and Principle of Operation (8)
Updated Development Targets

Main Target: A Tool for Education

- **Frequency Range > 500 MHz**
- **Continous Frequency Range – no Gaps**
- **Constructed on PCB / reproducible Design**
- **Lowest possible Cost**

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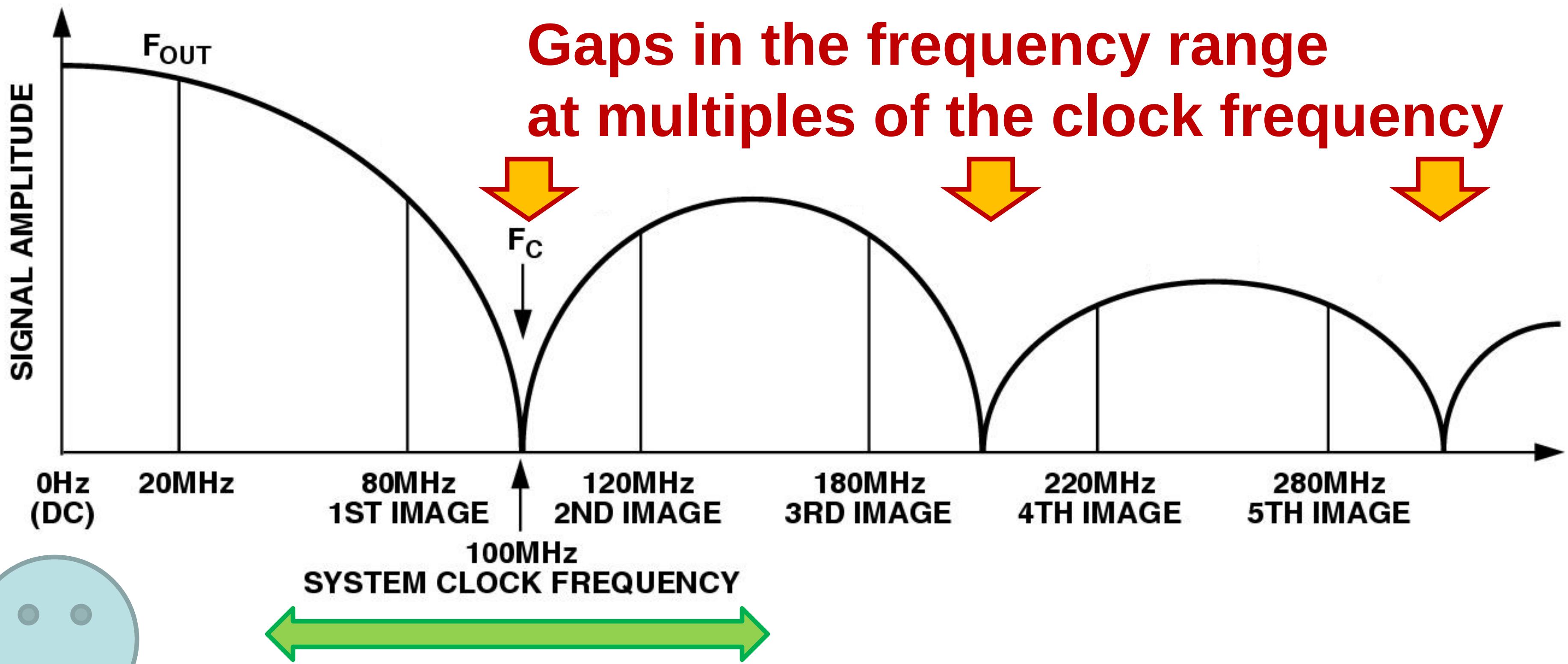
Evolution and Principle of Operation (9) Continous Frequency Range

Gaps in the frequency range at multiples of the clock frequency



Solution: variable clock frequencies by changing PLL-clock multipliers (integrated in DDS)

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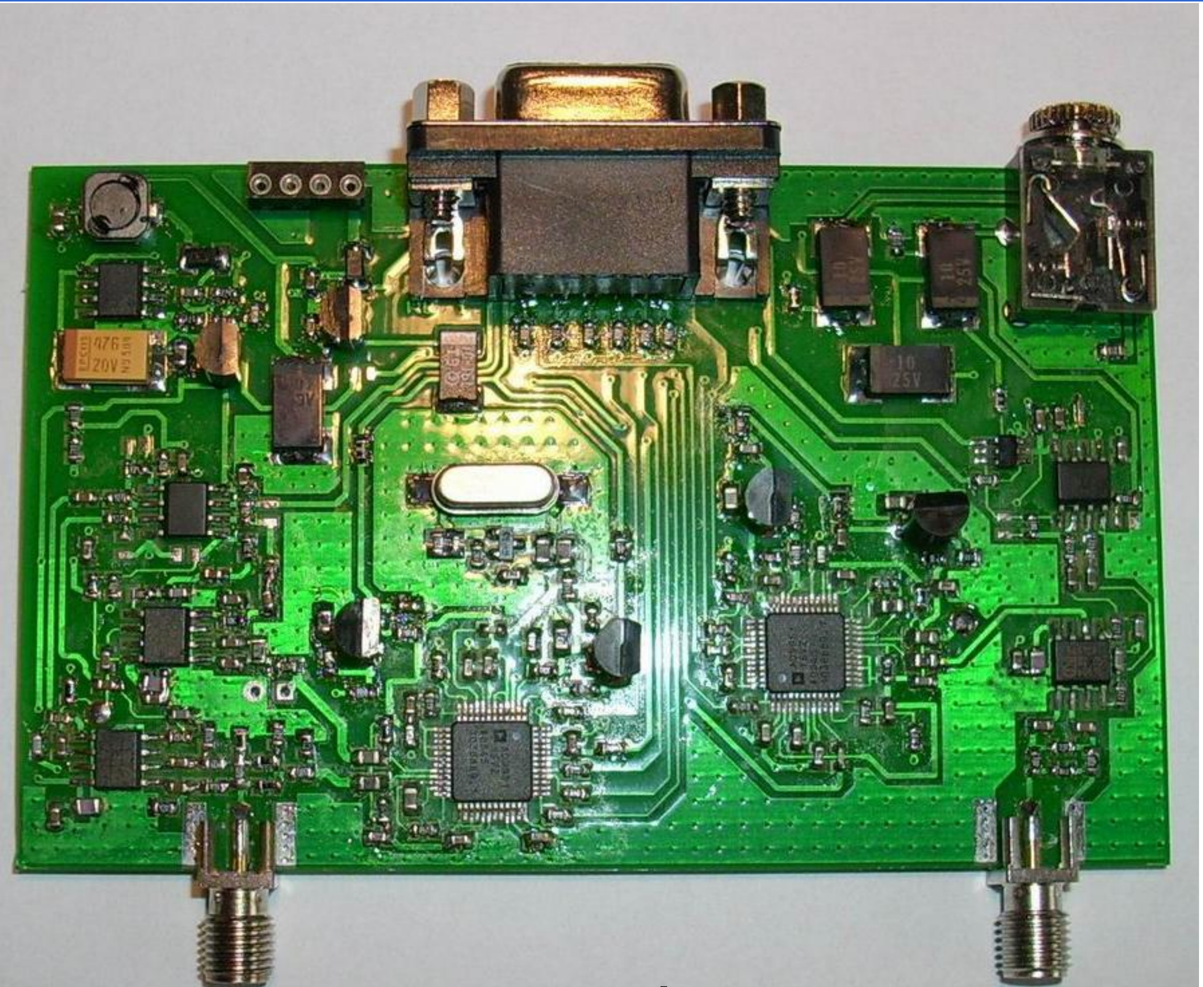
Evolution and Principle of Operation (10)
Result: VNWA2



Layout: Dan Andersson M0DFI

- Frequency Range:
  1 kHz…>1,3 GHz
- Dynamic Range:
  >90 dB (f ≤ 500 MHz)
  >60dB (f > 500 MHz)
  S11, S21 Measurements
- Control via Parallel Port
- Signal processing via external (PC) Sound Card

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Evolution and Principle of Operation (10)
Milestone 2009: VNWA from SDR-Kits

SDRKits

=

Jan Verduyn G0BBL

- **Ex Merchant Navy Radio Officer**
- **Ex Motorola Engineer**
- **Retired and started SDR-Kits**
- **Radio Amateur**

Halle A1 Stand E812

Evolution and Principle of Operation (11)
Market impact on VNWA2 Developements

Fewer Computers with
Parallel Port Interface

Fewer Computers with
Stereo-Line-In

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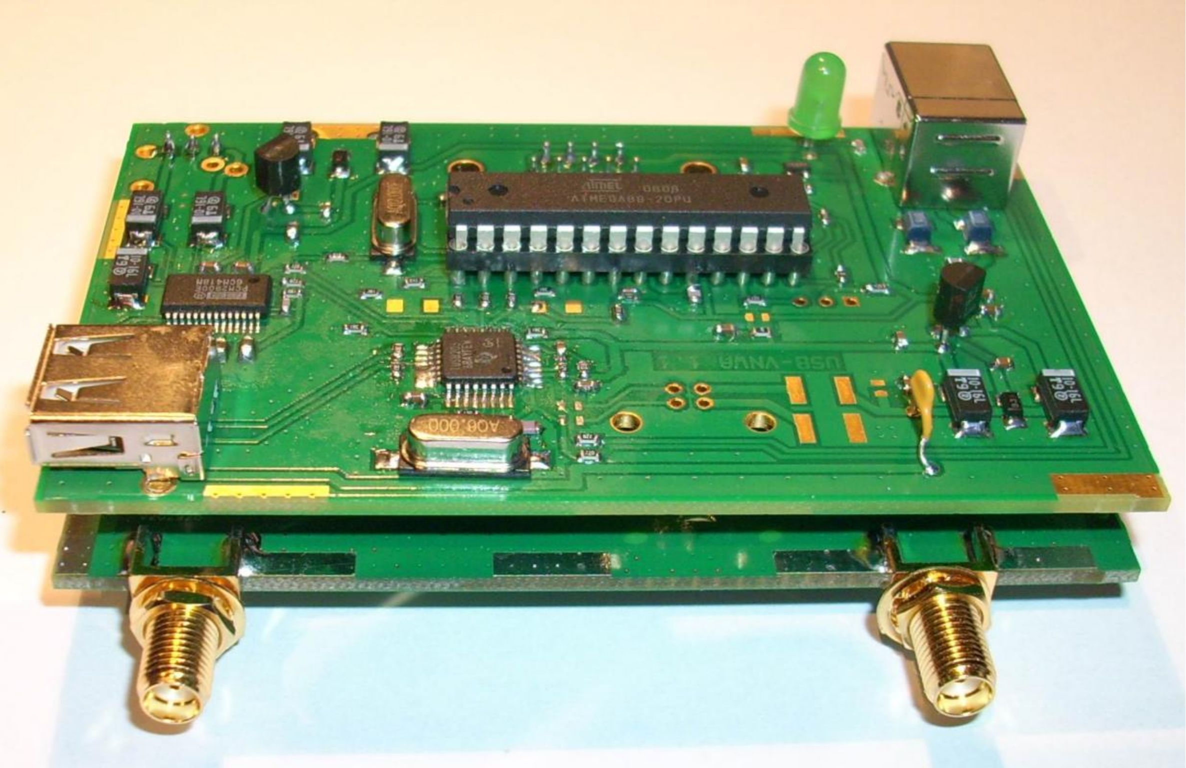
Evolution and Principle of Operation (12) VNWA2-USB



- USB Interface
- Controller
- USB Audio Codec
- Powered from USB

Only a USB cable connection to the PC

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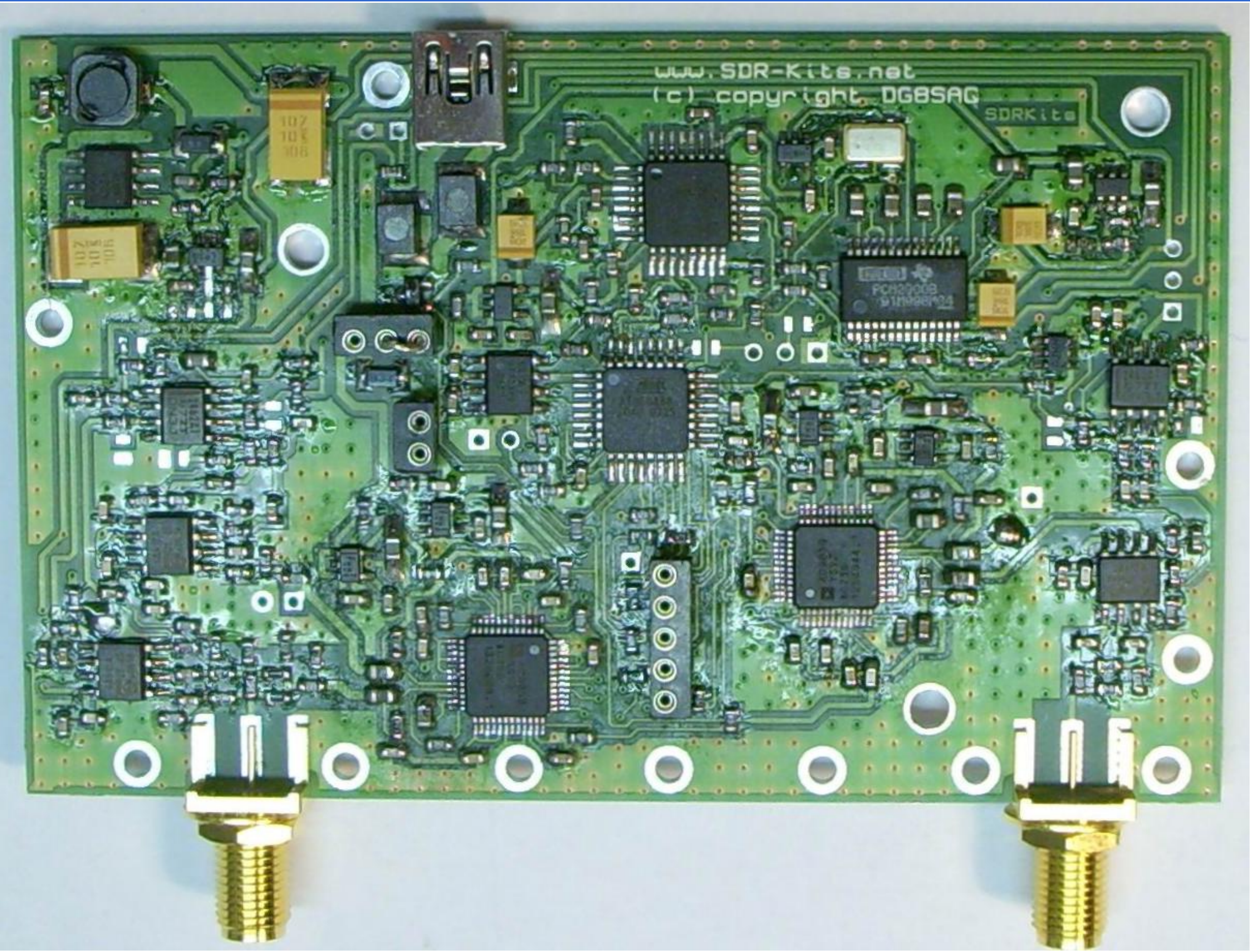
Evolution and Principle of Operation (13)
VNWA3: Ready Assembled in Factory



- TCXO
- Additional Clock-PLL!!

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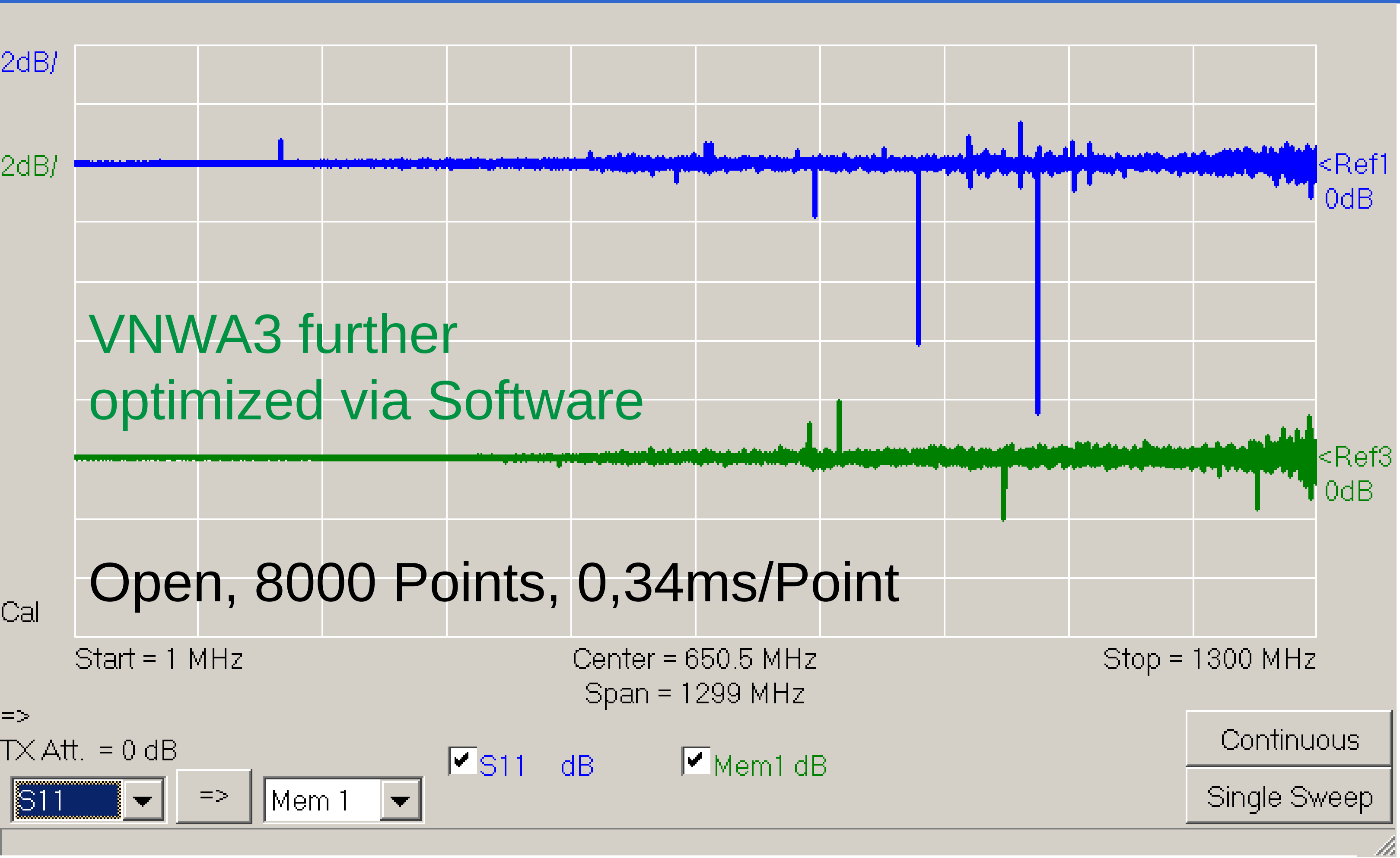
Evolution and Principle of Operation (14)
Less Interference with flexible Clock-PLL



VNWA2

VNWA3

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Evolution and Principle of Operation (15)
VNWA3 Options

- New expansion PCB with 2nd Audio-Codec to measure S_{11} and S_{21} simultaneously
- External Clock Input
- Possible to extend VNWA3 to a fully automatic 2 port Analyzer with an external Transfer Relay

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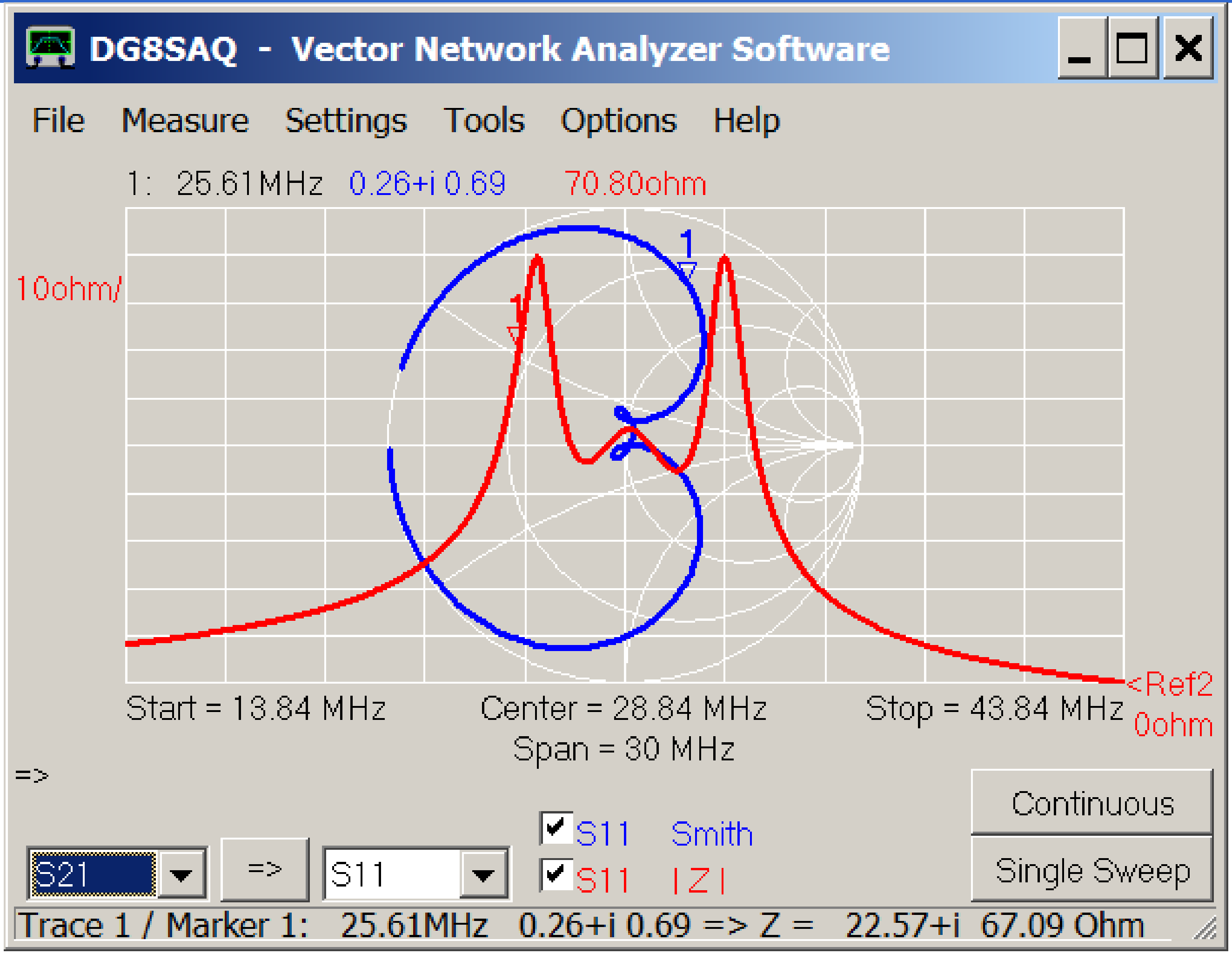
Applications:
Impedance Measurements (1)



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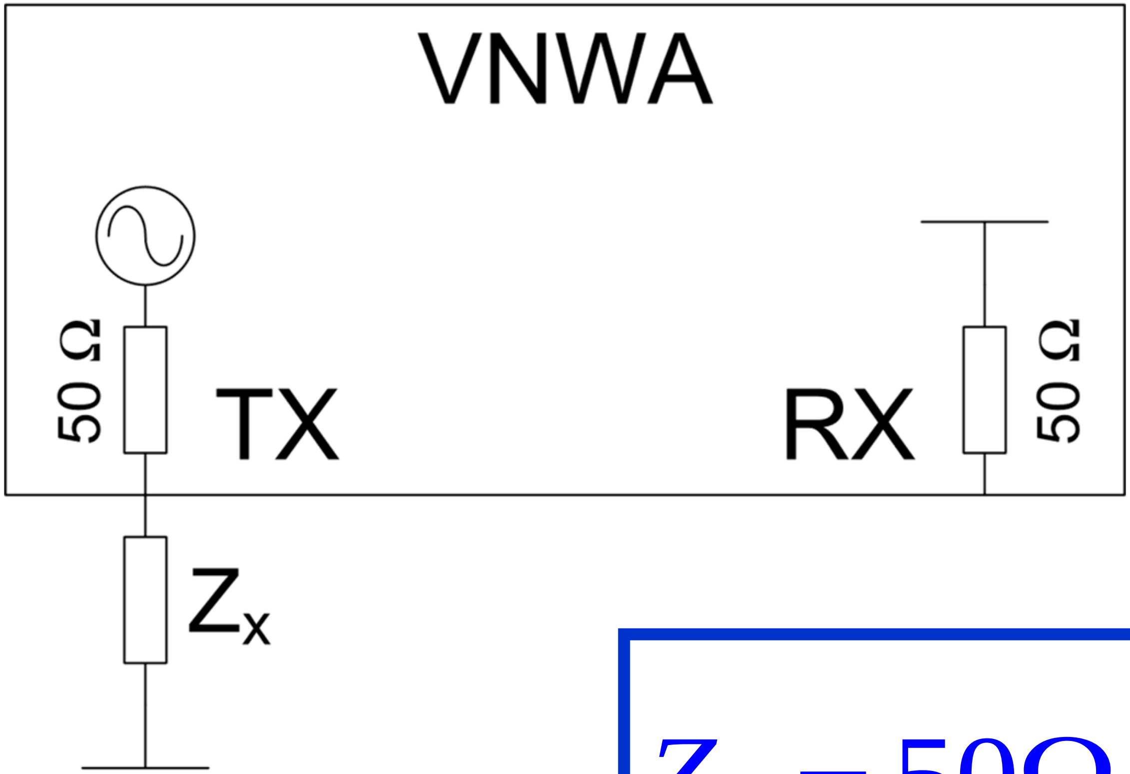
Impedance Measurements (2)
Variant 1: Return Loss Measurement



Highest accuracy for Z_x close to 50 Ω

Cal: SOL

$$Z_x = 50\Omega \cdot \frac{1+S_{11}}{1-S_{11}}$$

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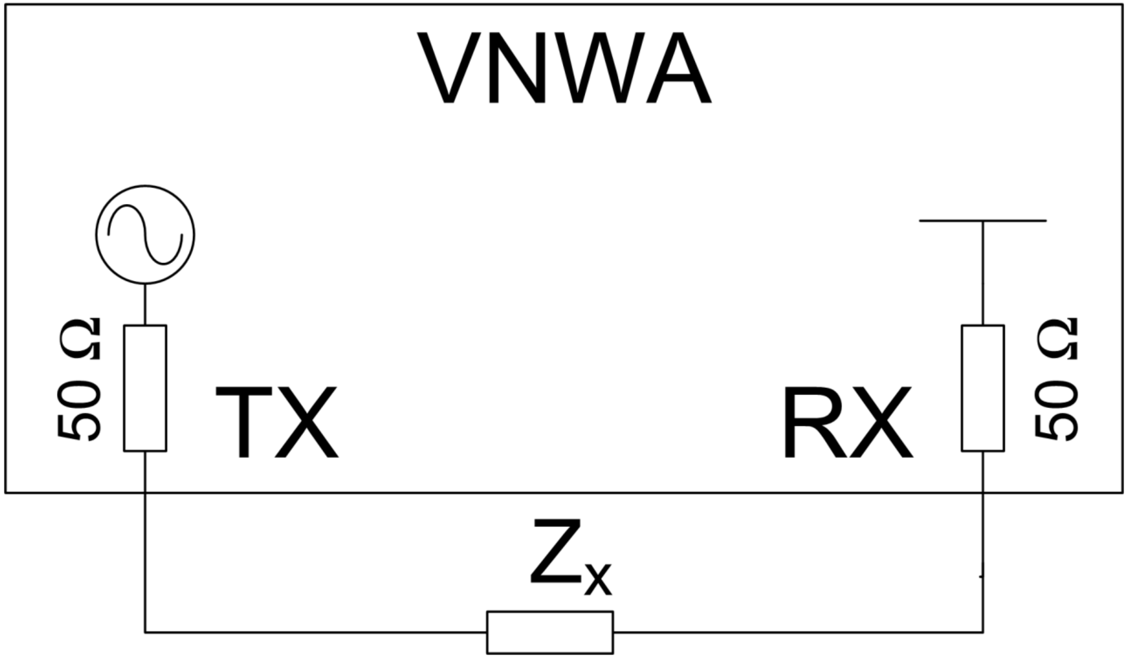
Impedance Measurements (3)
Variant 2: *I*-Messung



Highest for
large values of Z_x

Cal: Thru

RX measures current through Z_x

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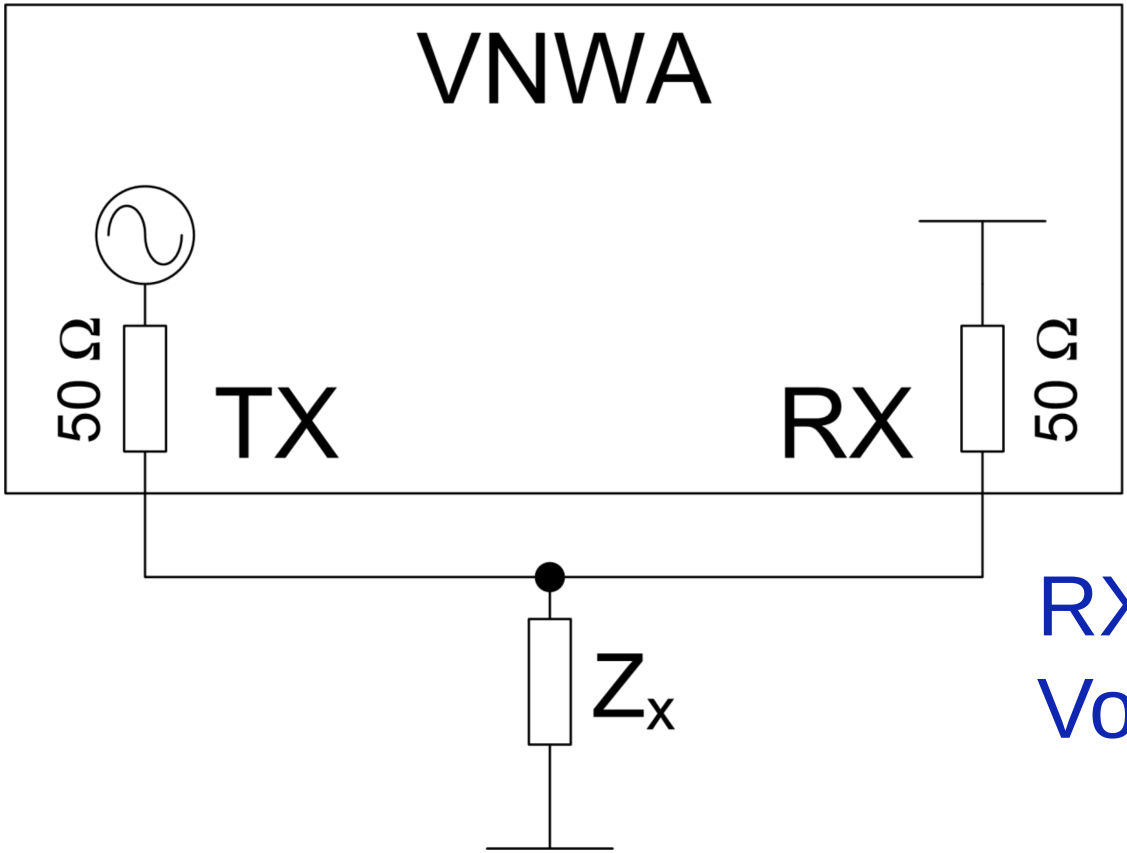
Impedance Measurements (4)
Variant 3: *V*-Measurement



Highest for
low values of $\boldsymbol{Z_x}$

RX measures
Voltage across Z_x

Cal: SOL

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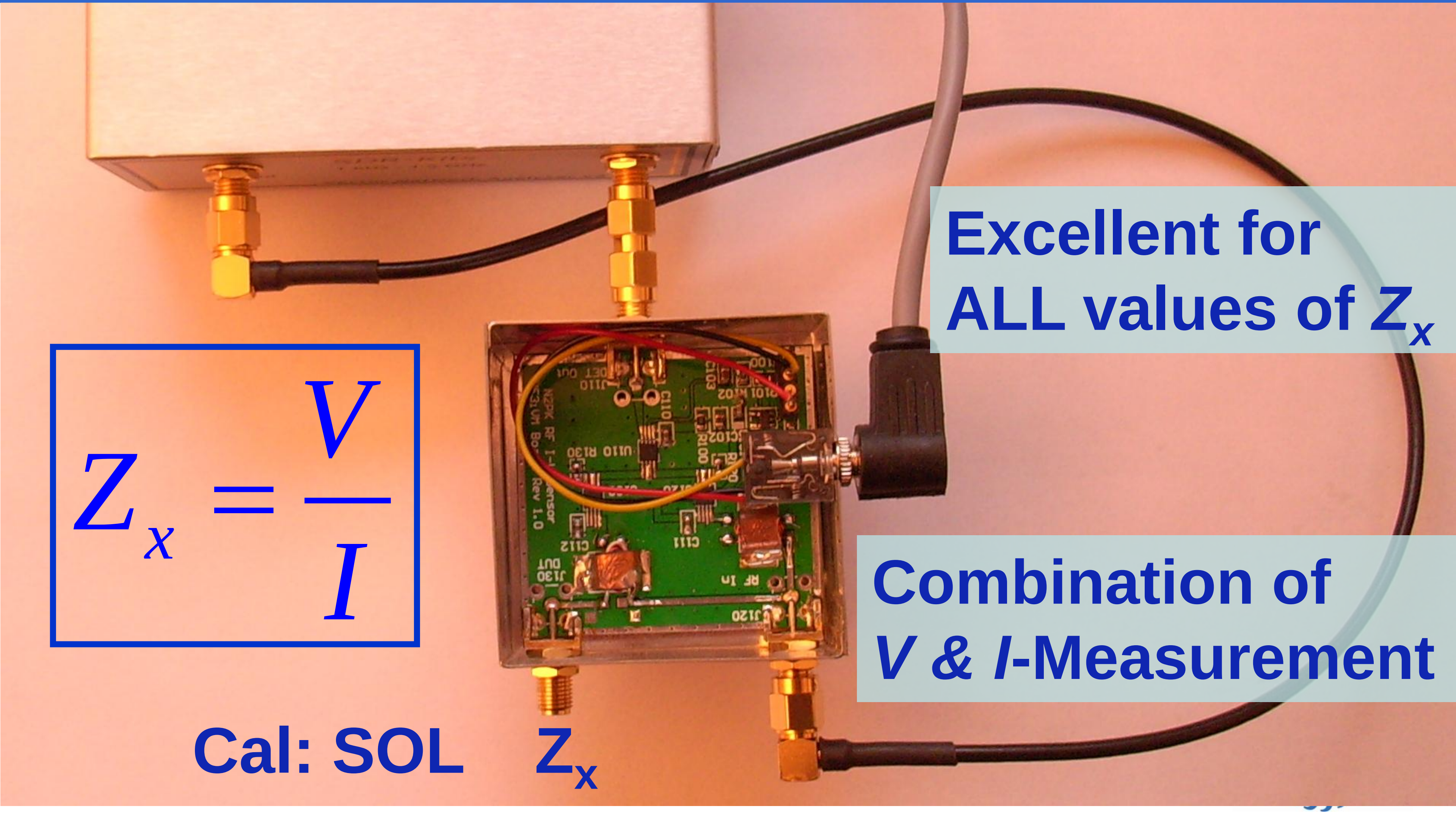
Impedance Measurements (5)
Variante 4: RF-IV Measurement



$$Z_x = \frac{V}{I}$$

Excellent for ALL values of Z_x

Combination of *V* & *I*-Measurement

Cal: SOL **Z_x**

RF-IV Test Head: http://www.makarov.ca/

Impedance Measurements (6)
Measurement Deviation-Variants 1 - 4

Impact of 10% increase of Z_x value on measurement result:

Z_x	S_{11}	I	V	V / I
0,1 Ω	-0,04%	0,01%	-9,96%	9,97%
51 Ω	480,68%	3,27%	-3,08%	6,56%
100 kΩ	0,01%	9,08%	0,00%	9,99%

⇨ RF-IV shows best overall sensitivity!

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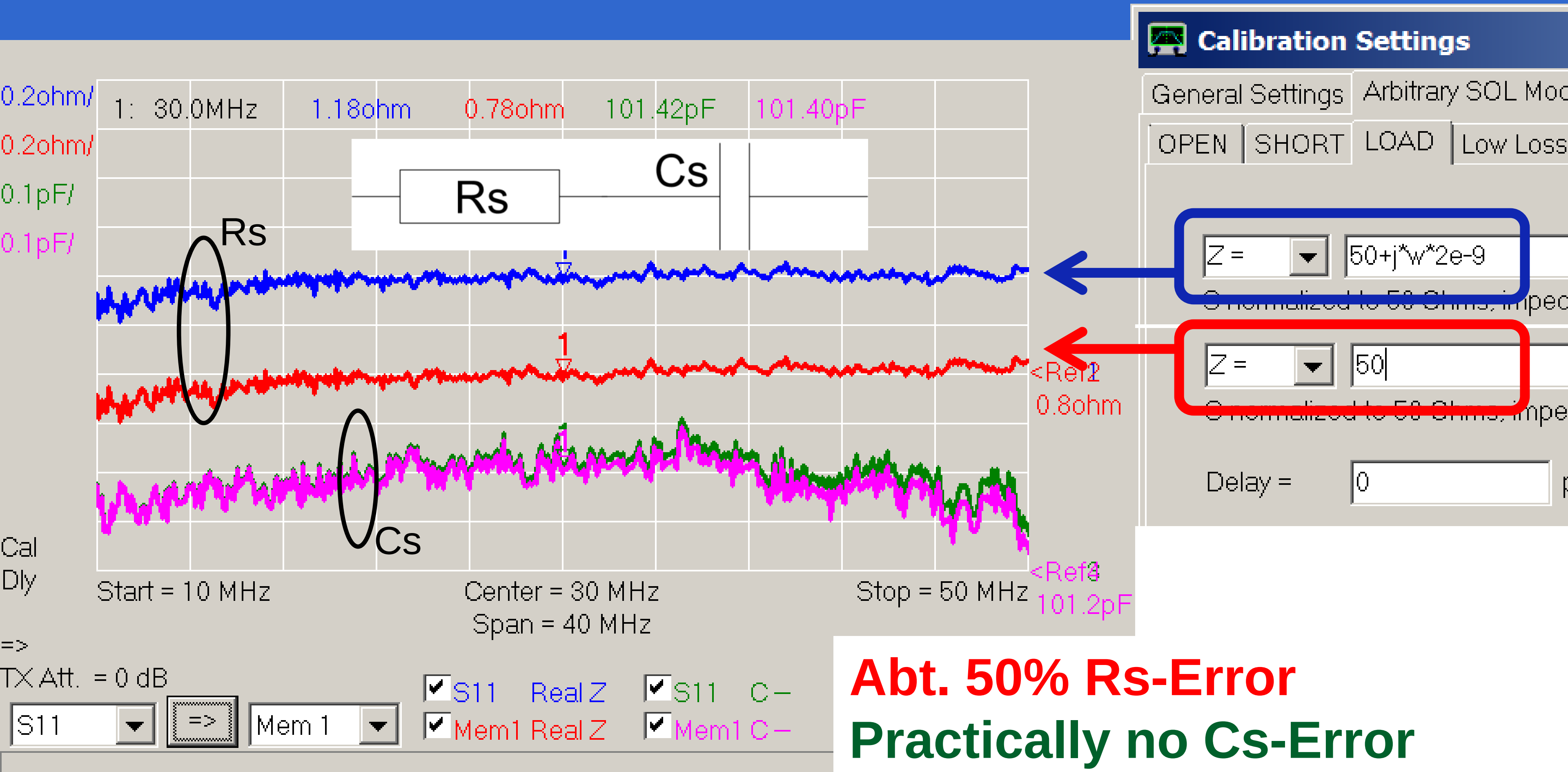
Impedance of a 100 pF SMD Capacitor: Effect of 2 nH in Load Standard



Abt. 50% Rs-Error

Practically no Cs-Error

Load-Model critical for Q measurements!

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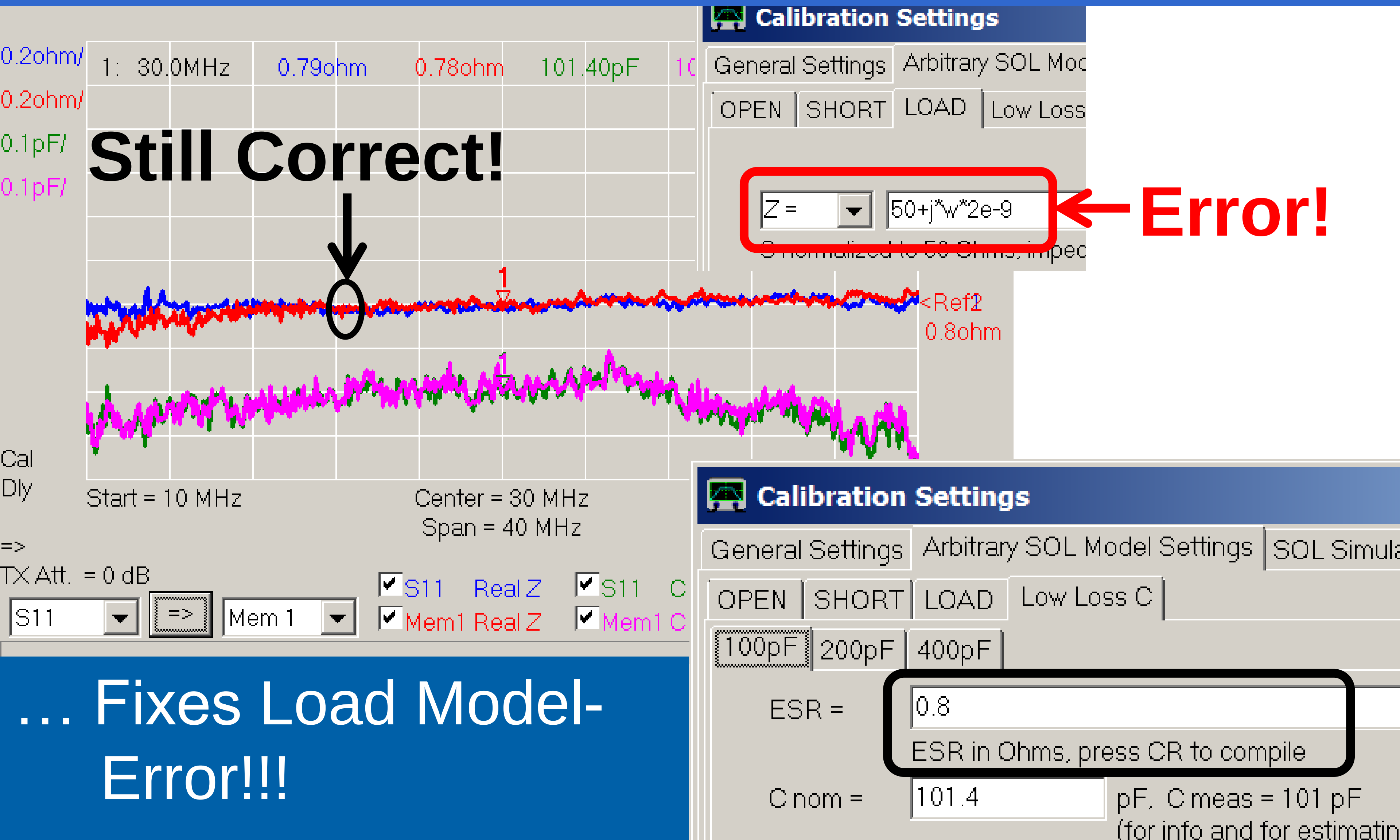
New: Low Loss Capacitor (LLC) as an additional Calibration Standard…



… Fixes Load Model-Error!!!

If you have a clock you always know what time it is …

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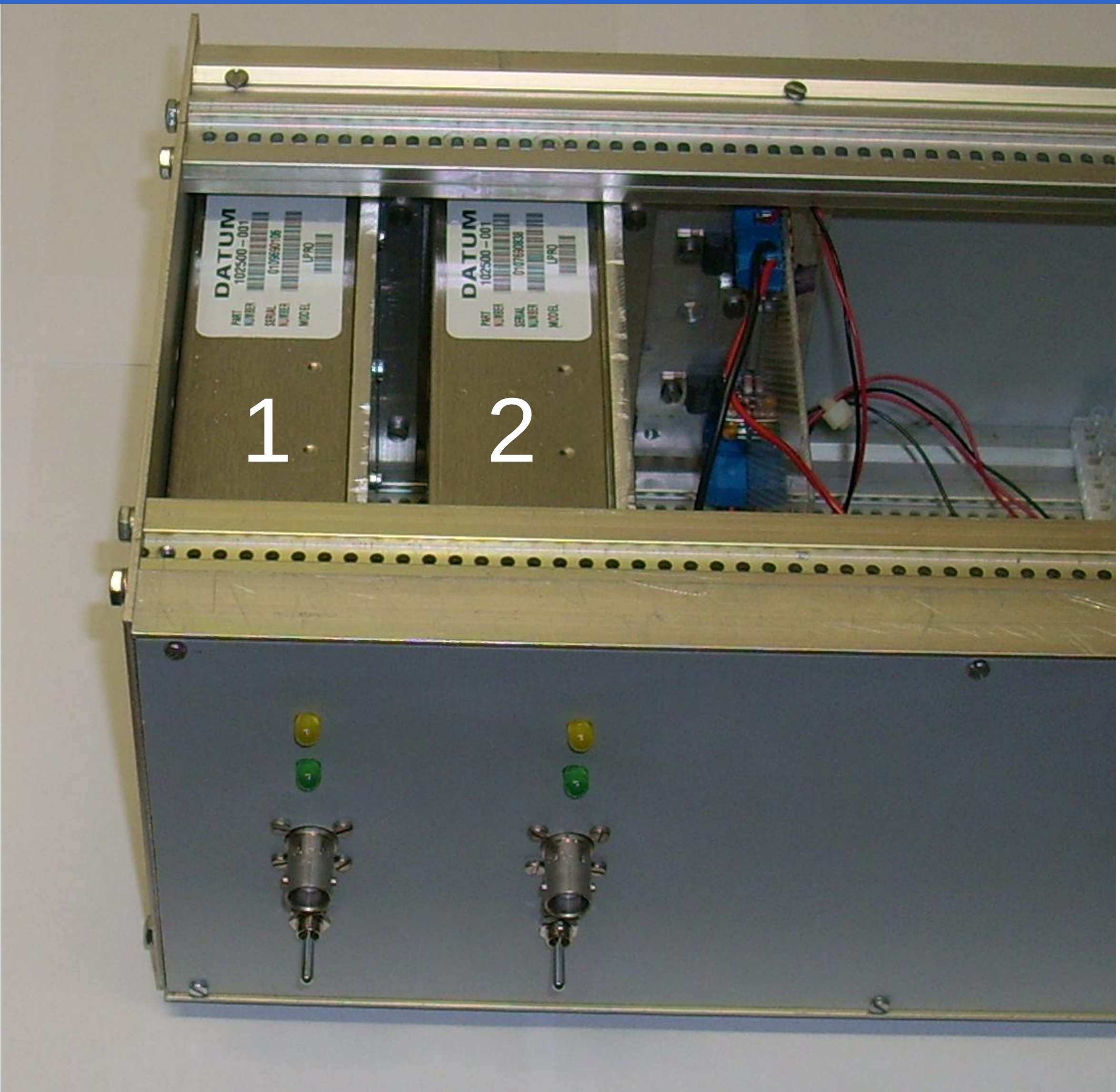
With TWO Clock you are never quite shure which time is right !



- My two Rubidium Frequency standards:
- **How accurately do they run in sync?**

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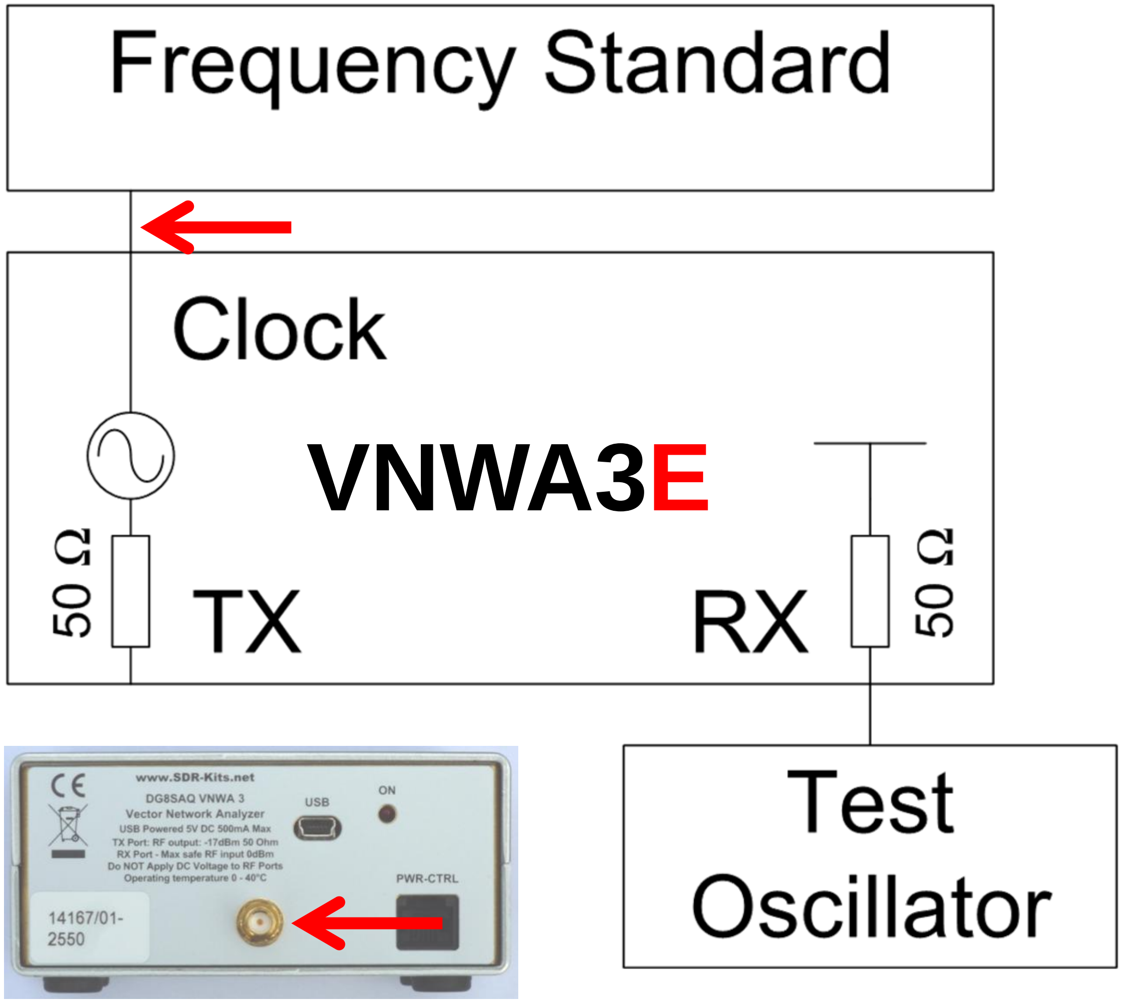
Application: Frequency Comparison (1)
VNWA3 as Phase Comparator



- Precise Phase Measurement with VNWA3
- Frequency deviation calculated from Phase

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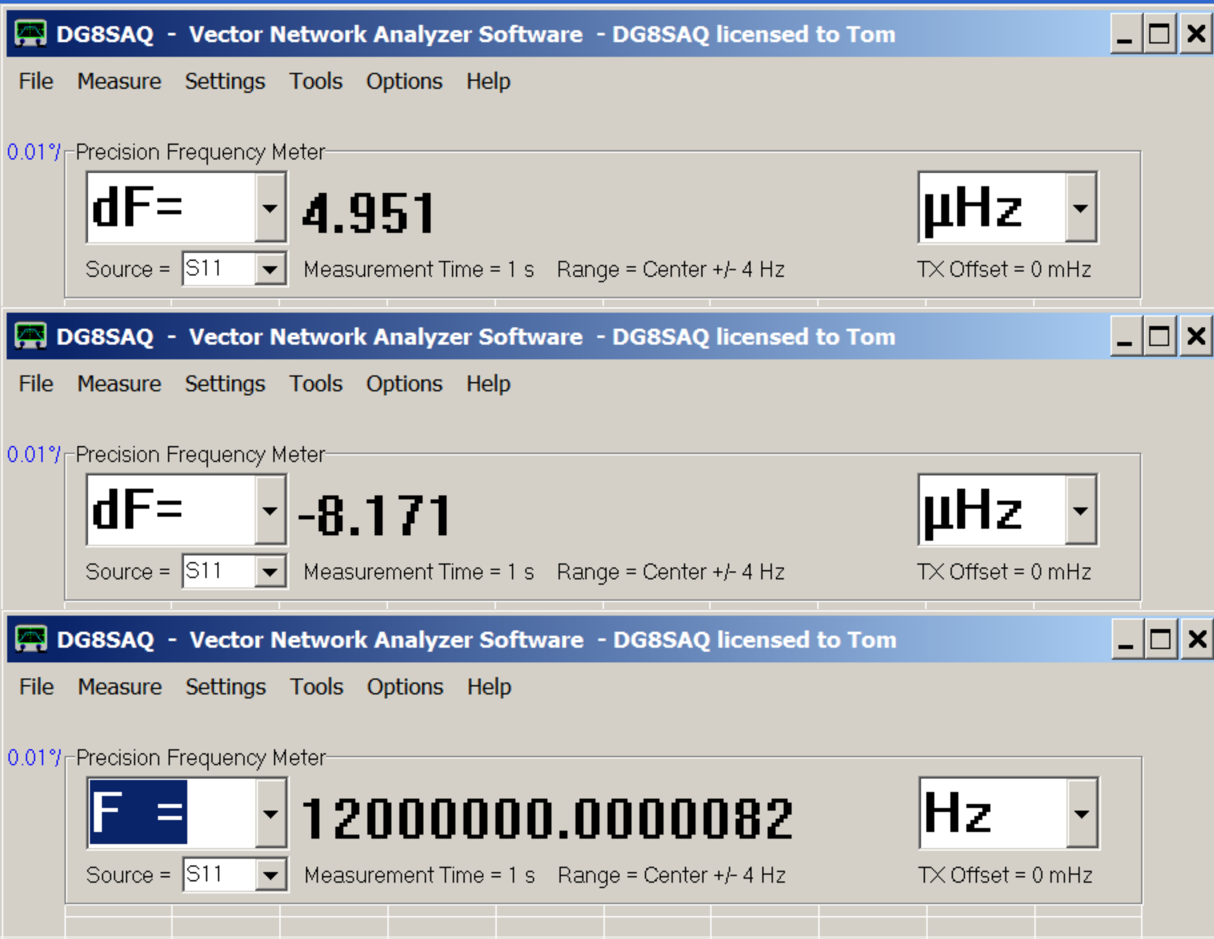
Frequency Comparison (2) Measurement Accuracy



- TCXO compared to itself
- 1s Measurement
- abt ±10 µHz variation!!!

3 Sweeps with 10 Points and 0,1s / Point

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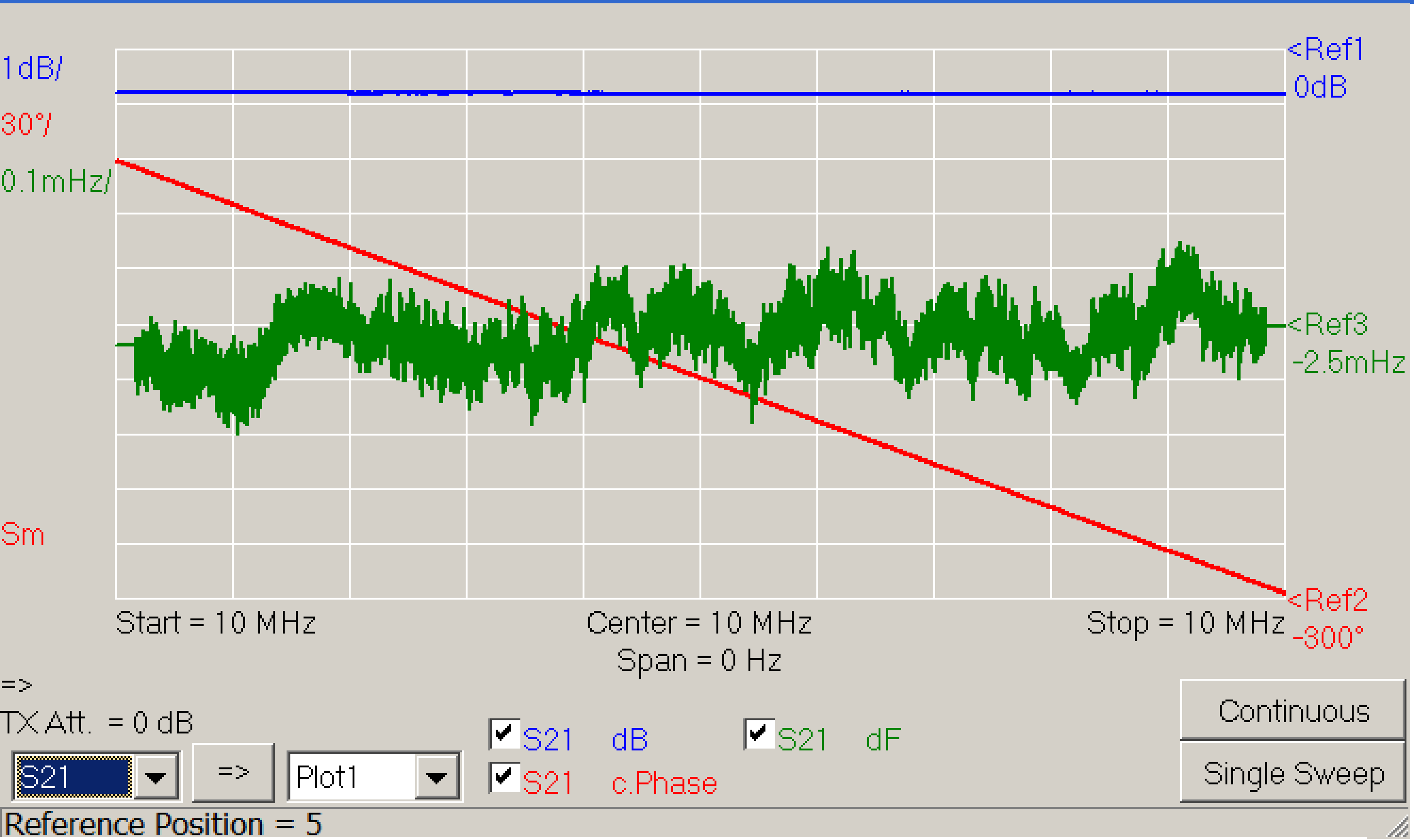
Frequency Comparison (3)
Rubidium 1 vs. Rubidium 2 over 260s



Deviation = -0,0025 Hz ± 0,0003 Hz at 10 MHz

$\equiv 2{,}5 \cdot 10^{-10}$

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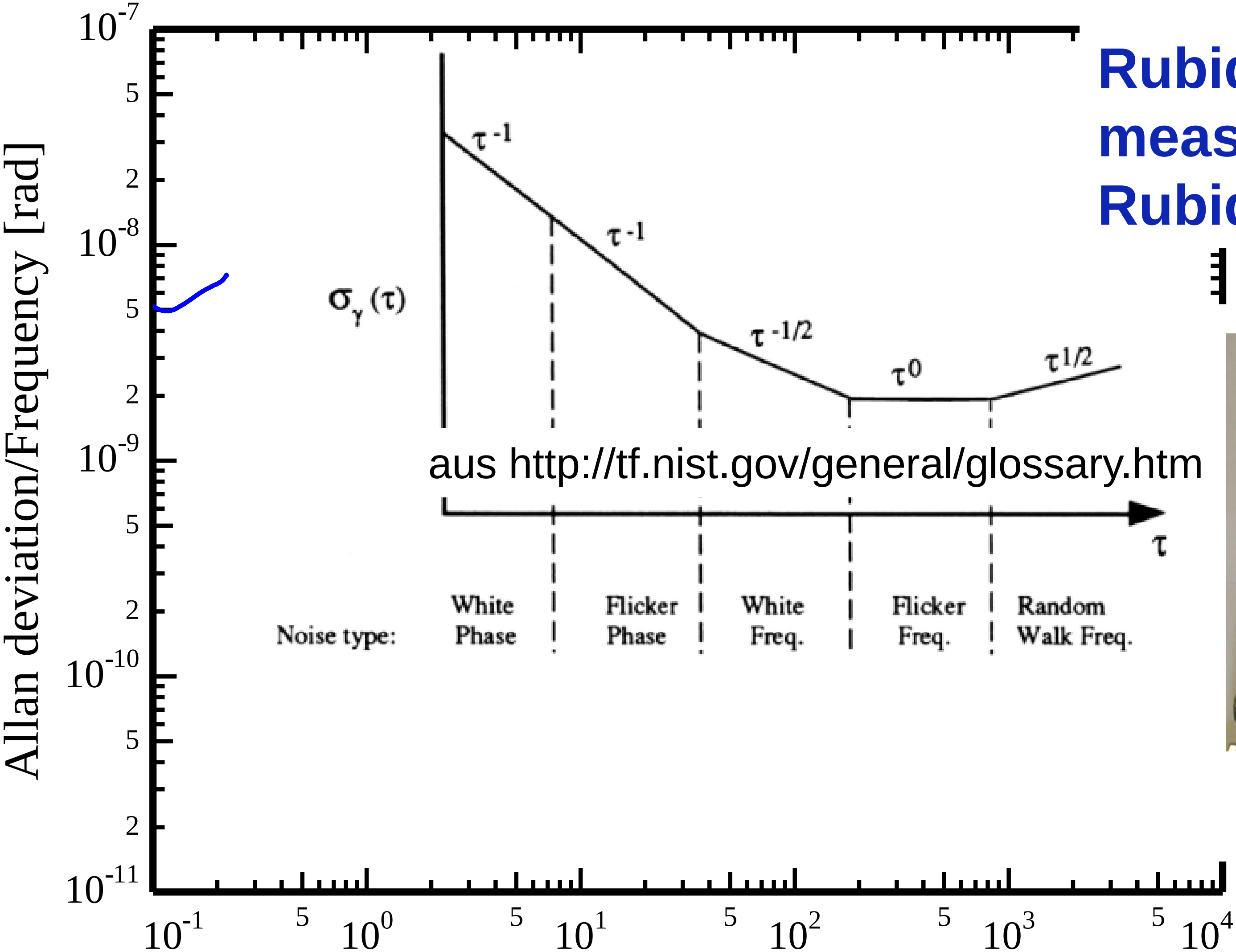
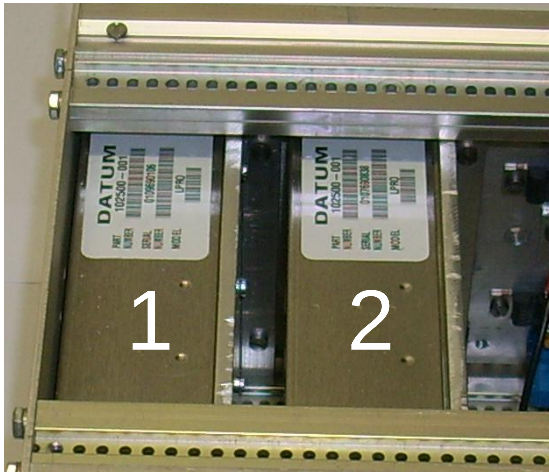
Frequency Comparison (4)
Allan Deviation from VNWA-Measurement



Rubidium Standard 1 measured against Rubidium Standard 2



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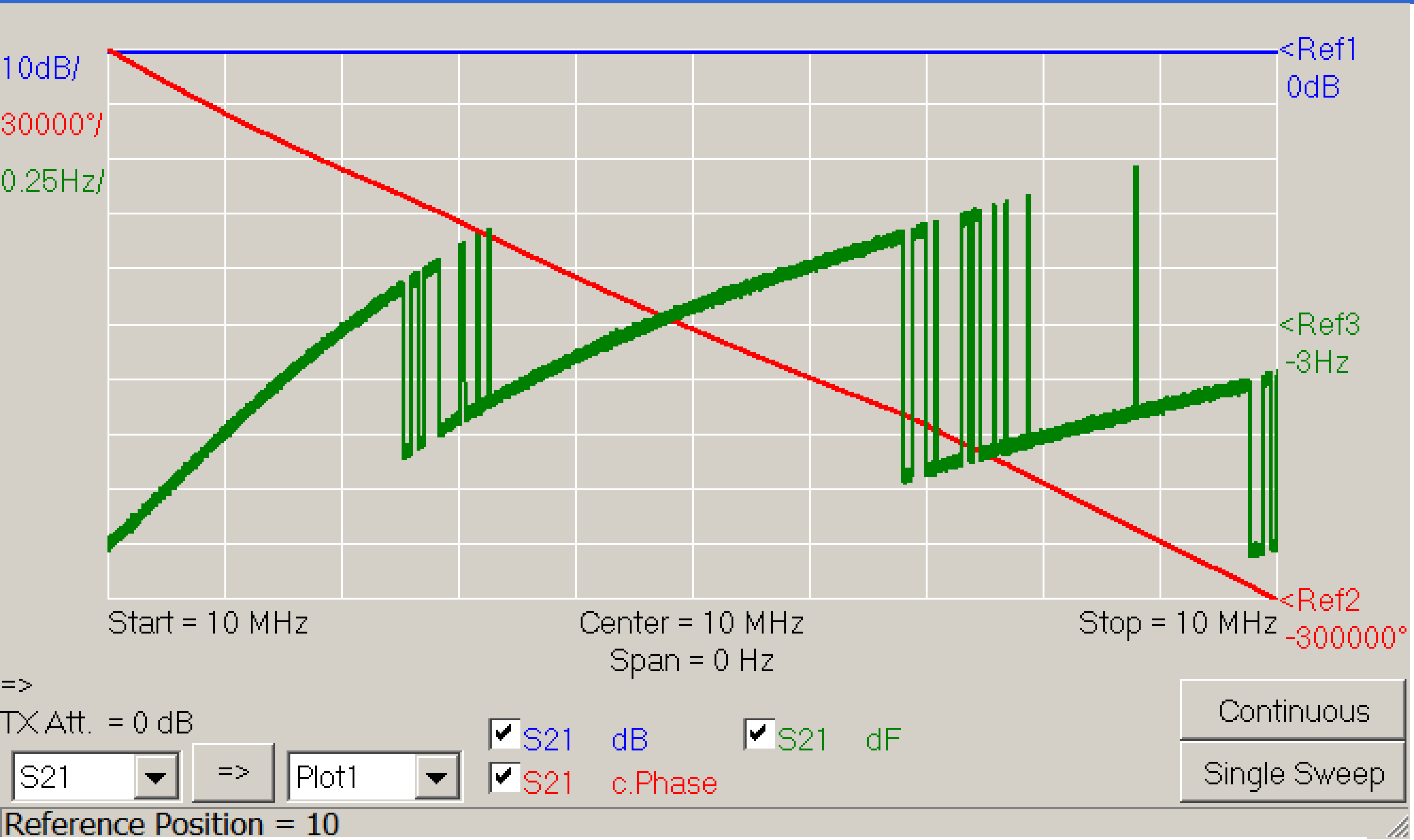
Frequency Comparison (5)
Rubidium Standard vs. VNWA3 TCXO



Deviation = -3 Hz ± 1 Hz at 10 MHz ≡ -0,3 ppm

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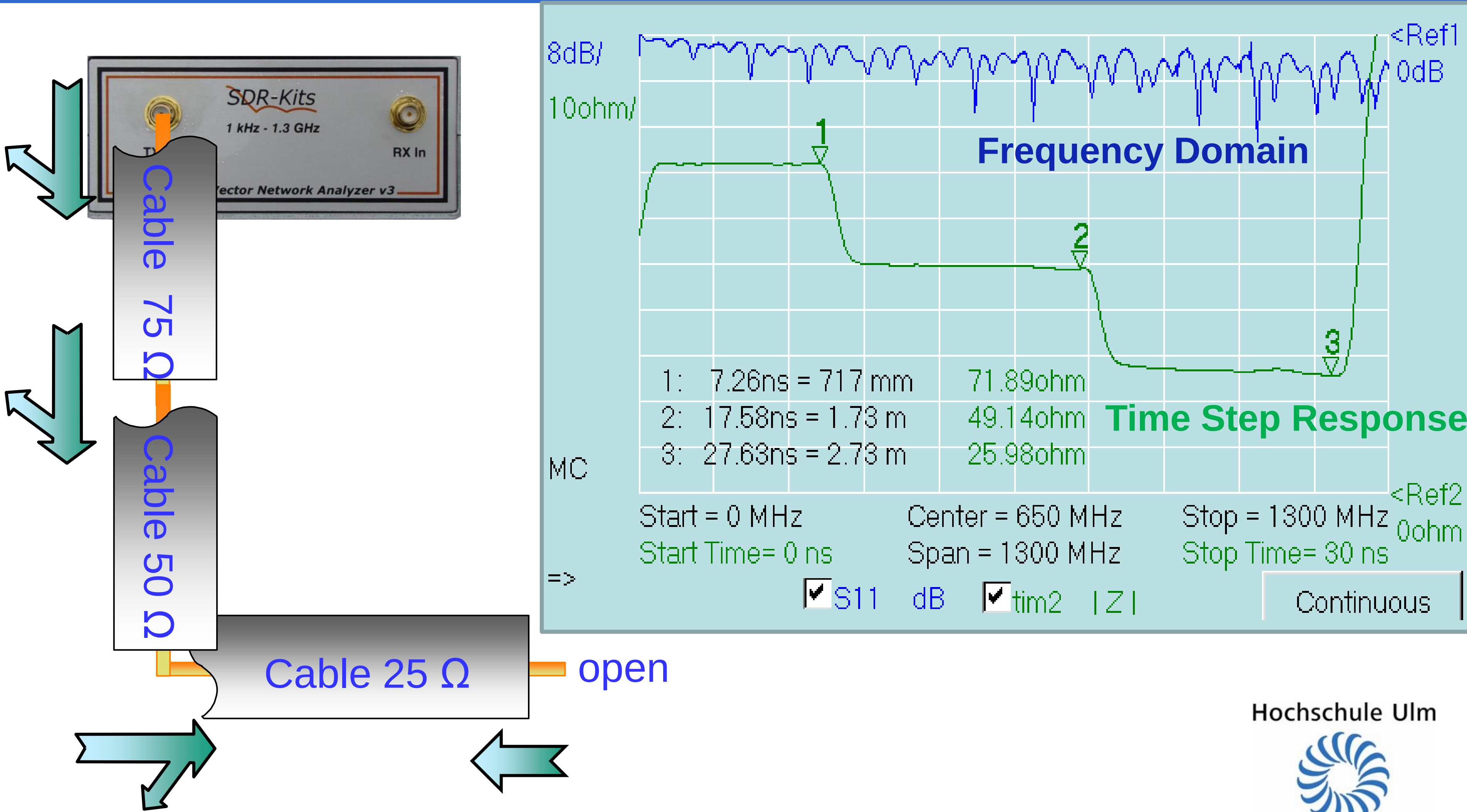
Application:
Time Domain Analysis (1)



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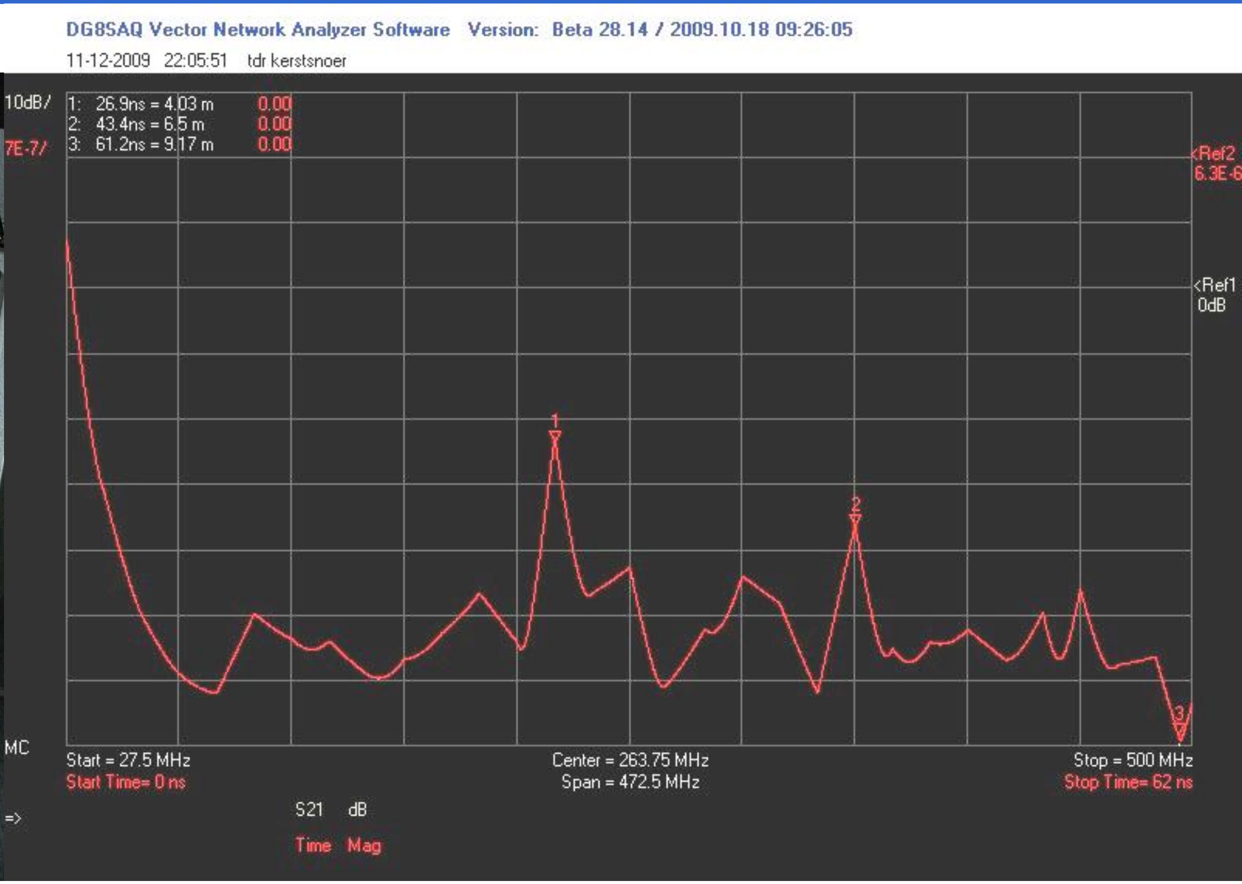
Time Domain Analysis (2)
Locate the faulty Christmas Tree Light Bulb !!



http://www.pa4tim.nl/?p=345

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Application Example: Cavity Resonance (1)

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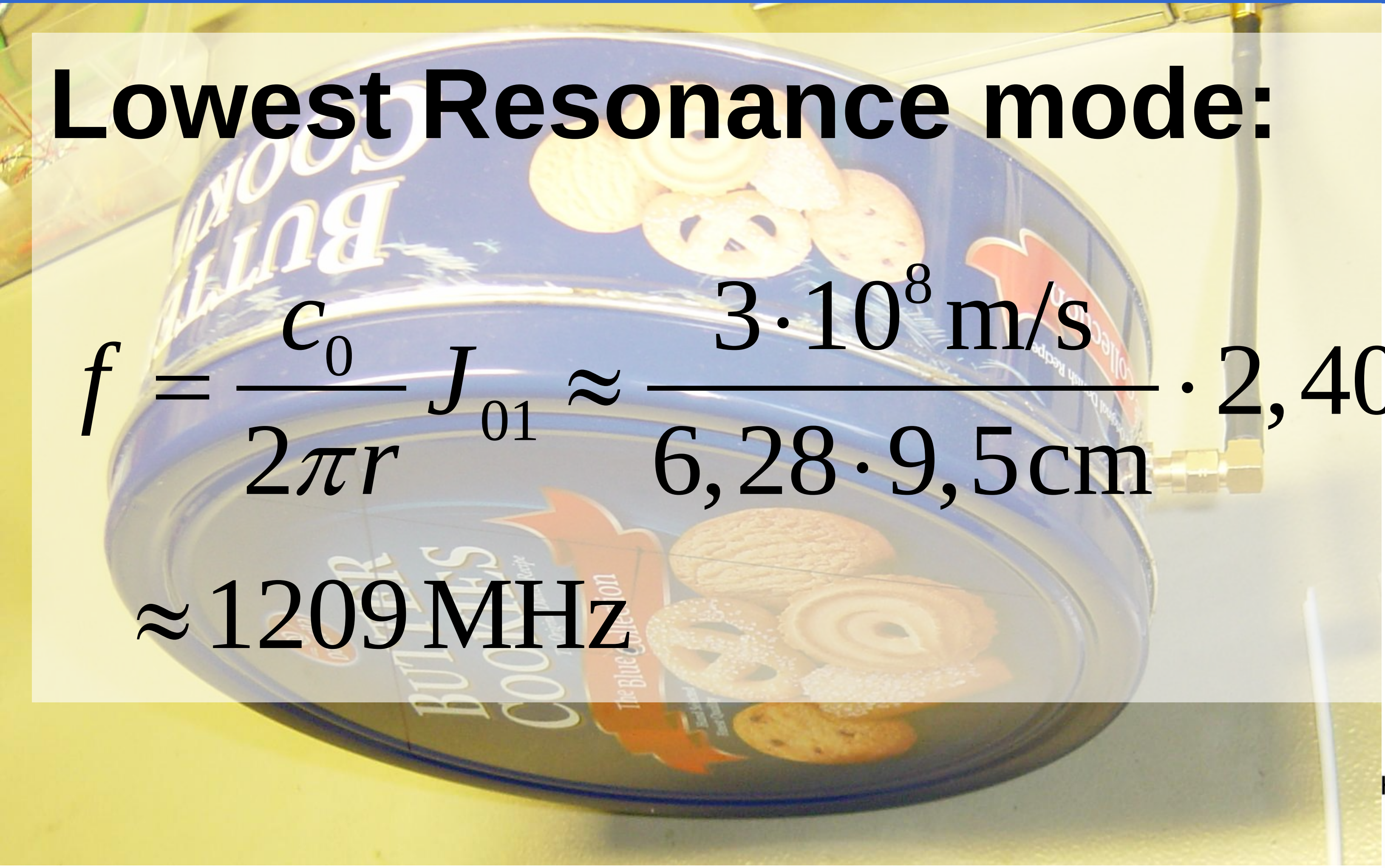
Cavity Resonance (2)



Lowest Resonance mode:

$$f = \frac{c_0}{2\pi r} J_{01} \approx \frac{3 \cdot 10^8 \,\mathrm{m/s}}{6{,}28 \cdot 9{,}5\,\mathrm{cm}} \cdot 2{,}405$$

$$\approx 1209\,\mathrm{MHz}$$

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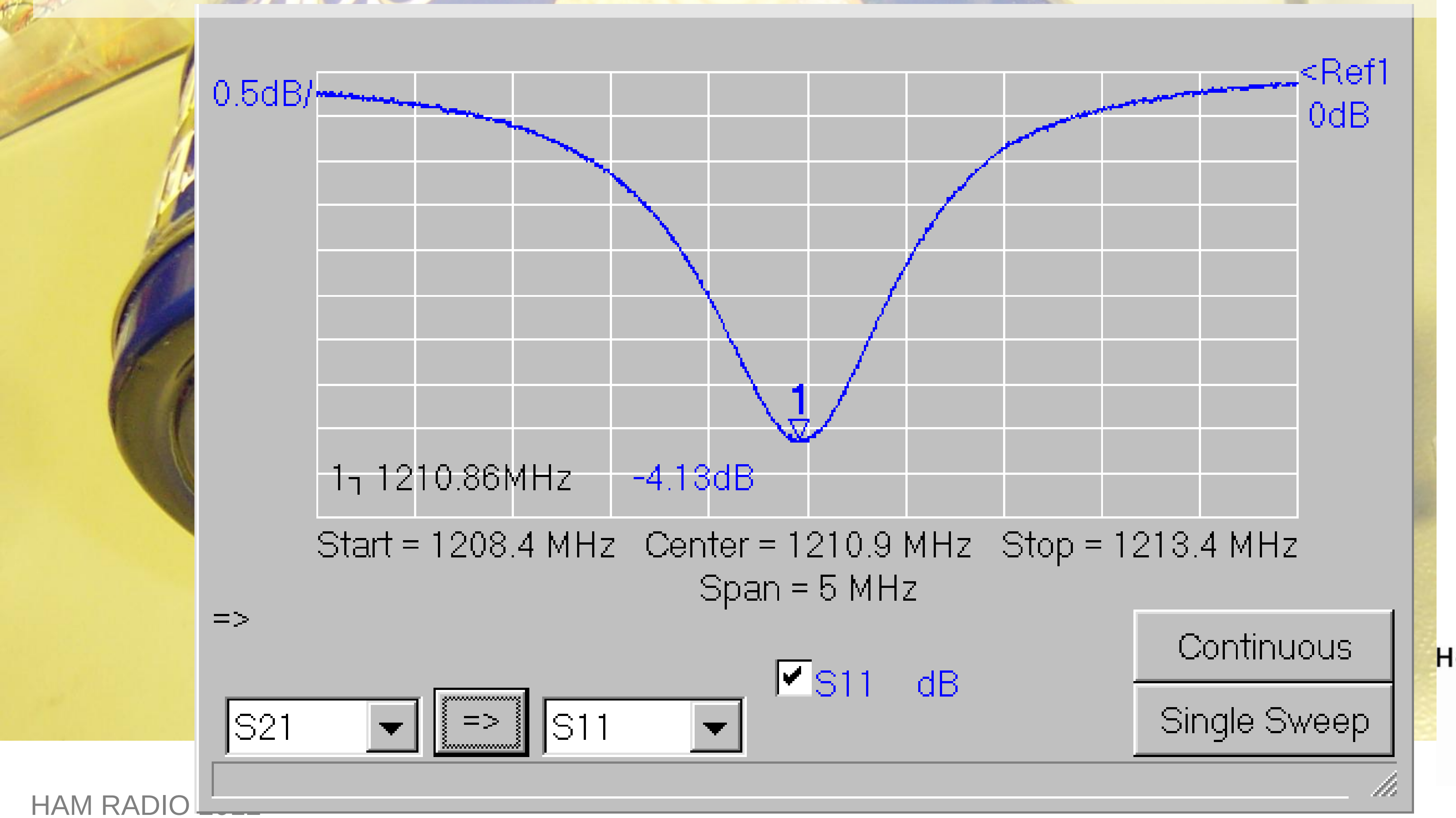
Cavity Resonance (3)

Lowest Resonance mode:



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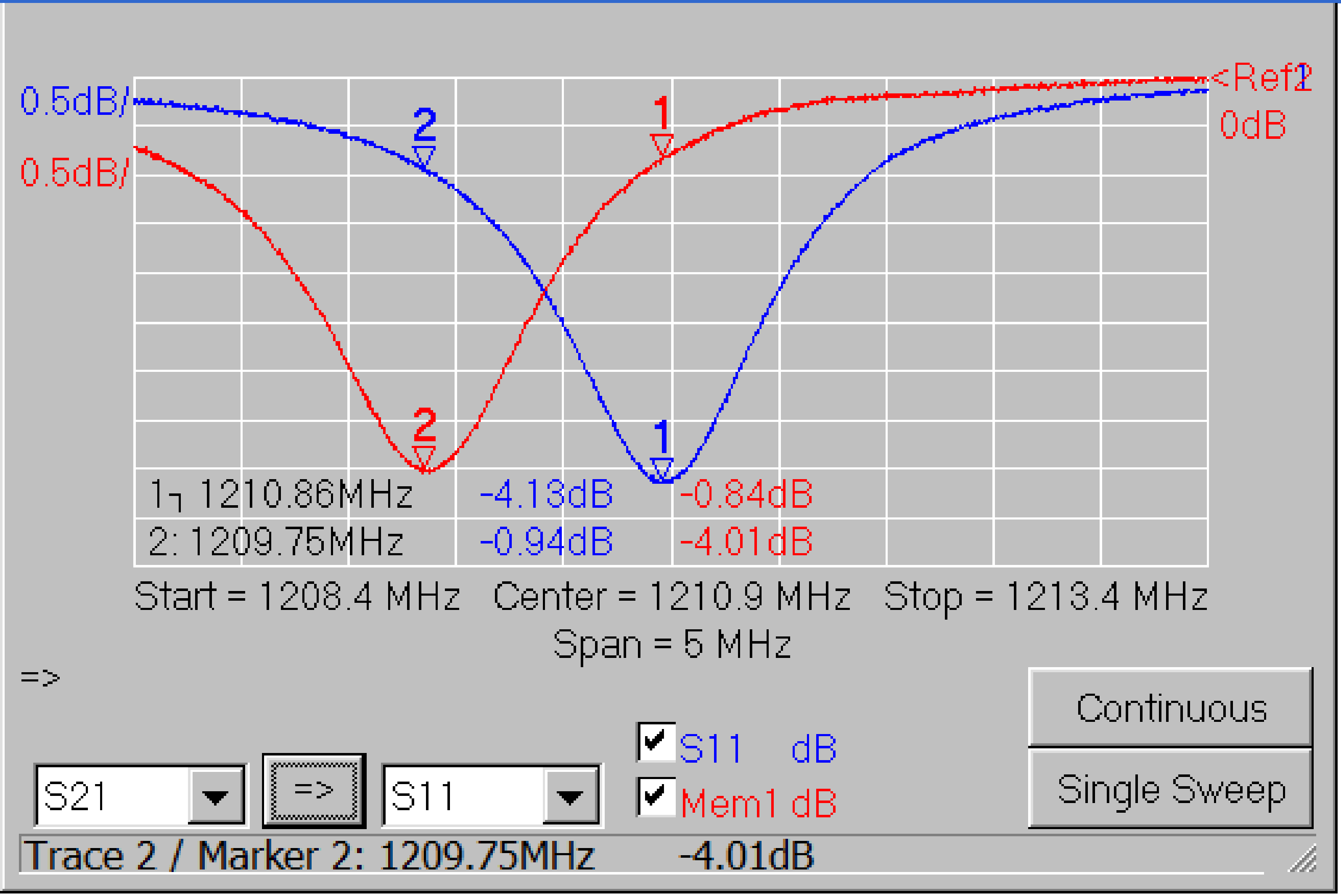
Cavity Resonance (4)



Empty vs. **Filled**

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Cavity Resonance (5)

NASA/TM—2007-214907 AIAA–2007–1198

Radio Frequency Mass Gauging of Propellants

Gregory A. Zimmerli and Karl R. Vaden
Glenn Research Center, Cleveland, Ohio

Michael D. Herlacher
Analex Corporation, Brook Park, Ohio

David A. Buchanan and Neil T. Van Dresar
Glenn Research Center, Cleveland, Ohio

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Cavity Resonance (6)

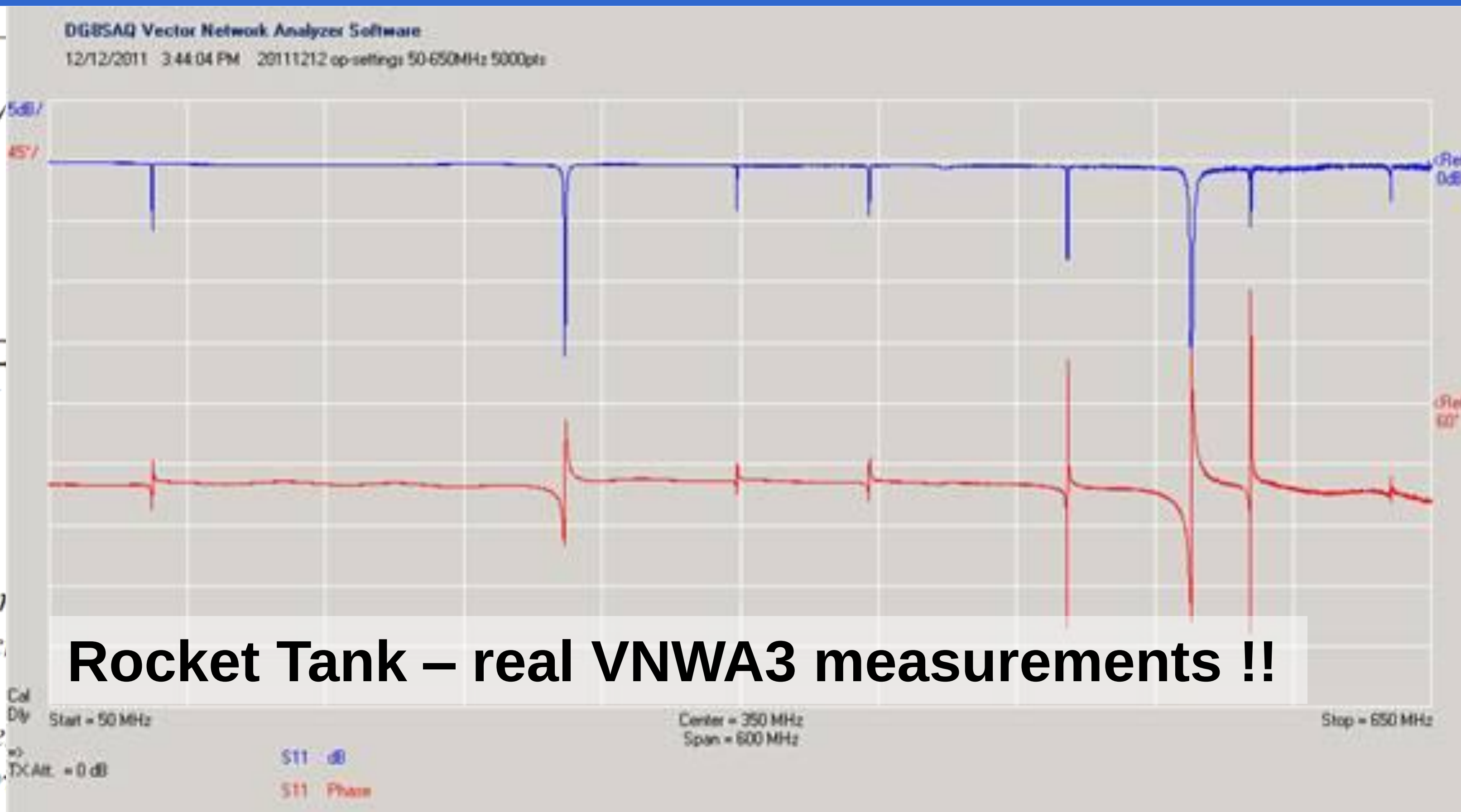
NASA/TM-

Radio F

Gregory A. Zin
Glenn Researc

Michael D. He
Analex Corpor

David A. Buchanan and Neil T. Van Dresar
Glenn Research Center, Cleveland, Ohio



Rocket Tank – real VNWA3 measurements !!

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Summary

- **The VNWA3 is a versatile Test Instrument**

- **Suitable for many - even - professional Applications!**

⇨ **VNWAs are used on 5 Continents**

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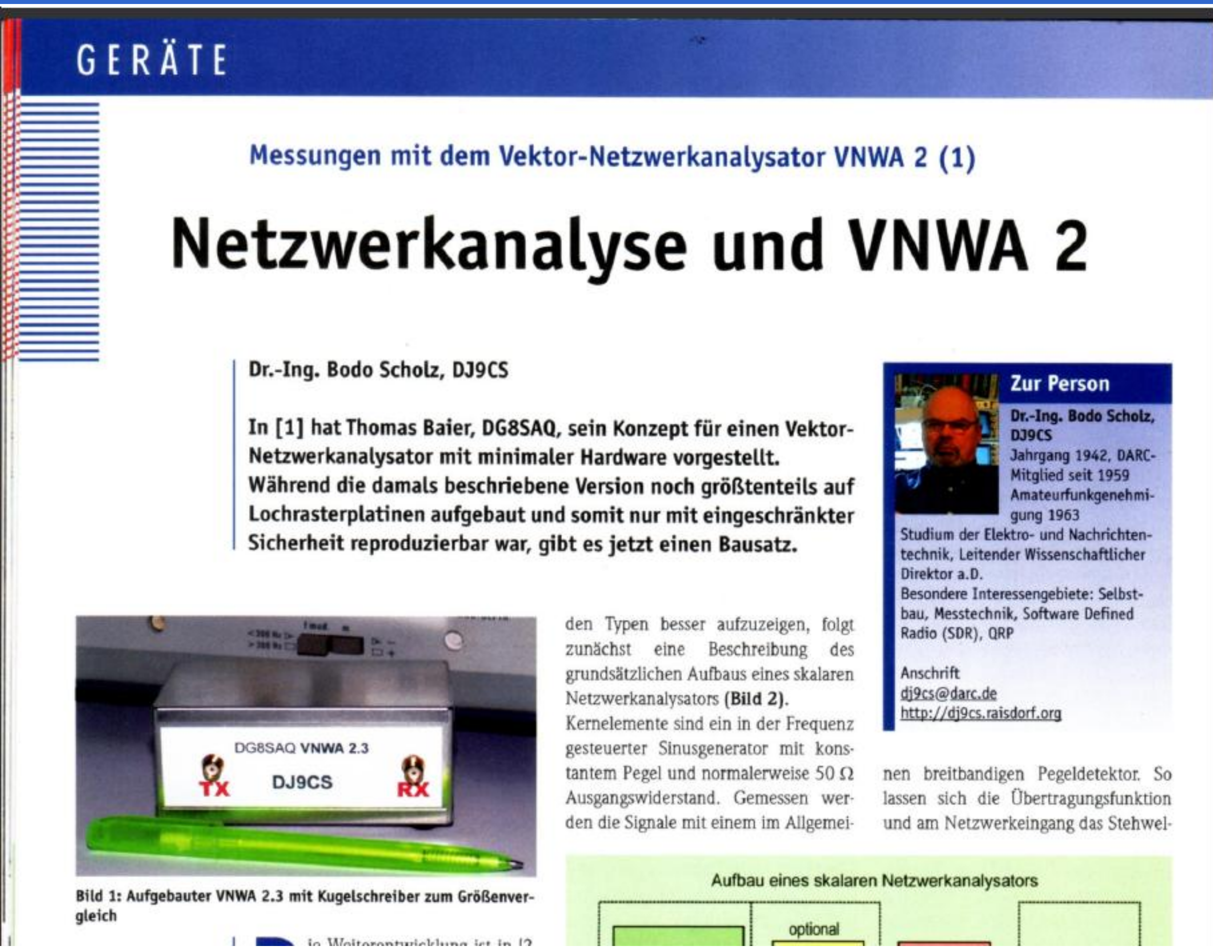
The VNWA3 is in use all over the World.



GERÄTE

Messungen mit dem Vektor-Netzwerkanalysator VNWA 2 (1)

Netzwerkanalyse und VNWA 2

Dr.-Ing. Bodo Scholz, DJ9CS

In [1] hat Thomas Baier, DG8SAQ, sein Konzept für einen Vektor-Netzwerkanalysator mit minimaler Hardware vorgestellt. Während die damals beschriebene Version noch größtenteils auf Lochrasterplatinen aufgebaut und somit nur mit eingeschränkter Sicherheit reproduzierbar war, gibt es jetzt einen Bausatz.

Bild 1: Aufgebauter VNWA 2.3 mit Kugelschreiber zum Größenvergleich

den Typen besser aufzuzeigen, folgt zunächst eine Beschreibung des grundsätzlichen Aufbaus eines skalaren Netzwerkanalysators (**Bild 2**). Kernelemente sind ein in der Frequenz gesteuerter Sinusgenerator mit konstantem Pegel und normalerweise 50 Ω Ausgangswiderstand. Gemessen werden die Signale mit einem im Allgemeinen breitbandigen Pegeldetektor. So lassen sich die Übertragungsfunktion und am Netzwerkeingang das Stehwel-

Zur Person

Dr.-Ing. Bodo Scholz, DJ9CS
Jahrgang 1942, DARC-Mitglied seit 1959
Amateurfunkgenehmigung 1963
Studium der Elektro- und Nachrichtentechnik, Leitender Wissenschaftlicher Direktor a.D.
Besondere Interessengebiete: Selbstbau, Messtechnik, Software Defined Radio (SDR), QRP

Anschrift
dj9cs@darc.de
http://dj9cs.raisdorf.org

Aufbau eines skalaren Netzwerkanalysators

optional

Thanks to all VNWA Users and Supporters!

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The VNWA3 is in use all over the World.

GERÄTE

Messungen mit dem Vektor-Netz

Netzwerkanalys

Dr.-Ing. Bodo Scholz, DJ9CS

In [1] hat Thomas Baier, DG8SAQ, sein Ko
Netzwerkanalysator mit minimaler Hardw
Während die damals beschriebene Versio
Lochrasterplatinen aufgebaut und somit n
Sicherheit reproduzierbar war, gibt es jet

Bild 1: Aufgebauter VNWA 2.3 mit Kugelschreiber zum Größenvergleich

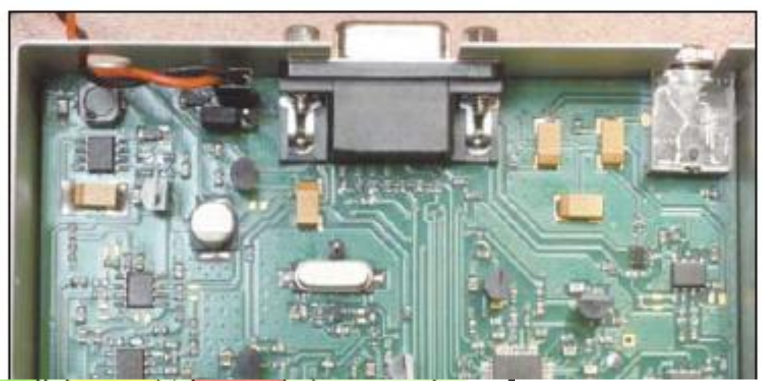
den Type
zunächst
grundsätz
Netzwerk
Kernelem
gesteuert
tantem P
Ausgangs
den die S

LABORATORIO-STRUMENTAZIONE

di Vittorio Carboni I6DVX

Un accurato e prezioso strumento: VNWA2

Un analizzatore di reti per radioamatori



sostanza consente di misurare i parametri S: S11, S12, S21, S22 e VSWR. Dei singoli componenti può misurare: resistenza, ammettenza, capacità induttanza e fattore di qualità (Q). Le misure S12 e S22 sono effettuate scambiando manualmente l'ingresso e l'uscita del dispositivo in misura (DUT) oppure realizzando una commutazione esterna delle porte(5). Le ultime versioni del software di gestione permettono di caratterizzare i quarzi ricavandone automaticamente tutti i parametri. È inoltre prevista la possibilità di usare il VNWA2 come analizzatore di spettro. Tutte queste informazioni vengono fornite dalle elaborazioni del software di gestione e sicuramente oggi, quando queste note sono lette, altre possibilità di misure si saranno aggiunte a quelle qui indicate.

Lo schema a blocchi è visibile in Figura 1. La generazione dei segnali RF è demandata all'ormai classico DDS, che in questo

The VNWA3 is in use all over the World..

The VNWA3 is in use all over the World.

The VNWA3 is in use all over the World.

Finally, … a Warning:
VNWA´s <u>are</u> Addictive!