



HAM RADIO 2012

Evolution of the DG8SAQ Vector Network Analyzer: New VNWA3 Features & Applications

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DG8SAQ

Hochschule Ulm

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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*

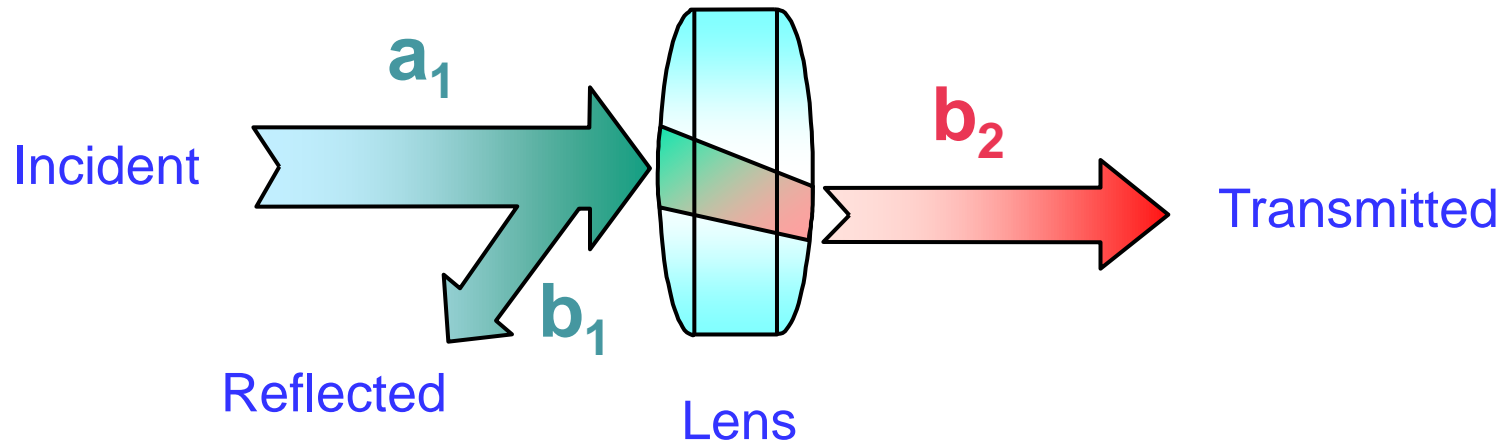
- *Mario Armando Natali*

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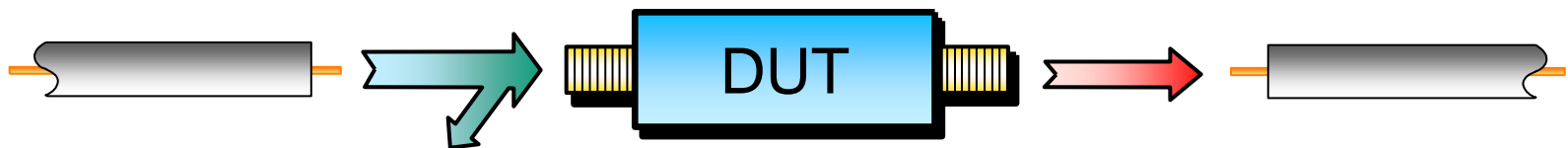


It is all about scattering of Waves

Optic



Electrical

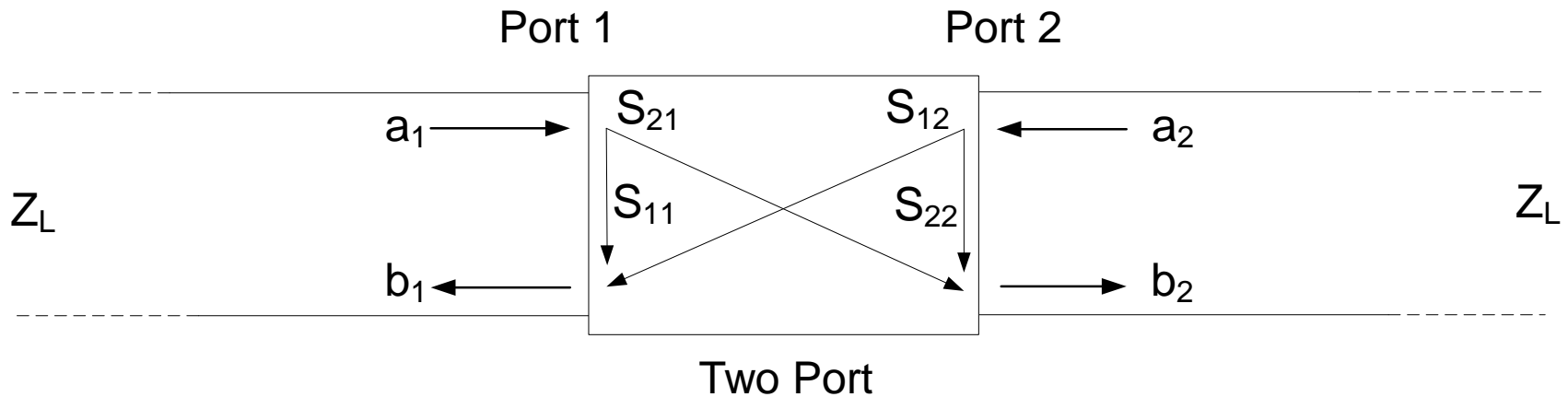


DUT : DEVICE UNDER TEST

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S-Parameter = Scattering Parameter S_{ik}

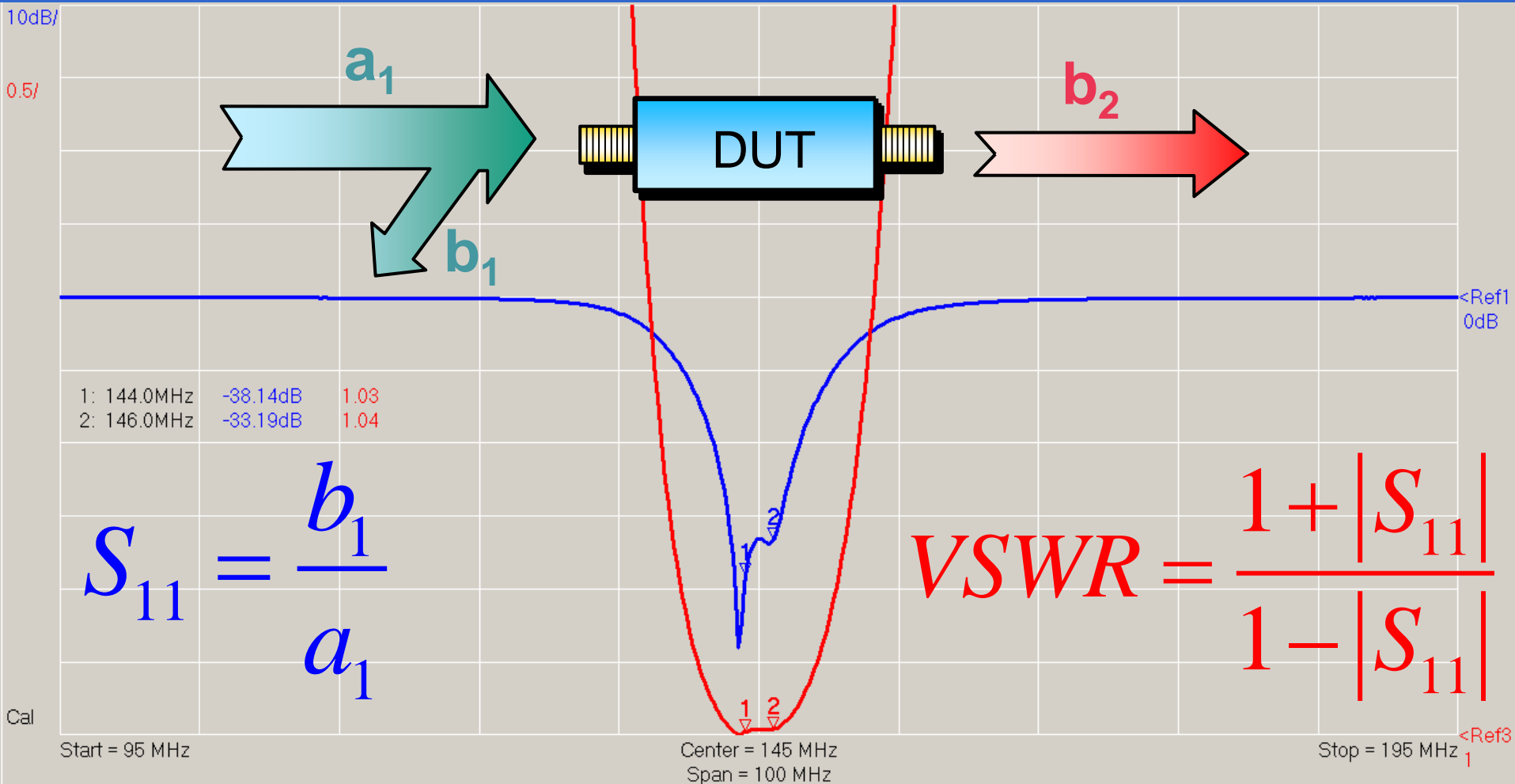


- Complex S-parameters: $S_{ik} = b_i / a_k$
- S_{ik} are complex numbers consisting of **Magnitude** and **Phase**!

S-Parameter S_{11}



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

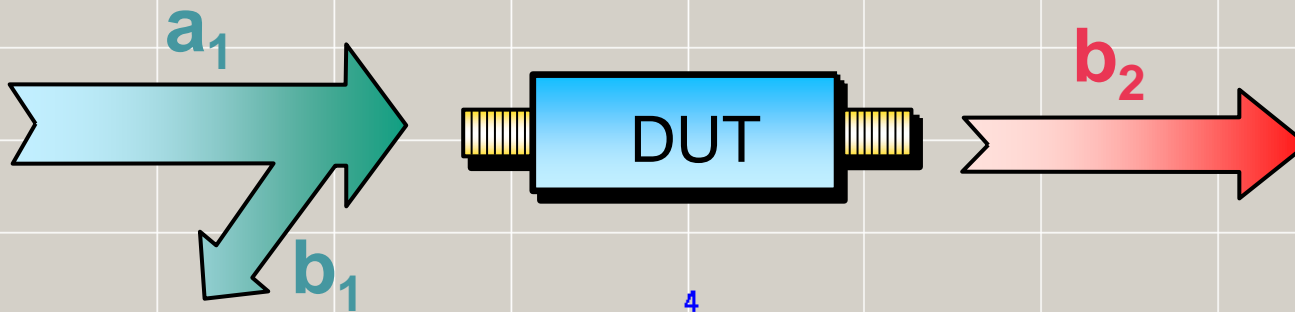


S-Parameter S_{21}



$|S_{21}| = \text{Transmission Loss}$

5dB/



1: 145.3MHz -0.34dB
2: <=1: 3.00dB -3.34dB
3: 2: 17.98 MHz -3.34dB
4: 145.2MHz -0.34dB

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

<Ref1
0dB

Cal

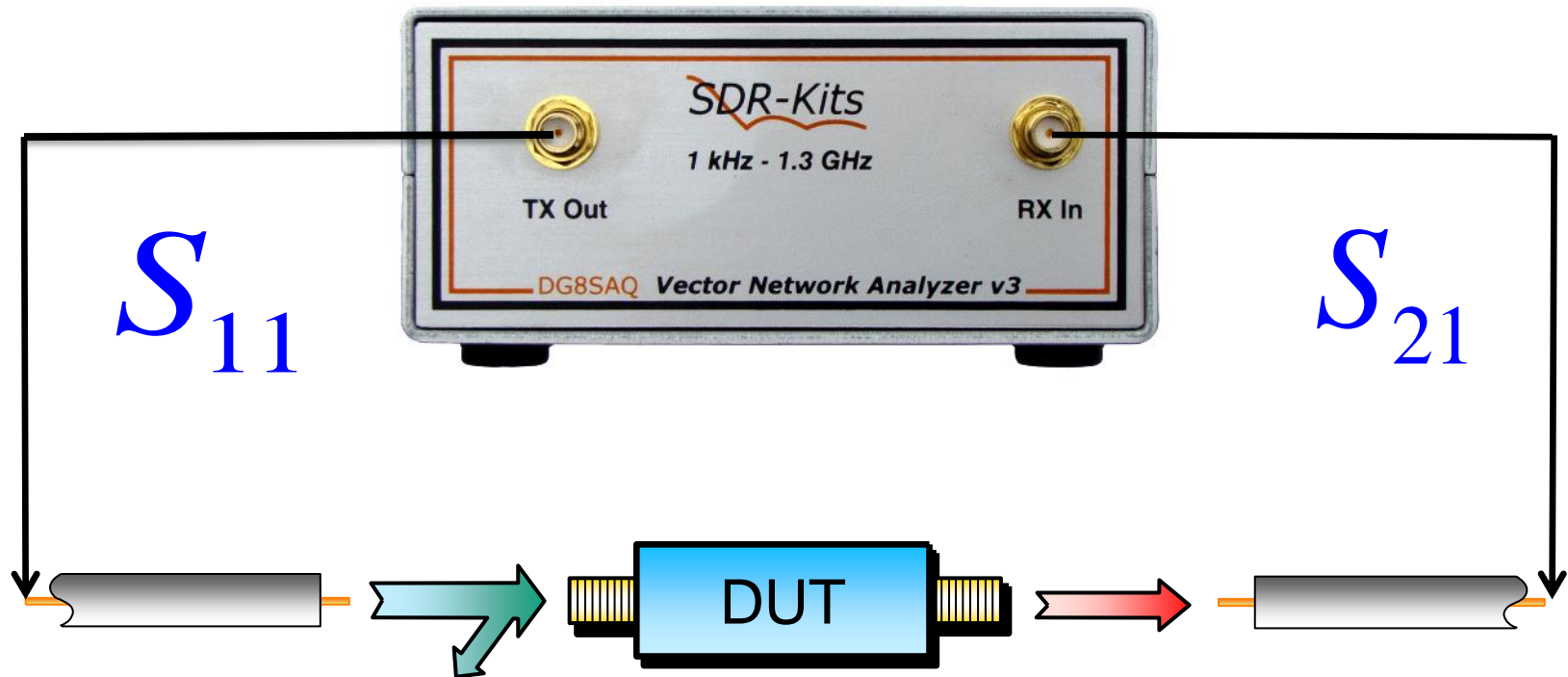
Start = 95 MHz

Center = 145 MHz
Span = 100 MHz

Stop = 195 MHz



The VNWA can measure these S-Parameters!



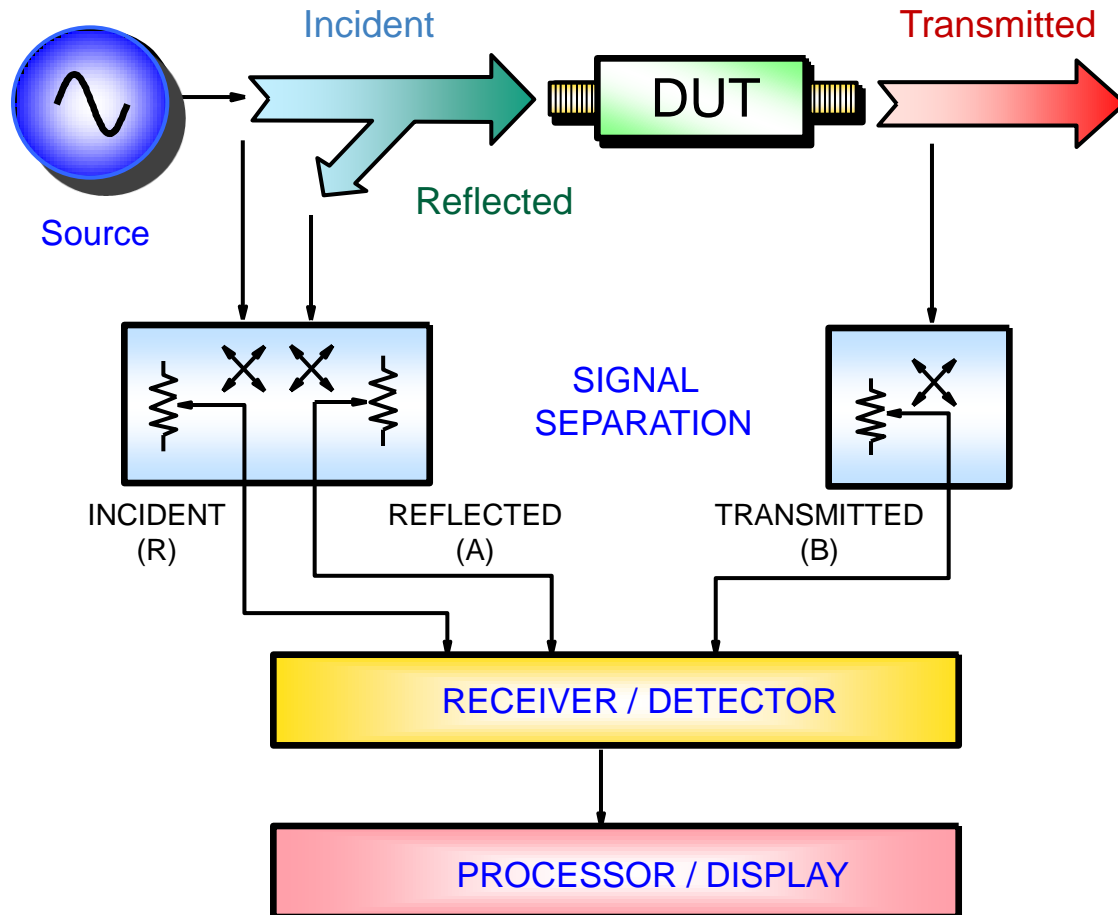
DUT : DEVICE UNDER TEST

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Evolution and Principle of Operation (1)

VNWA Basics



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

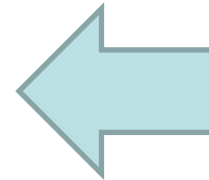
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Evolution and Principle of Operation (2)

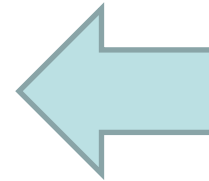
Functional Diagram

Direct Digital Synthesizer (DDS)

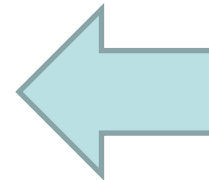


- Tuneable Signal Source

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



- 3 Coherent Receivers



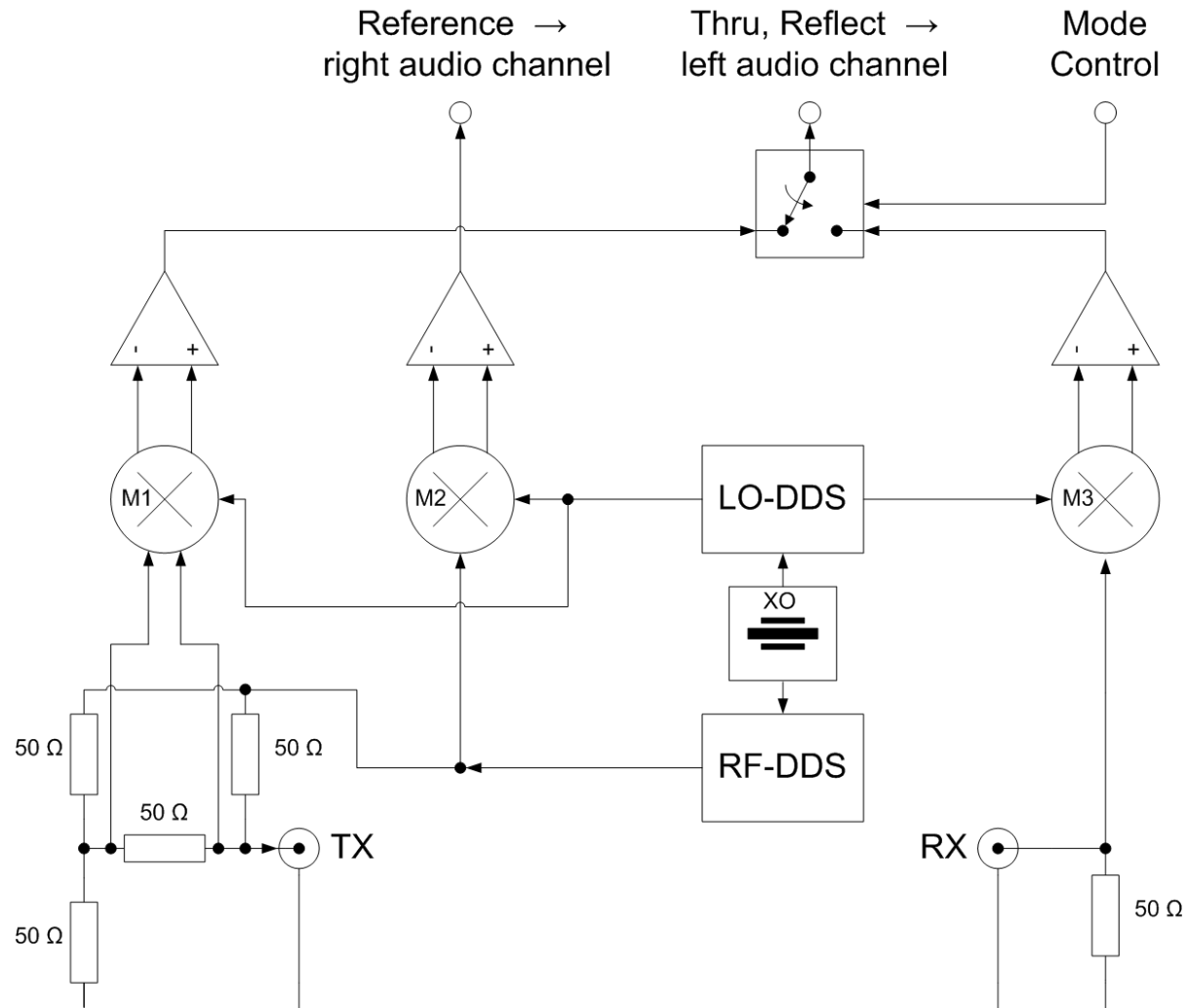
- Device Control
- Dataprocessing and Graphics

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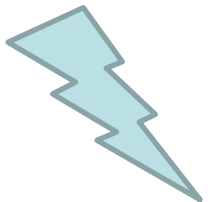
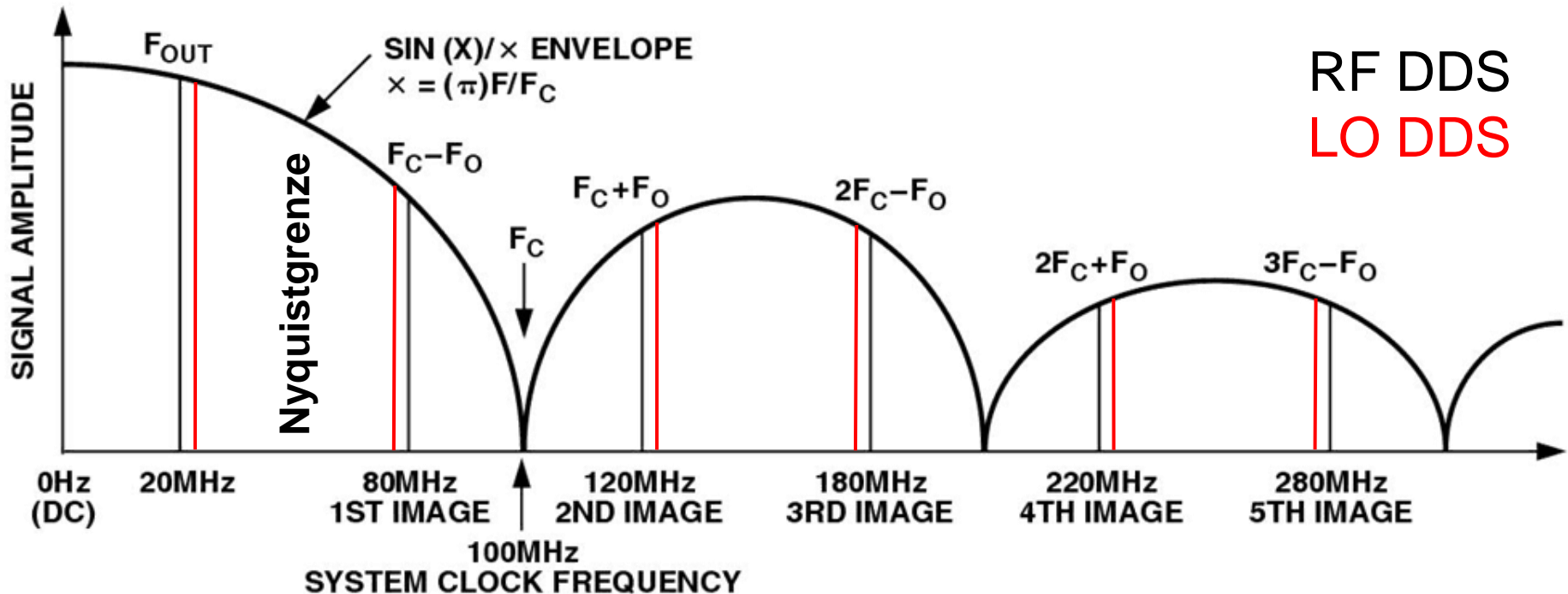
Evolution and Principle of Operation (3)

Functional Block Diagram



Evolution and Principle of Operation (4)

Problem: DDS Alias Frequencies

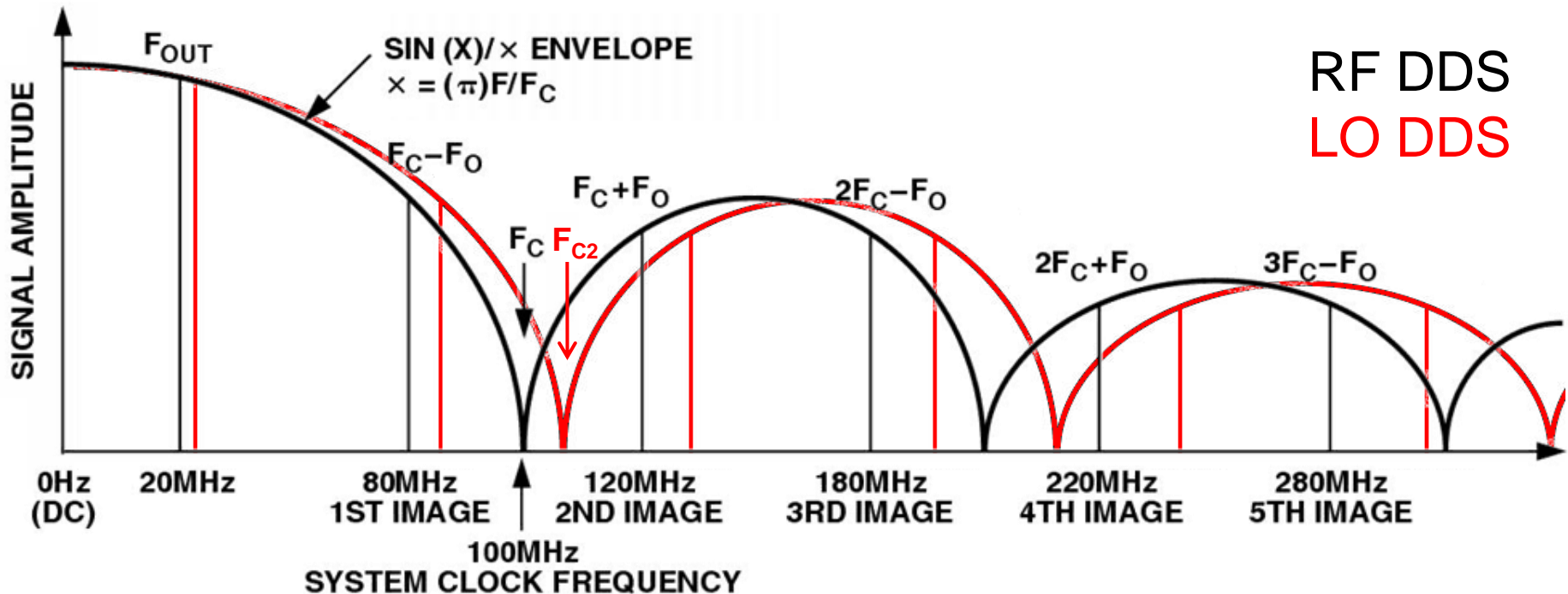


**All Alias-Frequencies mix down
to the same Intermediate Frequency
→ either use Low Pass filter, or...**



Evolution and Principle of Operation (5)

... use LO DDS with Clock Frequency Offset



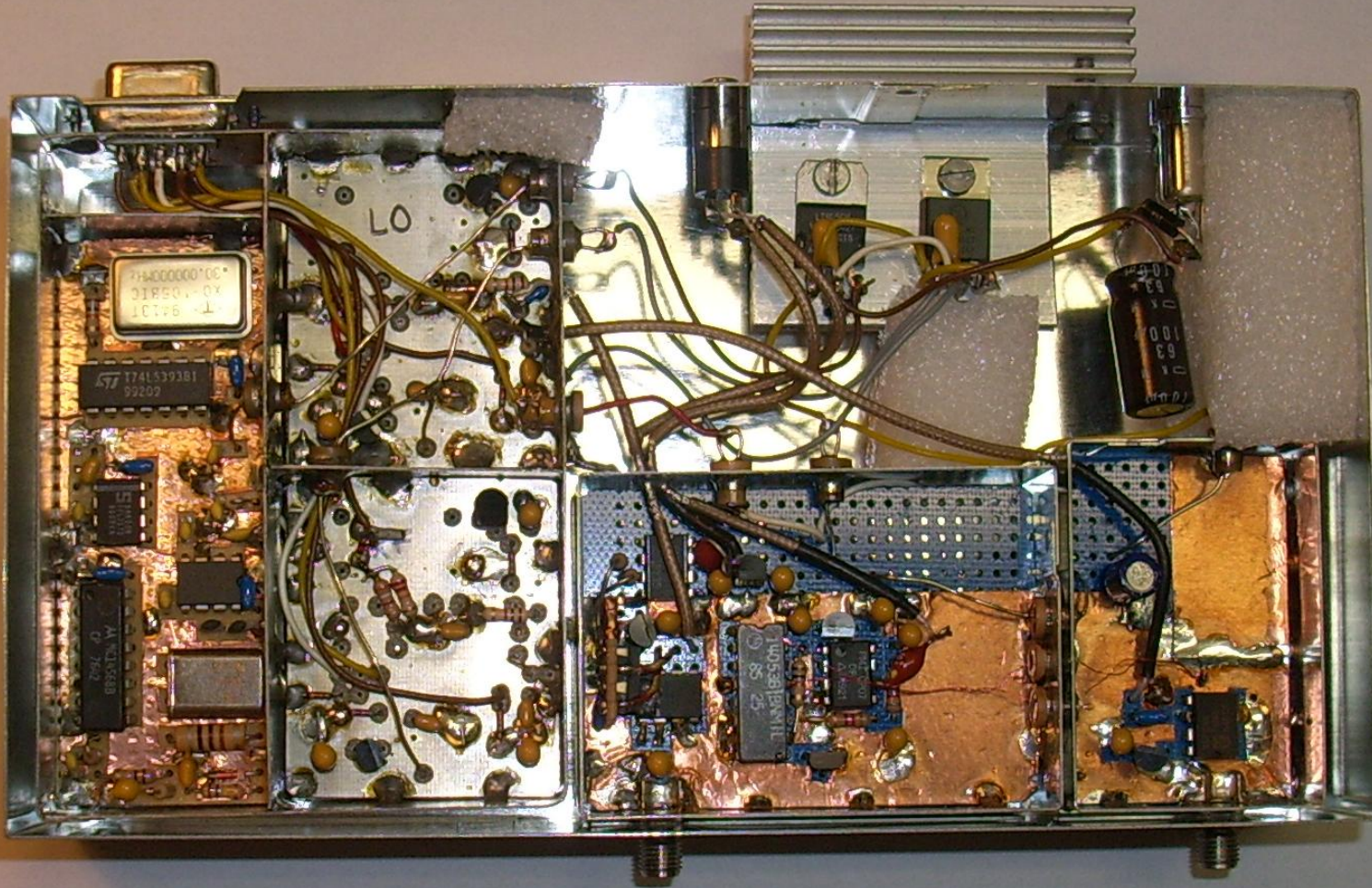
all Alias-Frequencies can now be used to extend the VNWA Frequency Range

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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)

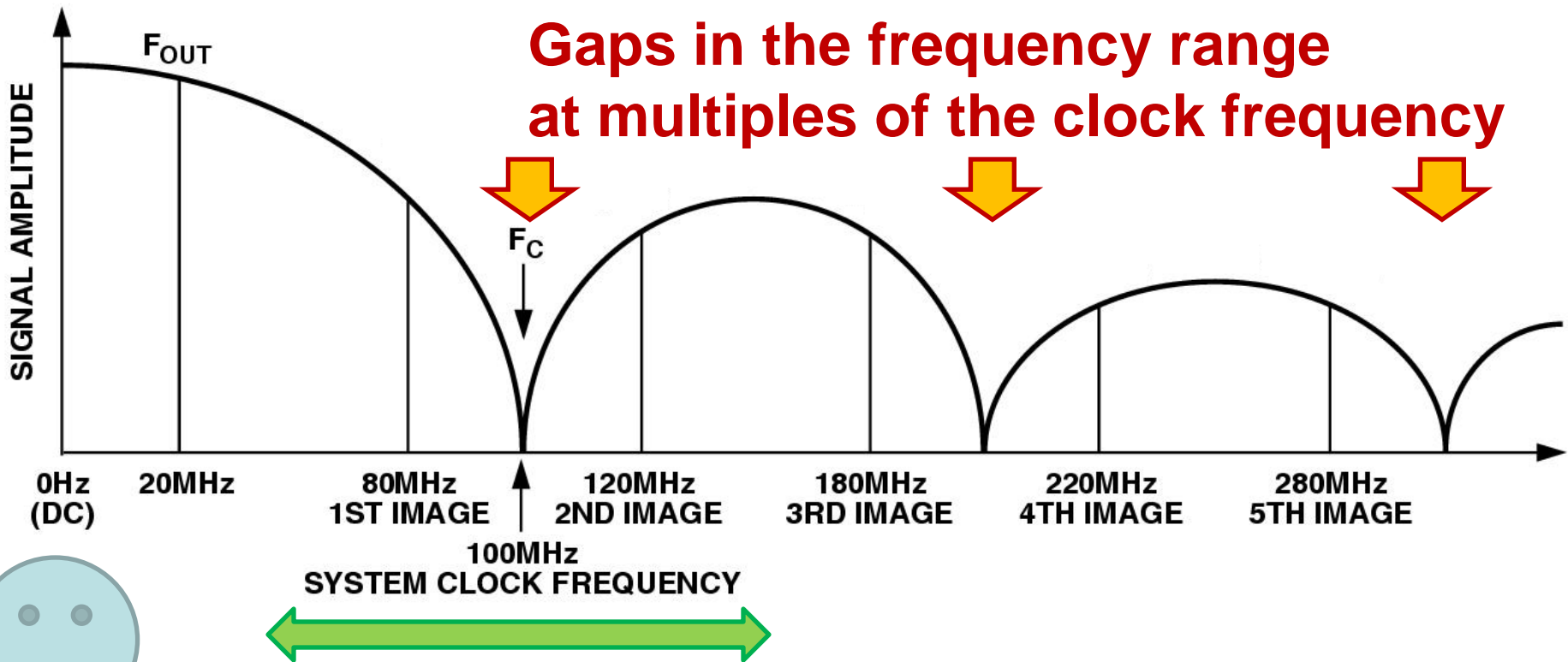
Updated Development Targets

Main Target: A Tool for Education

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

Evolution and Principle of Operation (9)

Continuous Frequency Range



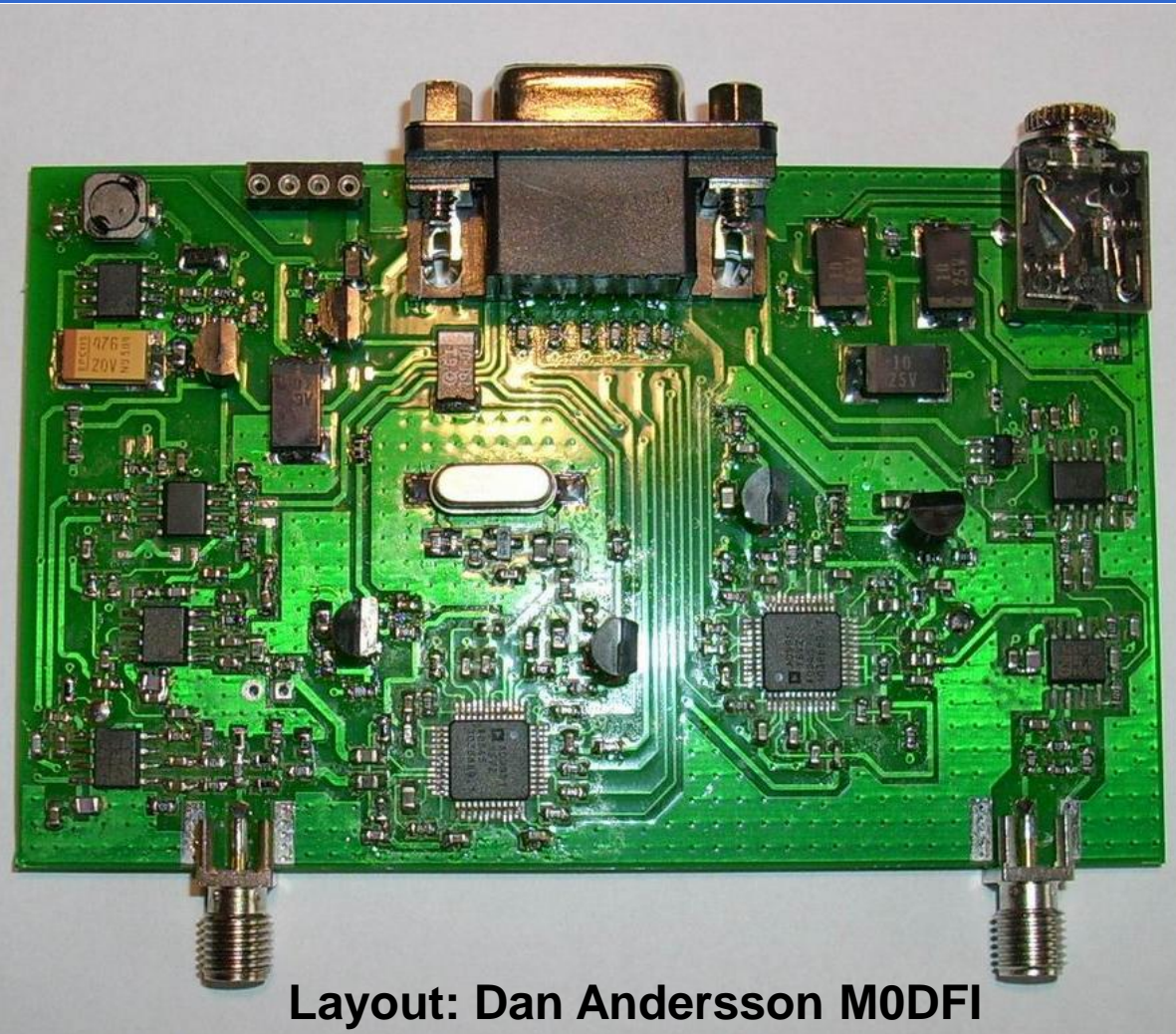
Solution: variable clock frequencies by changing PLL-clock multipliers (integrated in DDS)

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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 ($f \leq 500$ 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



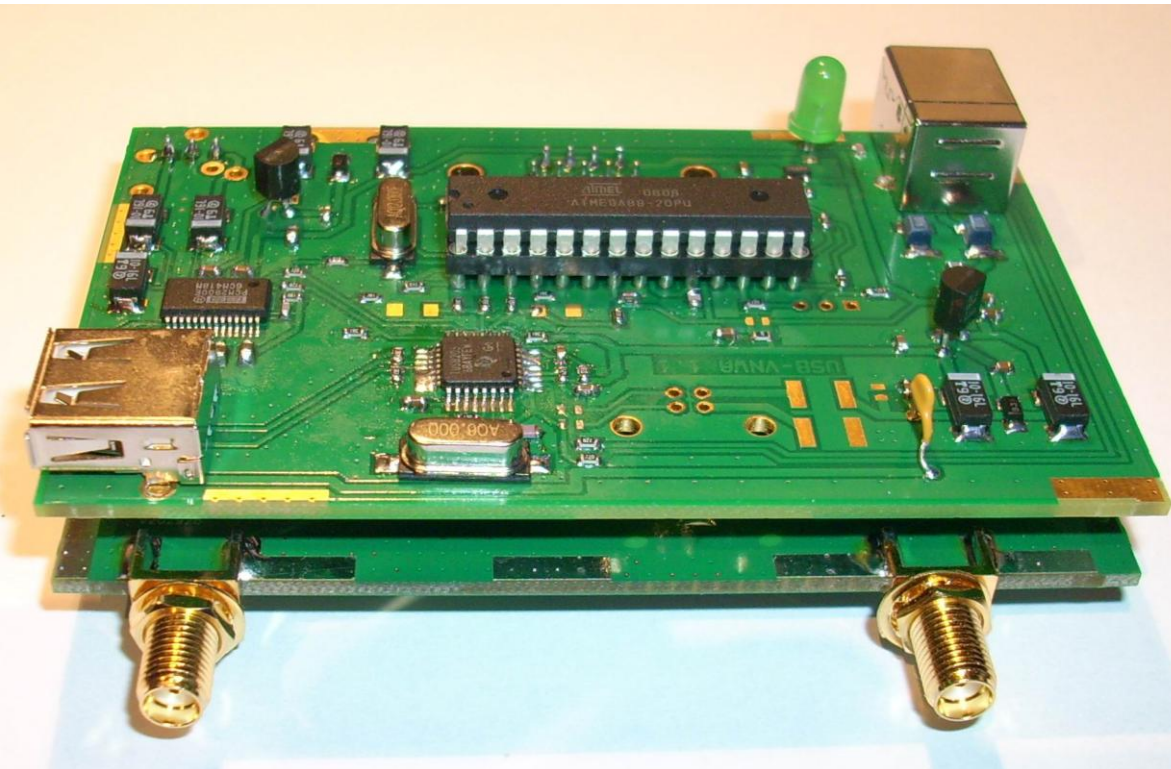
**Fewer Computers with
*Parallel Port Interface***



**Fewer Computers with
*Stereo-Line-In***

Evolution and Principle of Operation (12)

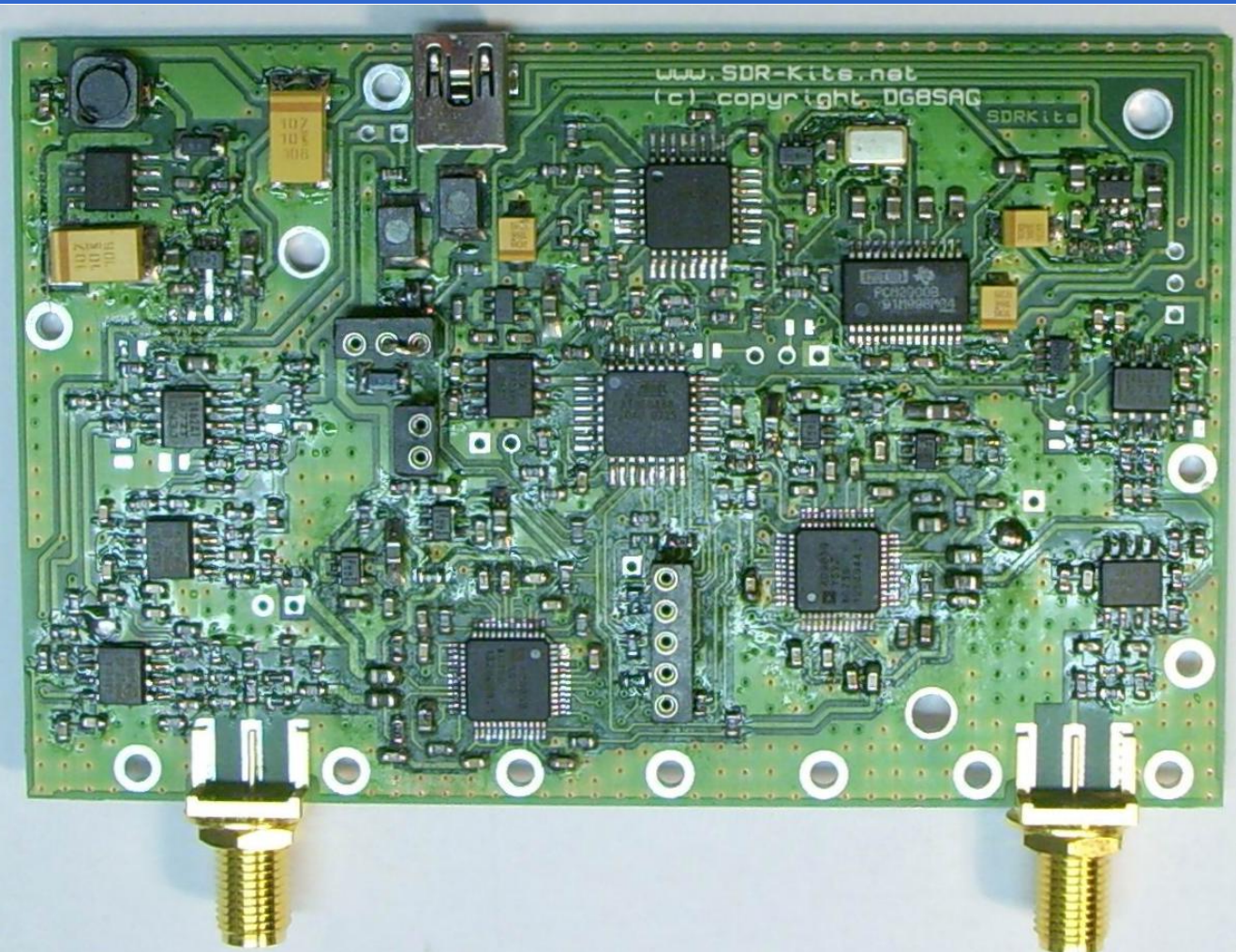
VNWA2-USB



- USB Interface
 - Controller
 - USB Audio Codec
 - Powered from USB
- Only a USB cable connection to the PC**

Evolution and Principle of Operation (13)

VNWA3: Ready Assembled in Factory



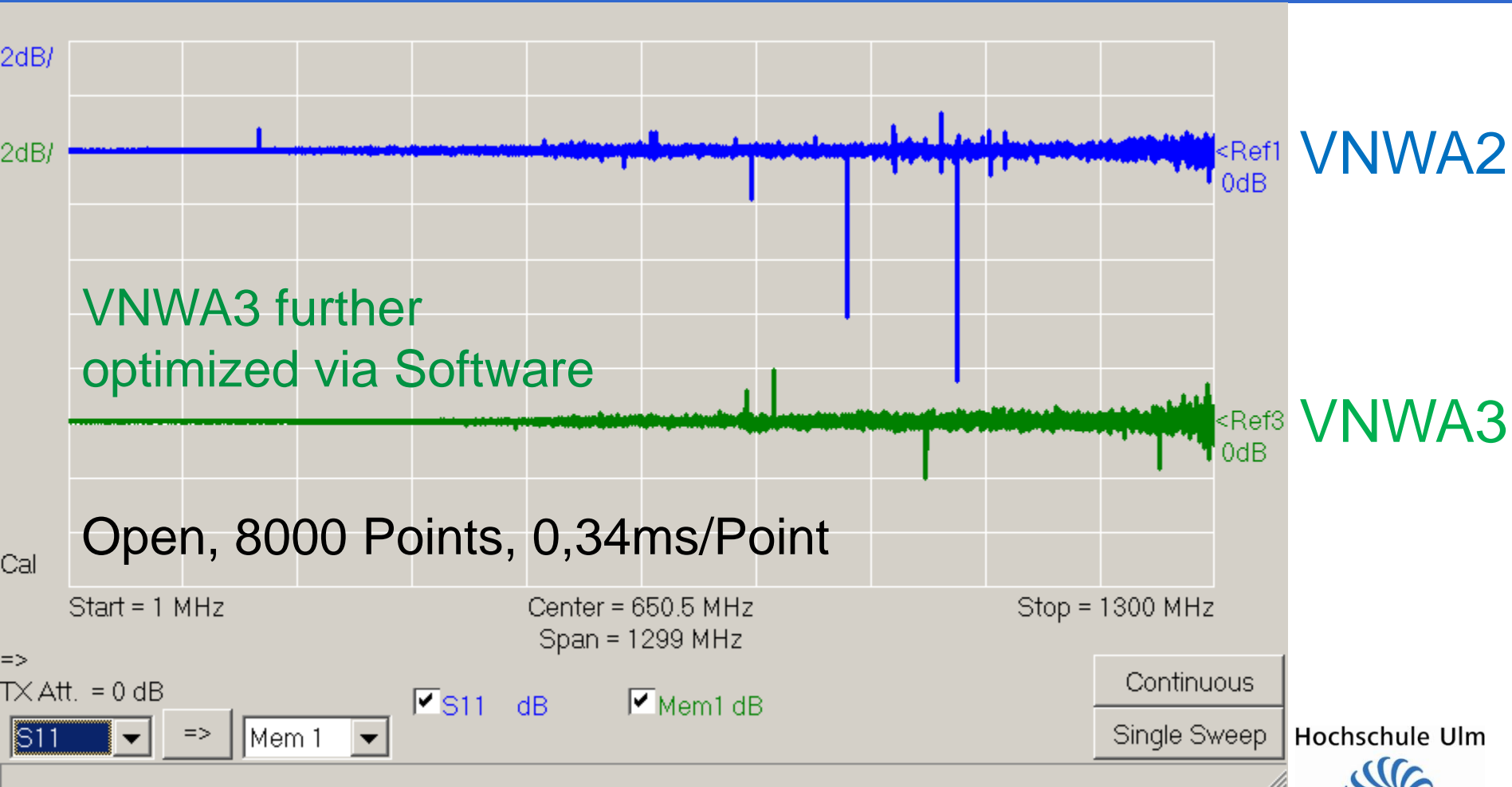
- TCXO
- Additional Clock-PLL!!

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Evolution and Principle of Operation (14)

Less Interference with flexible Clock-PLL



Evolution and Principle of Operation (15)

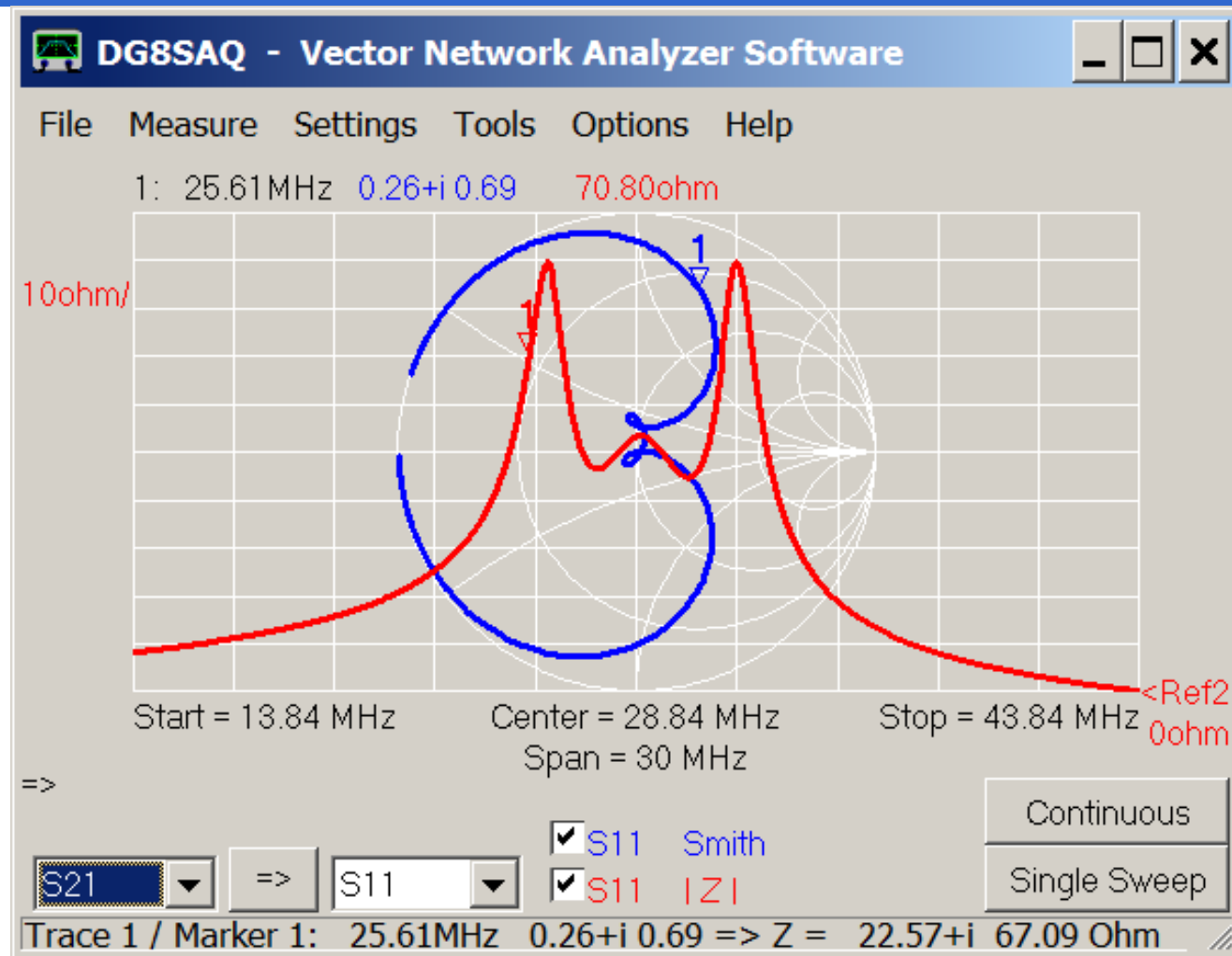
VNWA3 Options



- 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



Applications: Impedance Measurements (1)

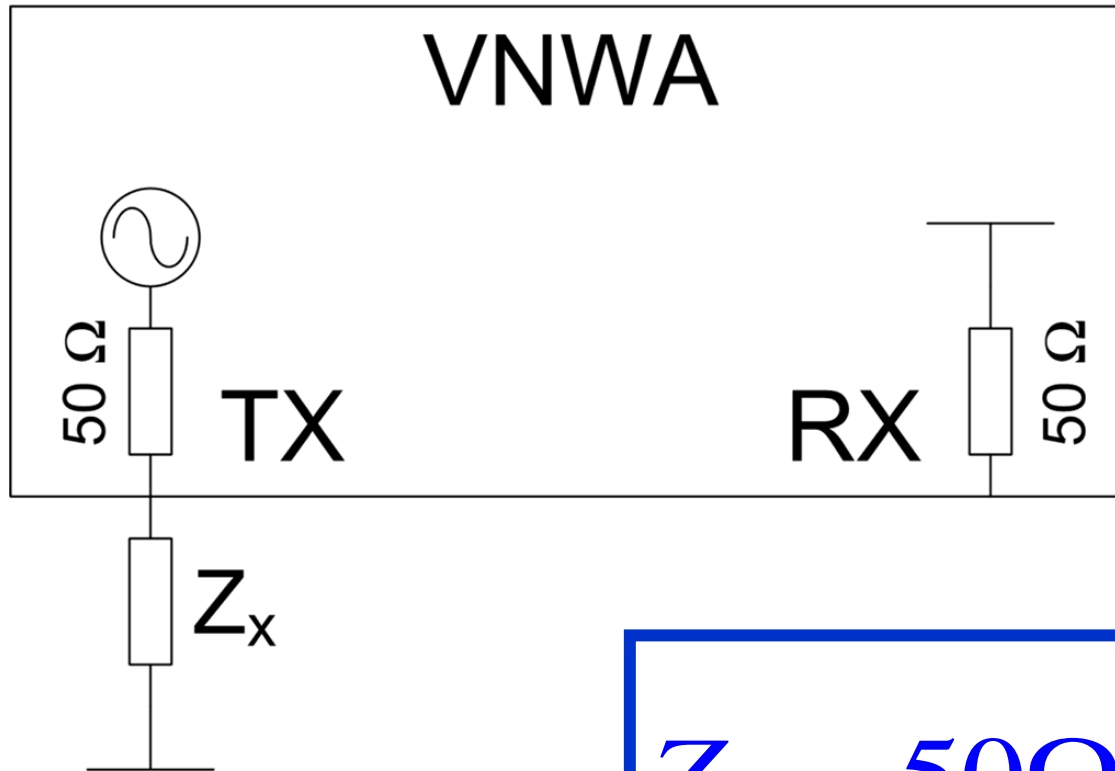


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Impedance Measurements (2)

Variant 1: Return Loss Measurement



**Highest
accuracy for
 Z_x close to 50 Ω**

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

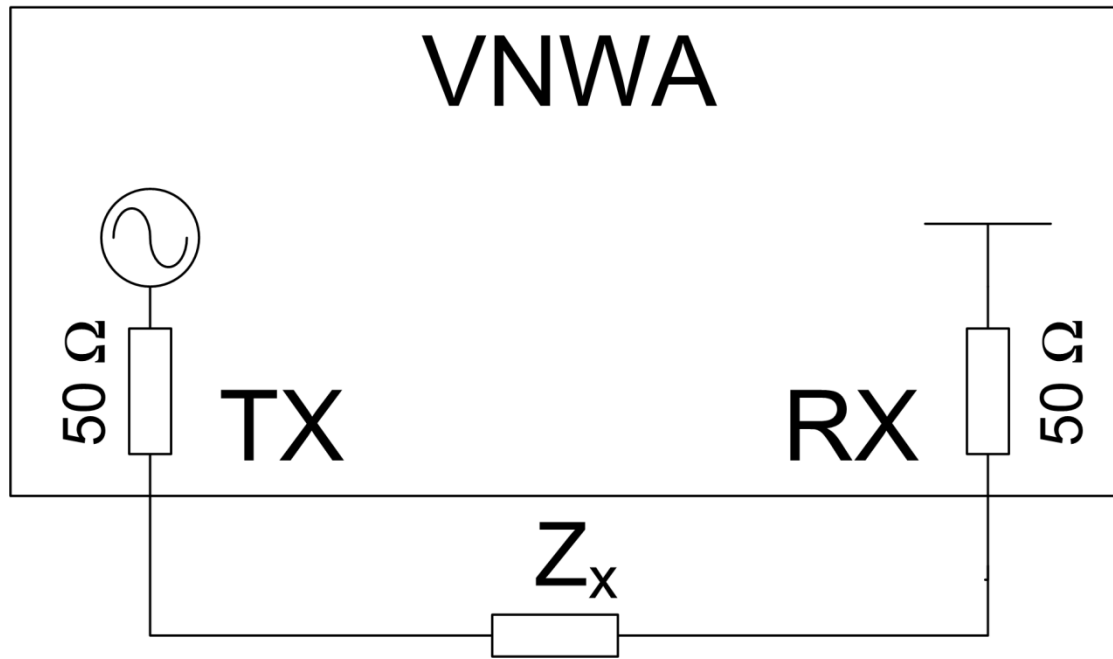
Cal: SOL

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Impedance Measurements (3)

Variant 2: I-Messung



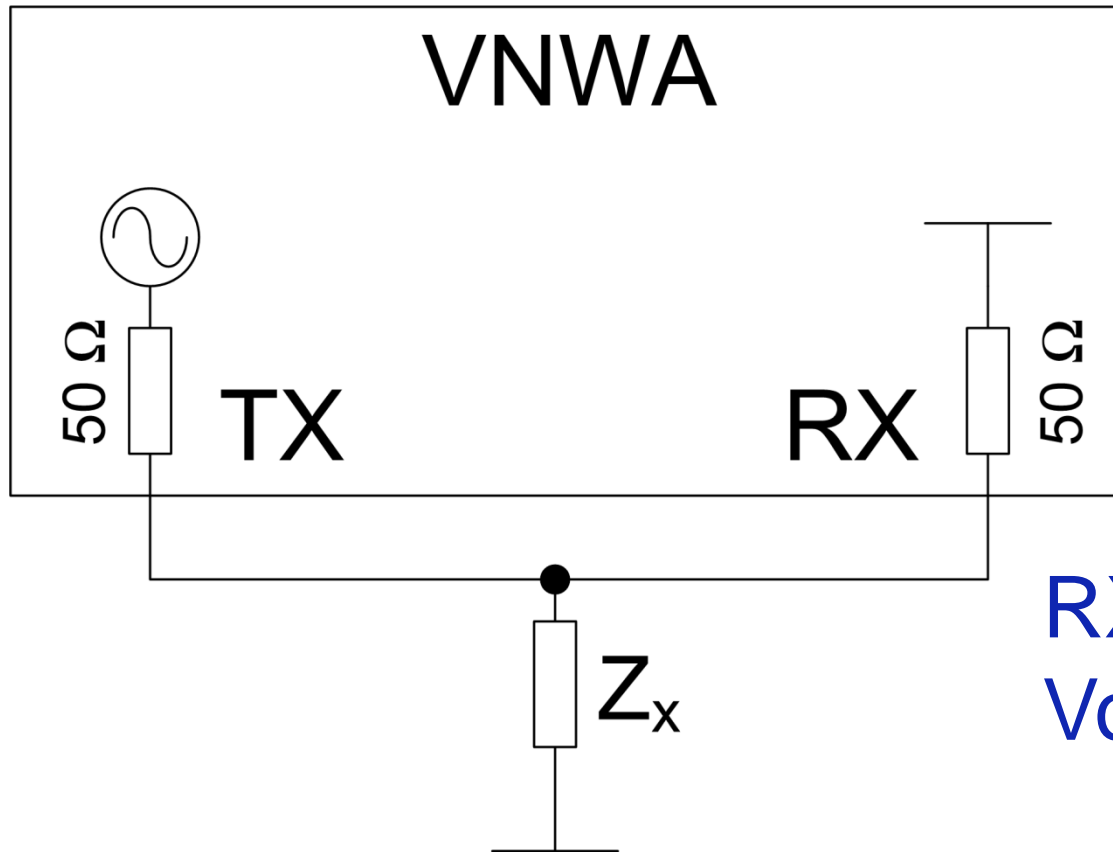
**Highest for
*large values of Z_x***

Cal: Thru

RX measures current through Z_x

Impedance Measurements (4)

Variant 3: V-Measurement



**Highest for
*low values of Z_x***

**RX measures
Voltage across Z_x**

Cal: SOL

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Impedance Measurements (5)

Variante 4: RF-IV Measurement

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

Cal: SOL Z_x

Excellent for
ALL values of Z_x

Combination of
V & I-Measurement

Impedance Measurements (6)

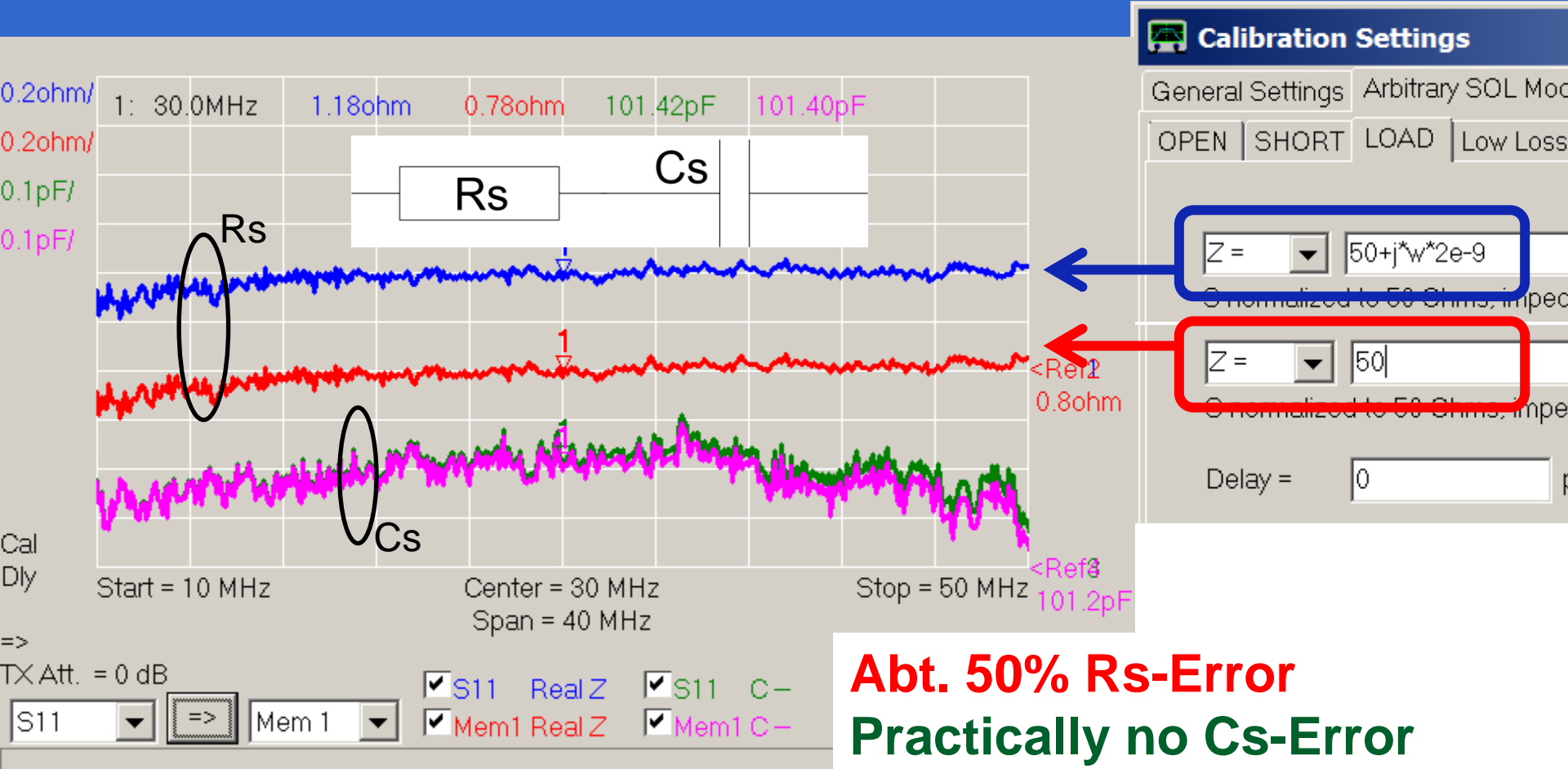
Measurement Deviation-Variants 1 - 4

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 k Ω	0,01%	9,08%	0,00%	9,99%

➡ RF-IV shows best overall sensitivity!

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

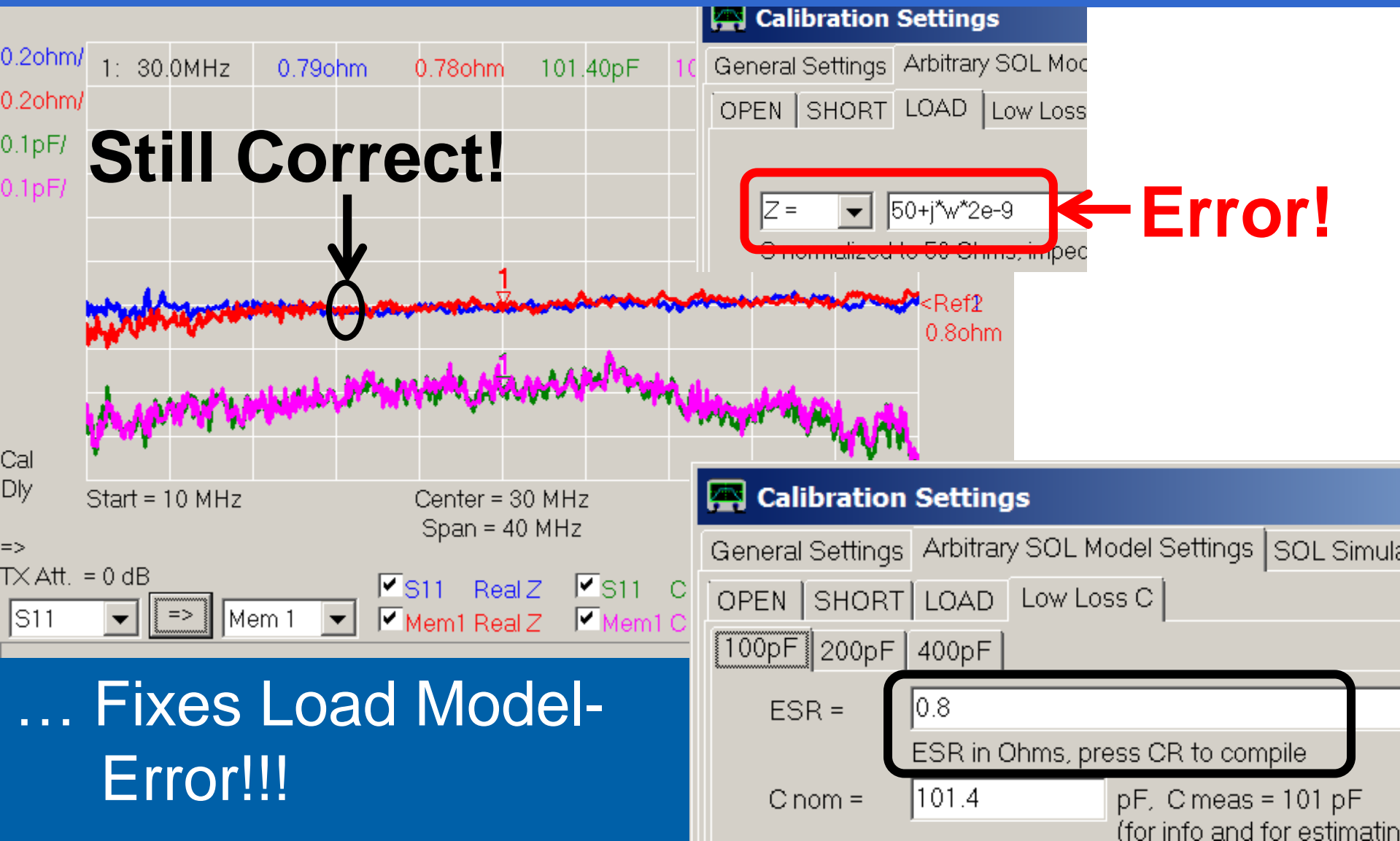


Load-Model critical for Q measurements!

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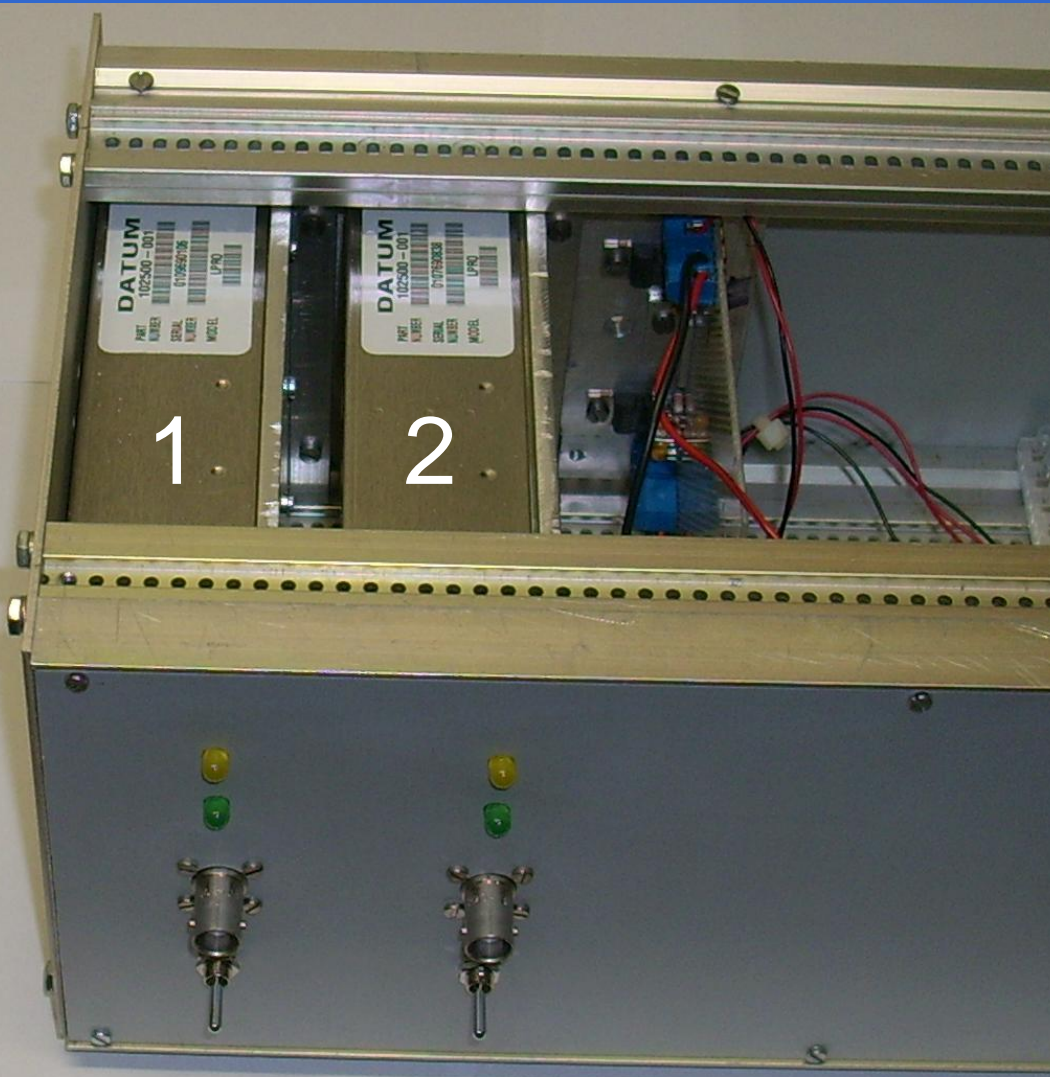
New: Low Loss Capacitor (LLC) as an additional Calibration Standard...



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



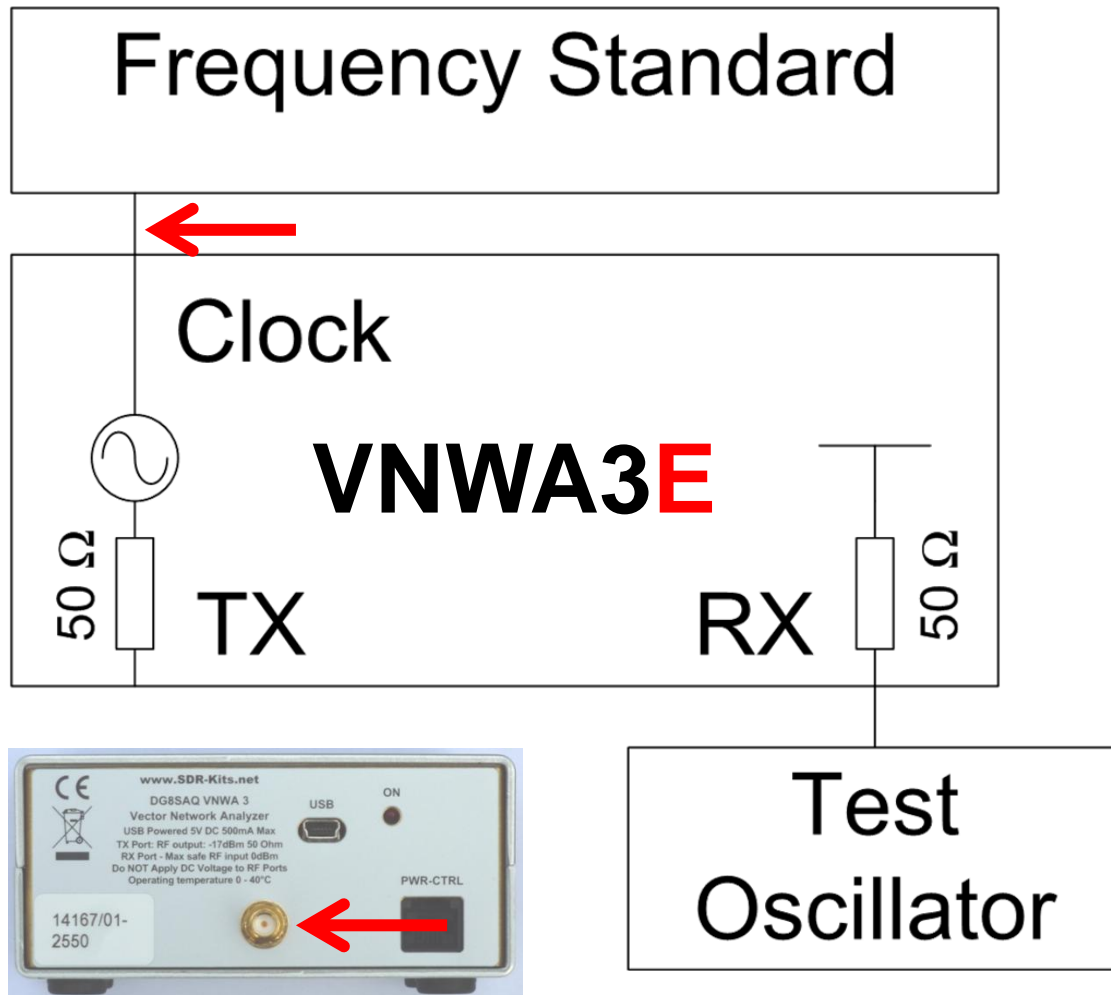
With TWO Clock you are never quite shure which time is right !



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

Application: Frequency Comparison (1)

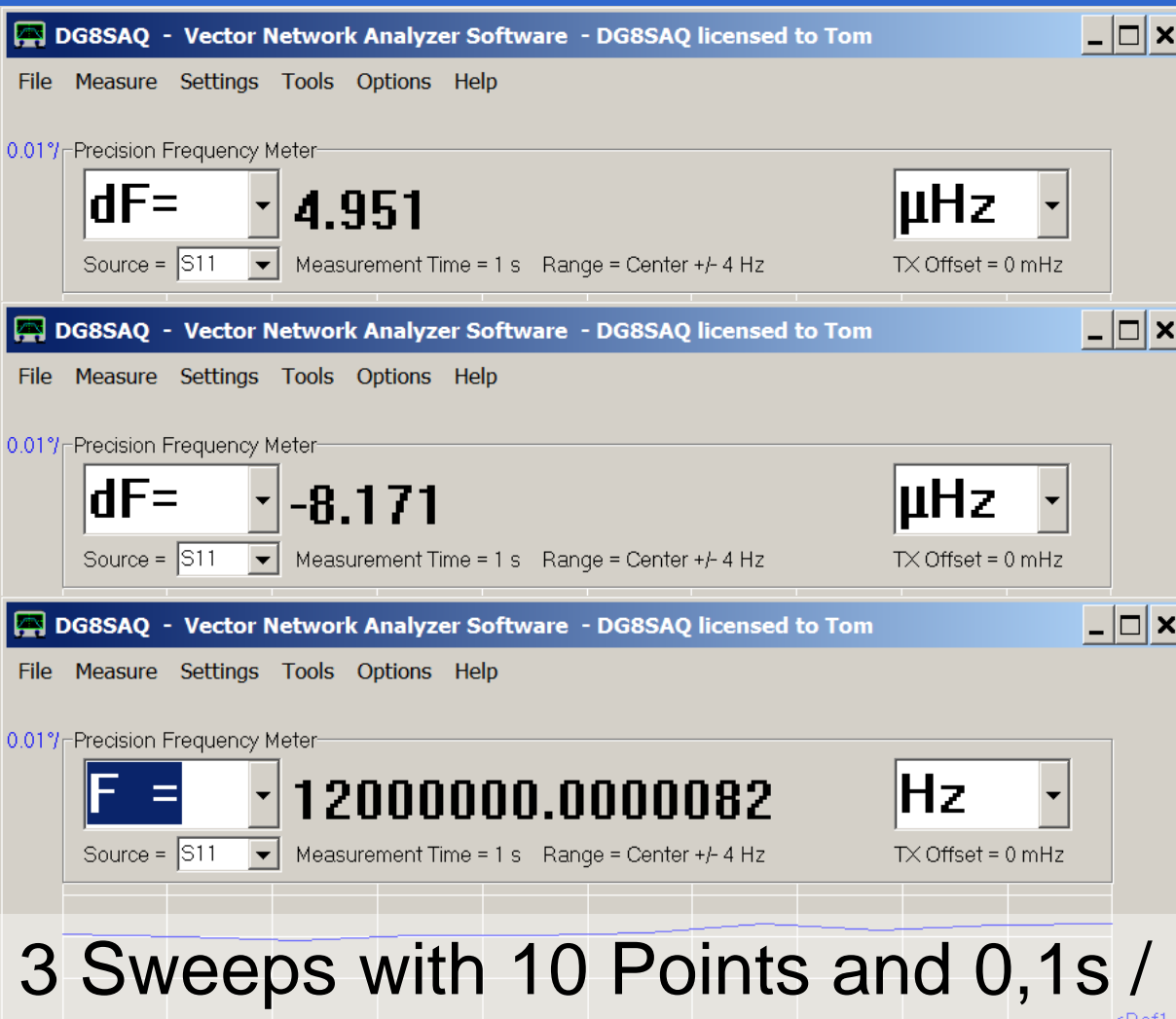
VNWA3 as Phase Comparator



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

Frequency Comparison (2)

Measurement Accuracy



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

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Frequency Comparison (3)

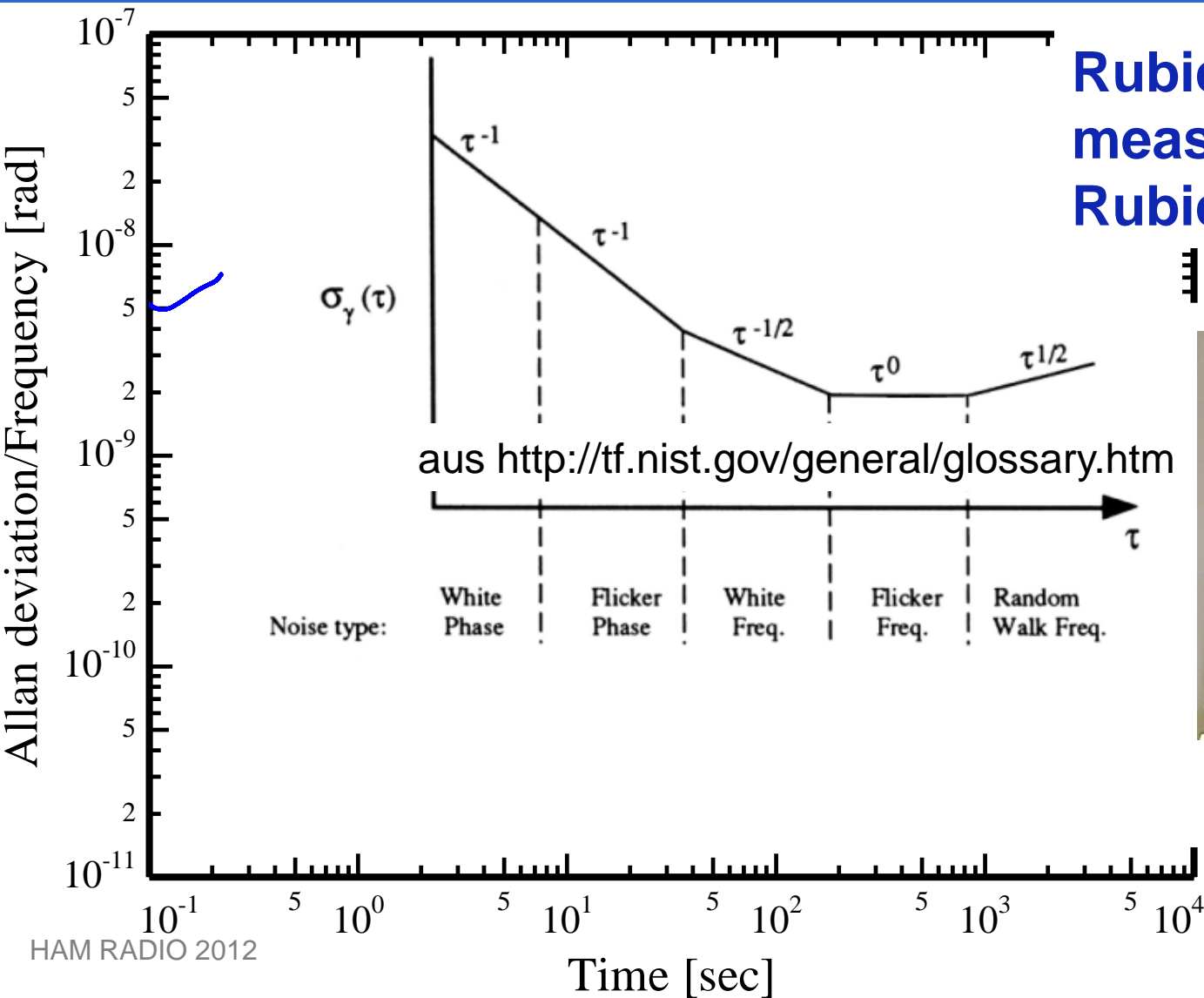
Rubidium 1 vs. Rubidium 2 over 260s



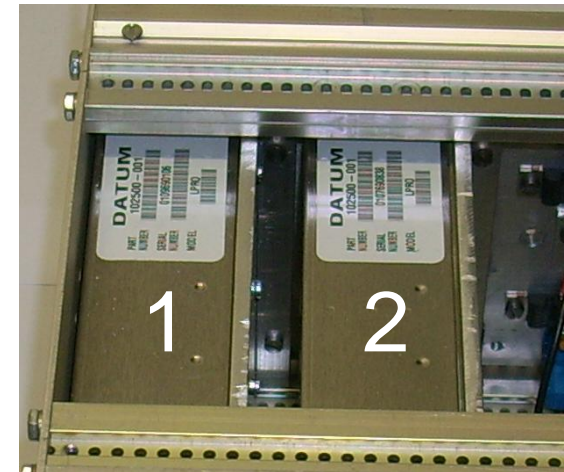
Deviation = -0,0025 Hz \pm 0,0003 Hz at 10 MHz
 $\equiv 2,5 \cdot 10^{-10}$

Frequency Comparison (4)

Allan Deviation from VNWA-Measurement



**Rubidium Standard 1
measured against
Rubidium Standard 2**

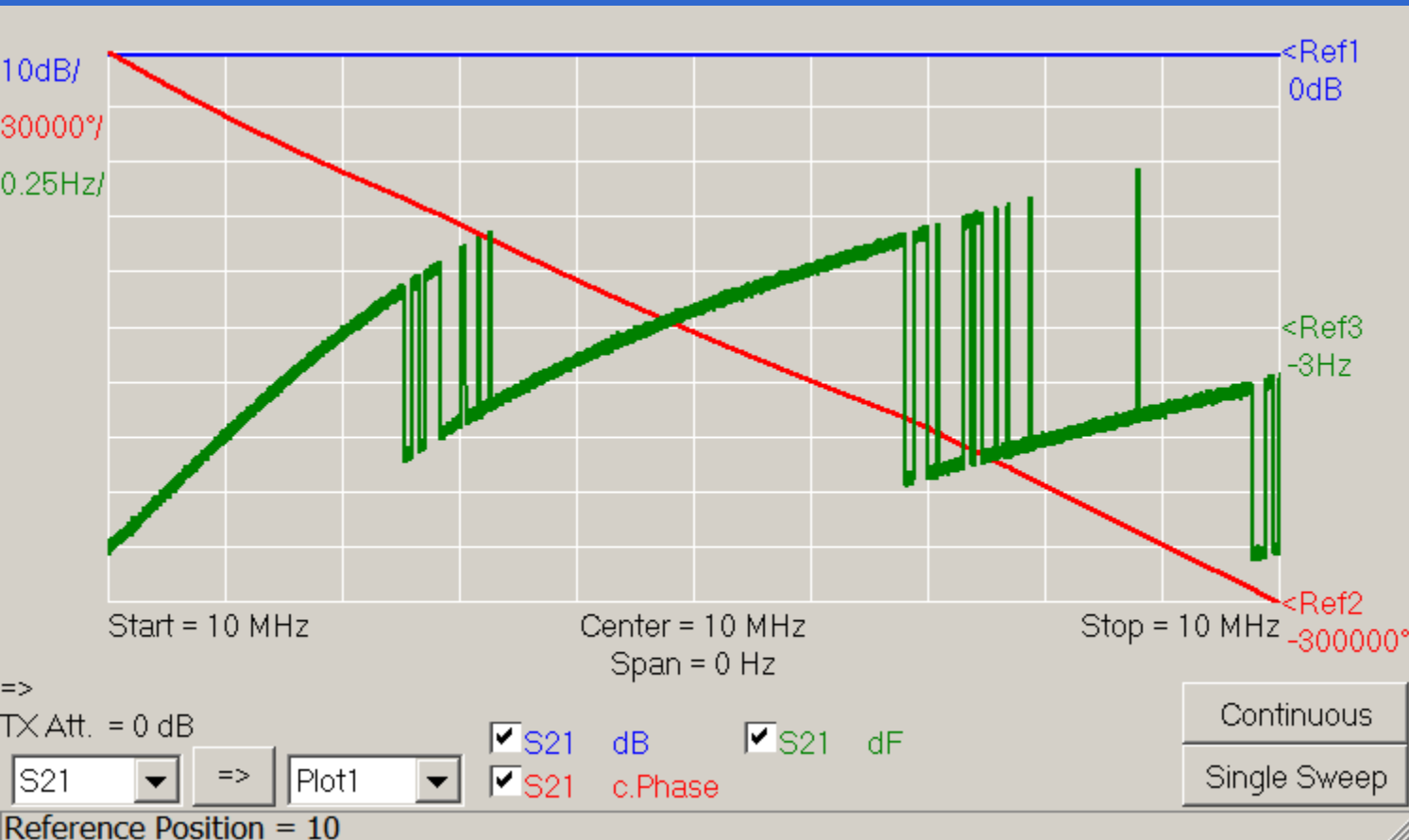


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Frequency Comparison (5)

Rubidium Standard vs. VNWA3 TCXO

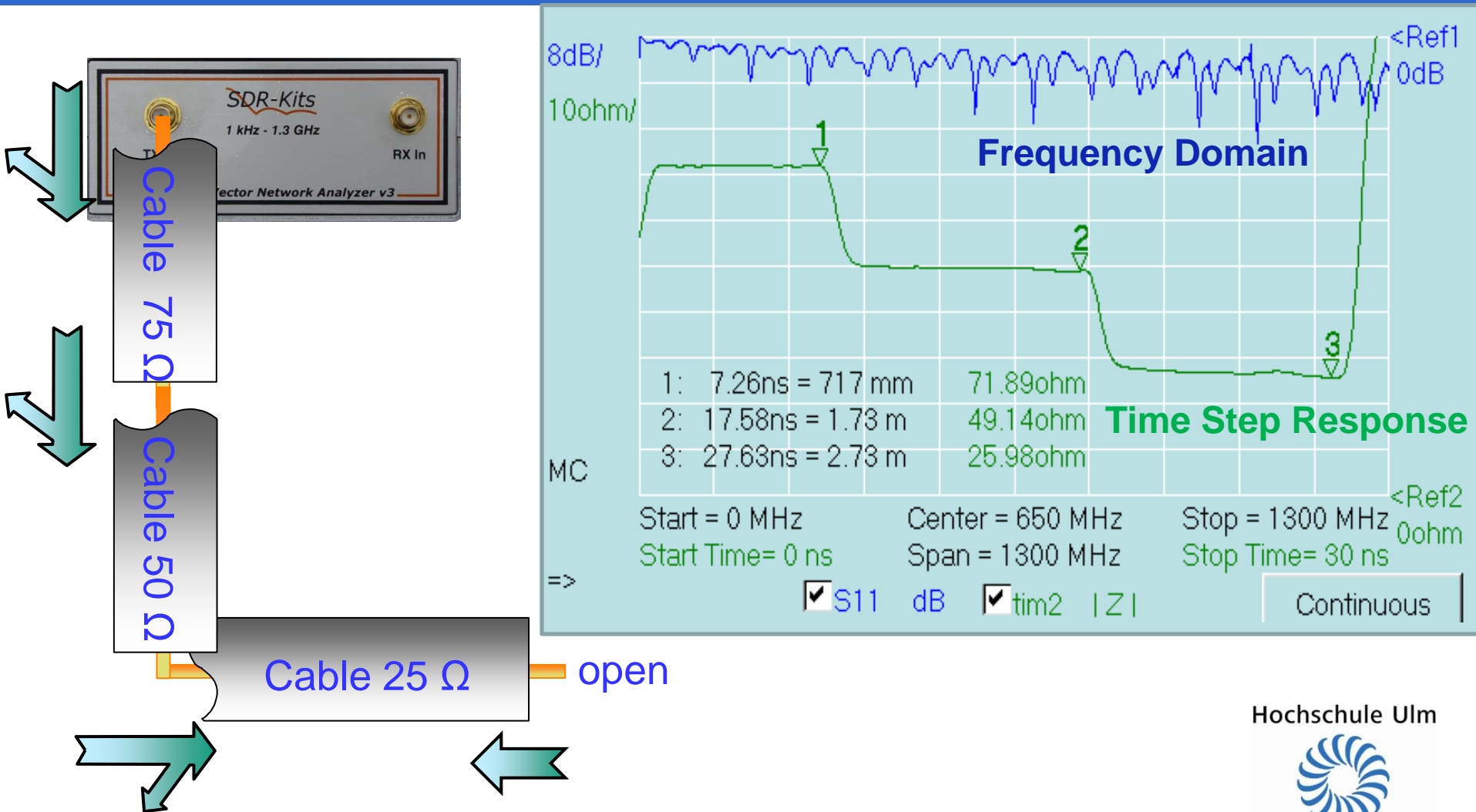


Deviation = -3 Hz \pm 1 Hz at 10 MHz \equiv -0,3 ppm

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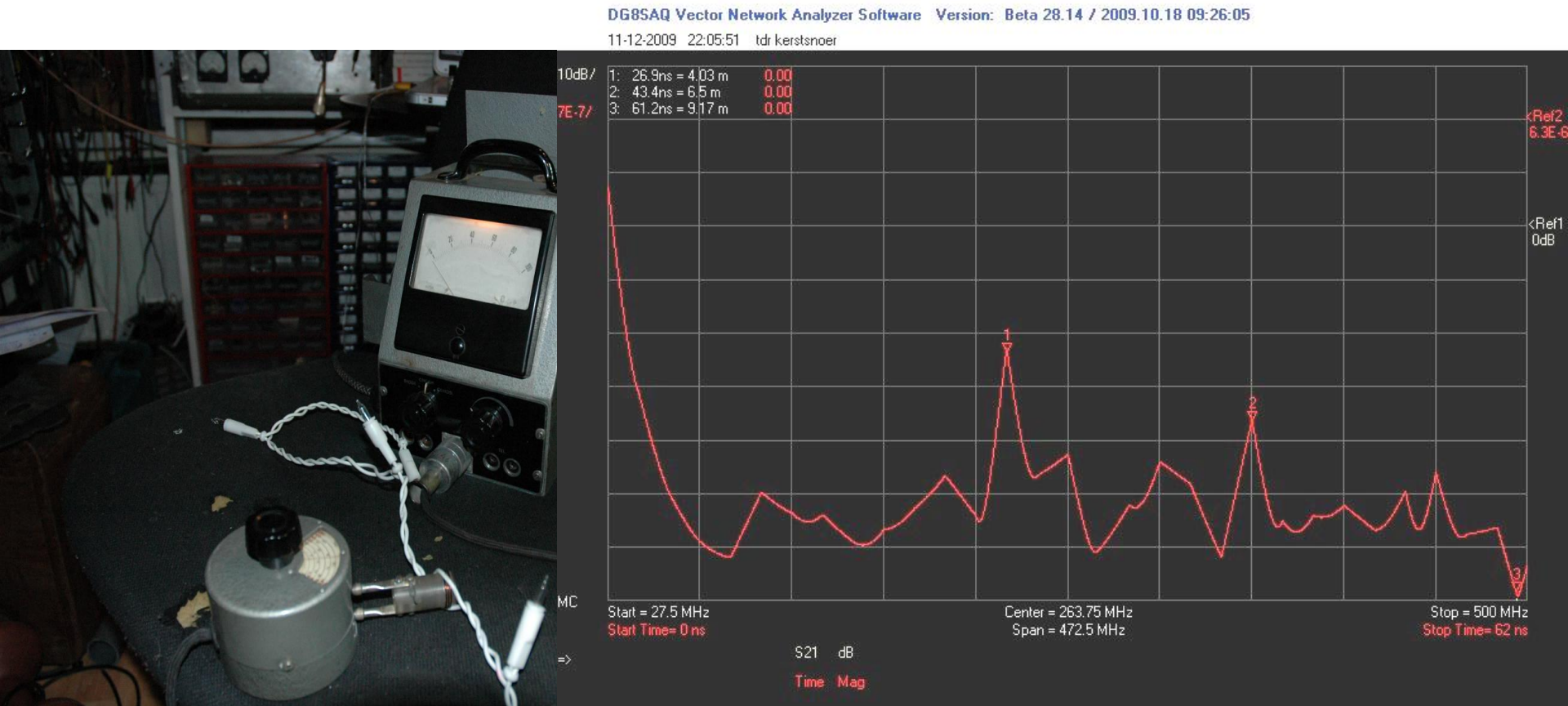


Application: Time Domain Analysis (1)



Time Domain Analysis (2)

Locate the faulty Christmas Tree Light Bulb !!



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

Application Example: Cavity Resonance (1)



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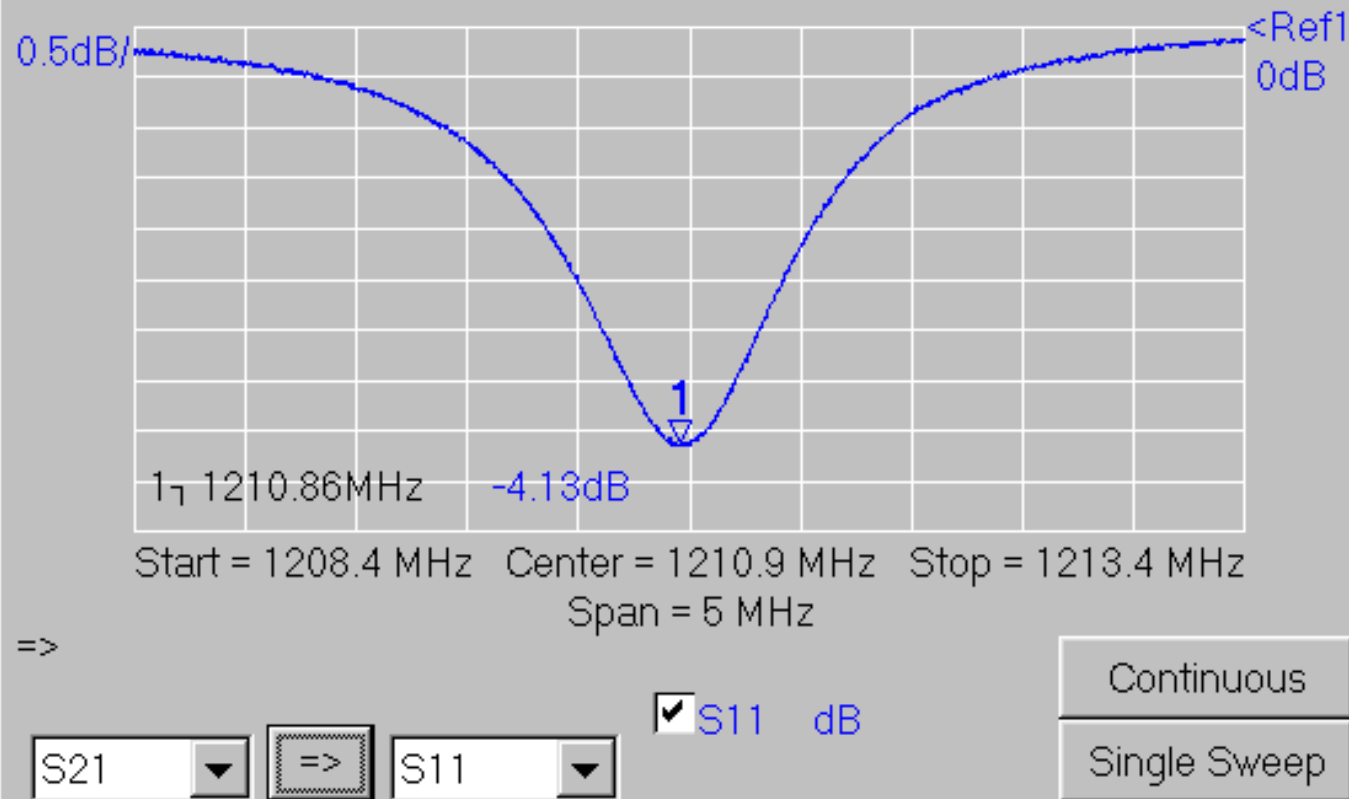
Cavity Resonance (2)

Lowest Resonance mode:

$$f = \frac{c_0}{2\pi r} J_{01} \approx \frac{3 \cdot 10^8 \text{ m/s}}{6,28 \cdot 9,5 \text{ cm}} \cdot 2,405$$
$$\approx 1209 \text{ MHz}$$

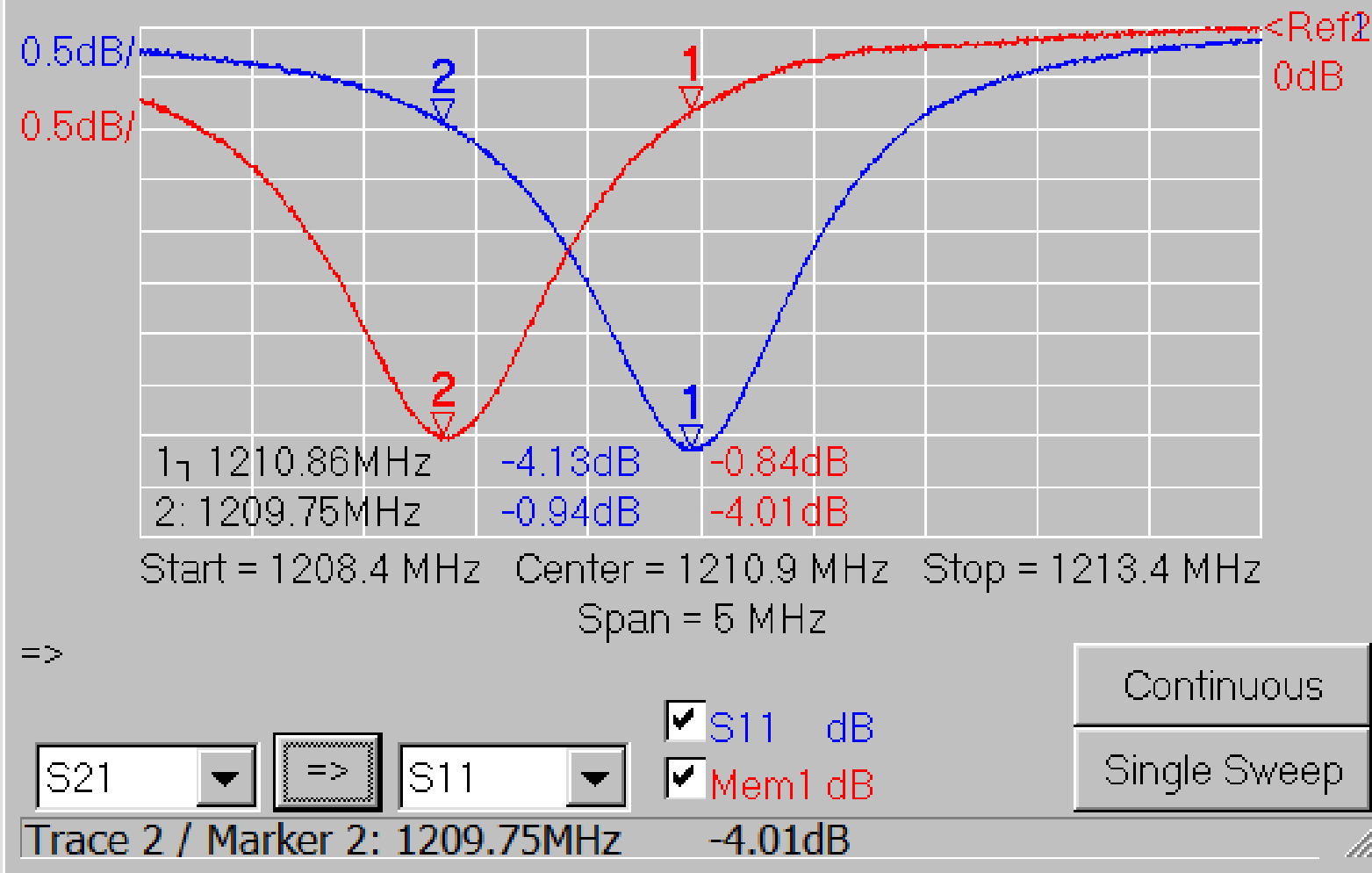
Cavity Resonance (3)

Lowest Resonance mode:



Cavity Resonance (4)

Empty
VS.
Filled



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

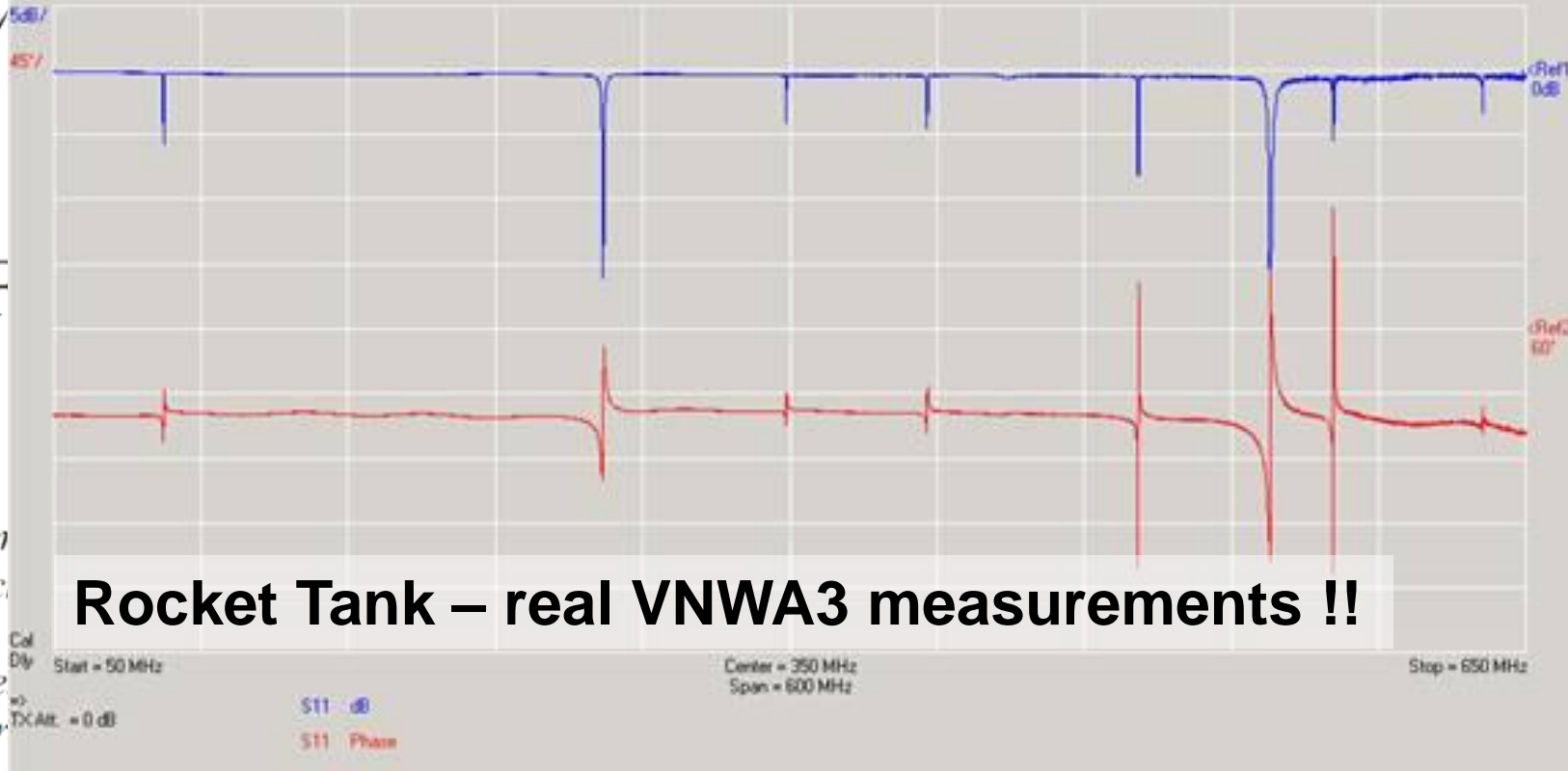
Gregory A. Zin
Glenn Research

Michael D. He
Analex Corpor

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

HAM RADIO 2012

DG8SAQ Vector Network Analyzer Software
12/12/2011 3:44:04 PM 20111212 op-settings: 50-650MHz 5000pts



Rocket Tank – real VNWA3 measurements !!



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Summary

- **The VNWA3 is a versatile Test Instrument**
- **Suitable for many - even - professional Applications!**

➡ **VNWA's are used on 5 Continents**

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 Lochrasterplatten aufgebaut und somit nur mit eingeschränkter Sicherheit reproduzierbar war, gibt es jetzt einen Bausatz.



Bild 1: Aufgebauter VNWA 2.3 mit Kugelschreiber zum Größenvergleich

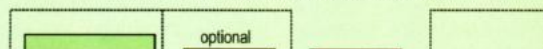
den Typen besser aufzuzeigen, folgt zunächst eine Beschreibung des grundsätzlichen Aufbaus eines skalaren Netzwerkanalysators (Bild 2). Kernelemente sind ein in der Frequenz gesteuerter Sinusgenerator mit konstantem Pegel und normalerweise 50 Ω Ausgangswiderstand. Gemessen werden die Signale mit einem im Allgemei-

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>

nen breitbandigen Pegeldetektor. So lassen sich die Übertragungsfunktion und am Netzwerkeingang das Stehwell-

Aufbau eines skalaren Netzwerkanalysators



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
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Bild 1: Aufgebauter VNWA 2.3 mit Kugelschreiber zum Größenvergleich

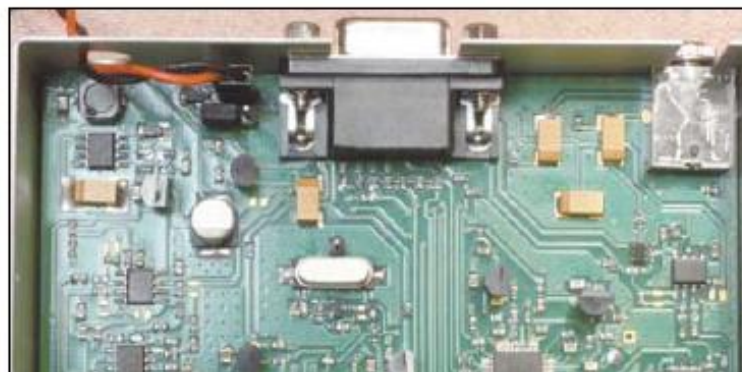
den Type
zunächst
grundsätz
Netzwerk
Kernelem
gesteuert
tantem P
Ausgangs
den die S

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 progetto è presente in numero di



The VNWA3 is in use all over the World..

GERÄTE

Messungen mit dem Vektor-Netzwerk

Netzwerkanalys

Dr.-Ing. Bodo

In [1] hat The
Netzwerkanal
Während die
Lochrasterpla
Sicherheit reg

LABORATORIO-STRUMENTAZIONE

di Vittorio Carboni I6DVX

Un accurato e prezioso strumento: VNWA2

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 S21 sono effettuate scambiando periodicamente l'ingresso e l'uscita del dispositivo in misura.

La versione attuale del software permette di realizzare una gestione esterna delle portate, le ultime versioni del software permettono di realizzare i quarzi ricambiando automaticamente tutti i parametri. Inoltre è prevista la possibilità di usare il VNWA2 come generatore di spettro. Tutte le operazioni vengono fornite con le istruzioni del software di installazione e sicuramente oggi, con queste note sono lette, la possibilità di misure si aggiunge a quelle qui in-

tema a blocchi è visibile in figura 1. La generazione del segnale RF è demandata all'oscillatore DDS, che in questo modo è presente in un unico

Ankieta czytelników „Świata Radio” (str. 65)

INDEKS 332739 ISSN 1425-1701

świat radio 6/2010

Magazyn wszystkich użytkowników eteru
KRÓTKOFALARSTWO CB RADIOTECHNIKA

wewnątrz

KRÓTKOFALOWIEC
POLSKI



nr 6 (545)/2010

9,80 zł

W tym VAT 20%

nakład: 14 500 egz.



Bild 1: Aufgebaute VNWA 2.3 mit Kugelschalter
gleich

in Metro

Wouxun
KG-UV1P



Analizator wektorowy
do 1,3 GHz



The VNWA3 is in use all over the World.

GERÄTE

Messungen mit dem Vektor-Netzwerk

Netzwerkanalyse

LABORATORIO-STRUMENTAZIONE

di Vittorio Carboni I6DVX

Un accurato e prezioso

EQUIPMENT REVIEW

SAM JEWELL, G4DDK ♦ E-MAIL: SAM@G4DDK.COM

DECEMBER 2011 ♦ RADCOM

DG8SAQ VNWA3 Vector Network Analyser

A compact and versatile unit that measures S parameters, VSWR, reactance and Q up to 1.3GHz



Bild 1: Aufgebaute VNWA3
gleich



PHOTO 1: The front panel of the VNWA3 with

Packard 8753C vector network analyser and S parameter test set, but this combination is large and heavy – definitely not a portable setup. When RadCom asked me if I would like to review the new DG8SAQ VNWA3, I immediately accepted the offer as I had already been thinking about purchasing something similar for use in the field, having tried a number of other small analysers. I was particularly keen to see how well the VNWA3 results compared with my own analyser.

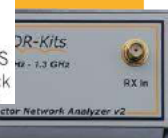
to the host computer. A red LED, visible through a hole on the rear panel, indicates that the unit is powered. Photo 2 shows the rear panel of the analyser.

The VNWA uses two Analog Devices AD9859 direct digital synthesisers (DDS). One is used to generate an RF test signal (stimulus) whilst the second generates the test receiver local oscillator signal. These DDS chips specify a maximum 400MHz core clock frequency. However in this application, both

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 periodicamente l'ingresso e l'uscita del dispositivo in misura oppure realizzando una connessione esterna delle portate. Le ultime versioni del software di gestione permettono di utilizzare i quarzi ricambiando automaticamente tutti i parametri. Inoltre è prevista la possibilità di utilizzare il VNWA2 come generatore di spettro. Tutte le operazioni vengono fornite dal software di gestione e sicuramente oggi, con queste note sono lette, la possibilità di misure si aggiunge a quelle qui in-



14 500 egz.



Analizator wektorowy
do 1,3 GHz



The VNWA3 is in use all over the World.

GERÄTE

Messungen mit dem Vektor-Netzwerk

Netzwerk

EQUIPMENT REVIEW

DG8S
Vector

A compact
VSWR, re



Bild 1: Aufgebaute VNWA2 gleich



PHOTO 1: The front panel

LABORATORIO-STRUMENTAZIONE

di Vittorio Carboni I6DVX

In accurately e prezioso

製作&実験



USB 接続で使える 1k ~ 1.3 GHz までの
低価格ベクトル・ネットワーク・アナライザ

“VNWA2”キットの製作・試用記

西村 芳一

Yoshikazu Nishimura

VNWA2 とは？

■ ベクトル・ネットワーク・アナライザ(VNA)は高額の花

ちょっとした高周波回路を試作するとき、ネットワーク・アナライザが手元にあるのとないのとでは大違いです。とくにマイクロ波などのインピーダンス・マッチングでは、強力なツールとなります。

しかしながら、ネットワーク・アナライザはとて大変価を測定器で、しかもナシロスコープのような稼動

トワーク・アナライザの製作記事でした。しかも、パソコンとUSBケーブル1本だけでつながり、電源もUSBから供給します。写真1にその外観、パソコンと組み合わせた全体の様子を写真2にそれぞれ示します。

普通のネットワーク・アナライザはとて大きくて重い測定器で、例えば写真3は仕事で使っているアンリツのネットワーク・アナライザですが、気軽に持ち歩くことは不可能です。



Analizator wektorowy
do 1,3 GHz

sostanza consente di misurare i parametri S: S11, S12, S21, S22. R. Dei singoli componenti misurare: resistenza, ammettenza, capacità, induttanza e fattibilità (Q). Le misure S12 sono effettuate scambiando periodicamente l'ingresso e l'uscita del dispositivo in misura. Inoltre, realizzando una connessione esterna delle porte, le ultime versioni del software permettono di misurare i quarzi ricambiando automaticamente tutti i parametri. Inoltre, è prevista la possibilità di usare il VNWA2 come analizzatore di spettro. Tutte queste operazioni vengono fornite dalle elaborazioni del software di base e sicuramente oggi, leggendo queste note, sono lette, la possibilità di misure si aggiunge a quelle qui in-

tema a blocchi è visibile in figura 1. La generazione dei segnali RF è demandata all'oscillatore DDS, che in questo modo è possibile misurare di



Finally, ... a Warning: VNWA's are Addictive!

Do I get this right? You tell your wife:
"Sorry dear, not tonight. I have a head-
ache" and then you can sit all night and
work with your Vector Network Analyzer!?!

Dipl. Psychologe

dra. Oron

OMICRON
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