

The nanoVNA ... from theory to practice!



UBA Section OST – Luc ON7DQ

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Preface

- Time is short ... some things will be explained in a “simple” way, so not always scientifically correct ... still too difficult ?
→ *Close your eyes, sit back and relax ...*
- Minimal use of math or formulas, but we can't do without some essential ones
- Only basic nanoVNA with standard firmware is discussed
- Halfway ... BREAK ! ... You will need a drink !
- Powerpoint presentation will be available for download
- At the end : lots of links to websites, videos and software

Content

- Some basics (actually ... a lot !)

Complex impedance and admittance, Transmission Lines, Reflection Coefficient, Return Loss, SWR, S-parameters, the Smith Chart

- Measuring is knowing

- What is a Vector Network Analyzer ?
- Functioning, calibration and capabilities of the nanoVNA
- Connecting to a PC: using the nanoVNA Saver program
- extra features of the nanoVNA

- Just do it !

- Practical examples:
measurements on cables, antennas, filters, components ...



Basic stuff - Complex Impedance

We know : **R, L & C** : in series : add R's, add L's \leftrightarrow in parallel : add C's

Combination of R, L & C \rightarrow **COMPLEX IMPEDANCE** $Z = R + j.X$ in Ohm (Ω)

Reactances also in Ω

Real (Re) and Imaginary (Im) part

with $\omega = 2 \cdot \pi \cdot f$ (angular velocity)

$$X_L = \omega \cdot L$$

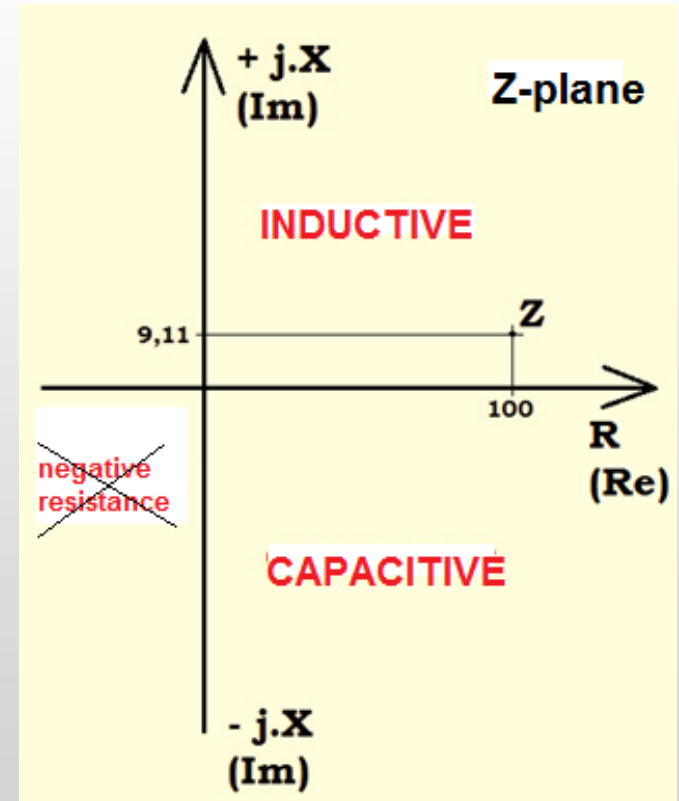
$$X_C = - \frac{1}{\omega \cdot C}$$

e.g. $R = 100 \Omega$, in series with $L = 10 \text{ nH}$,
at $145 \text{ MHz} \rightarrow Z = 100 + j.9,11$

Let's put this in a x/y GRAPH \rightarrow

Question :

Where would one draw $Z = 1000 + j.500$???
(solution is in the Smith Chart ... wait a while ...)



Complex Impedance

- Where do we encounter complex impedances ?
 - Transmission Lines (cables)
 - Components
 - Antennas
 - Filters
 - Amplifiers ... they all can present a **complex impedance** !



- **ADMITTANCE** $Y = \frac{1}{Z} = \frac{1}{R + j.X} = G + j.B$ unit **S** (Siemens)*
(*in USA : mho)
[G = the “conductance” , B = the “susceptance”]

Useful in parallel circuits : just add the admittances !

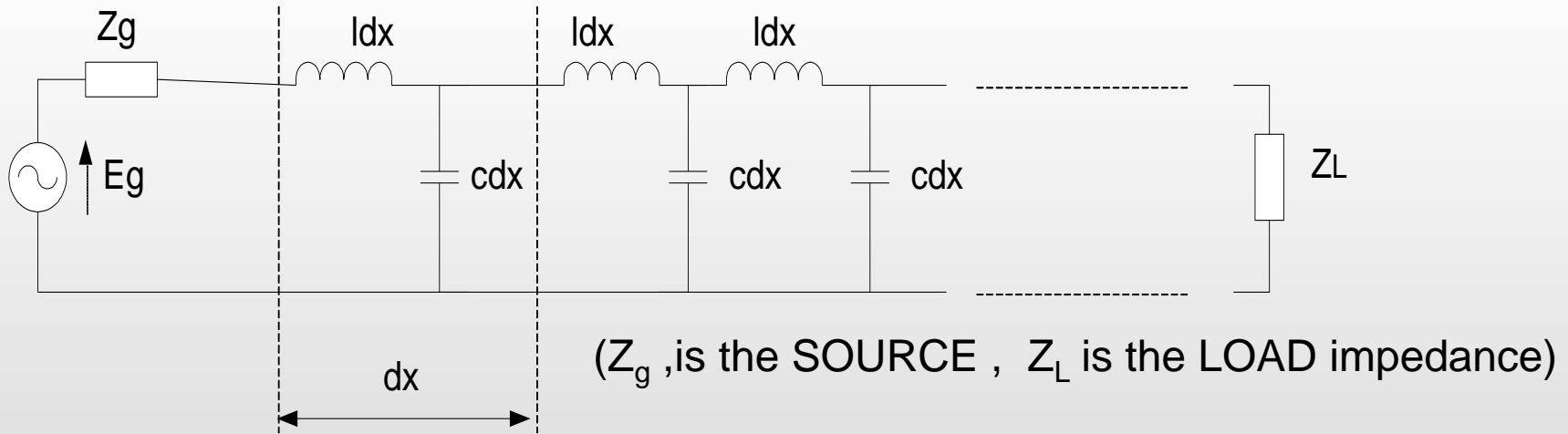
e.g. $R = 150 \Omega$ in parallel with $C = 100 \text{ pF}$, at 28 MHz

$Y = 1/R + j.2.\pi.f.C = 0,0066 + j.0,0176 \text{ S} \rightarrow$ but $Z = 1/Y = ??$ Wait a while ...
(\uparrow NOTE : capacitive susceptance = positive !)

Transmission Lines (TL)

Consider an **ideal** TL : it has NO LOSS, and can be drawn as a cascade of small L/C cells (dx is a small unit of distance) :

e.g. for RG-58 : $l = 250 \text{ nH/m}$ and $c = 100 \text{ pF/m}$



Every cable has a **characteristic impedance Z_0**

$$Z_0 = \sqrt{\frac{l}{c}} \quad (\text{e.g. } 50 \Omega, 75 \Omega)$$

TL – Velocity Factor

Radio waves travel in free space at what speed ? ...

→ the speed of light $v_0 = 300.000$ km/s

Waves in a TL go much slower ... (due to phase shift in the L/C cells), typically 66% of v_0 , or 200.000 km/s

→ the **velocity factor** is **$k = 0,66$** (*USA : VF)

It depends on the dielectric constant ϵ_r of the insulating material

$$\text{and } k = \frac{1}{\sqrt{\epsilon_r}} \quad \text{e.g. if } k = 0,66, \epsilon_r = 2,30$$

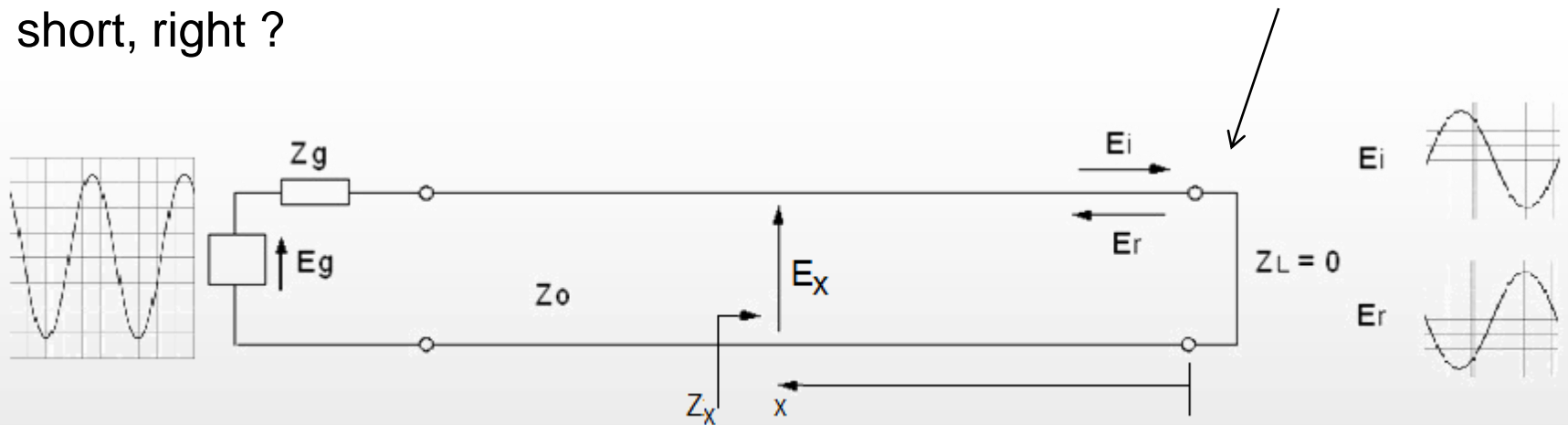
the “**g**uided wavelength” is $\lambda_g = k \cdot \lambda_0$ (with λ_0 : the wavelength in free space = v_0/f) → so **k** is also a “**shortening**” factor

e.g. How long is a piece of RG-58 to obtain a $\lambda/4$ in the 2m band ?

Answer : +/- 34 cm , not 50 cm !

„Waves“ in a TL ... and „Reflections“

e.g. : the load is a SHORT ... we all know there can't be any voltage on a short, right ?



E_i = incident wave, E_r = reflected wave

E_x is the sum, at Z_L it's always ZERO, but not so in other places, it depends on amplitude & phase of E_i and E_r in those places

And so ... also the impedance Z_x can be any value !

... Involves complex math, but ... → We'll leave that to a PC program !

Three ways to express how bad the “mismatch” is

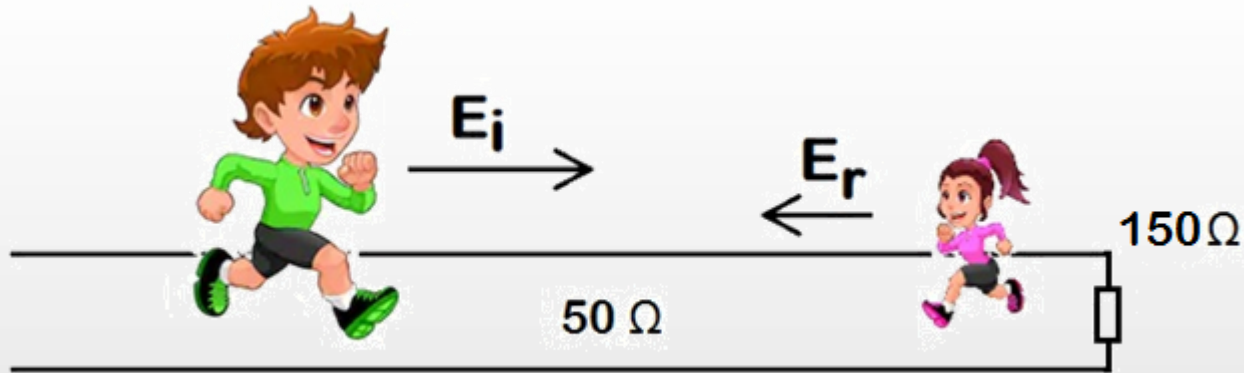
Reflection Coefficient

Return Loss

(V)SWR

Reflection Coefficient : how much reflected voltage ?

- the load (e.g. a $150\ \Omega$ antenna) is not “matched” to the cable (e.g. a coax with $Z_0 = 50\ \Omega$). There will be reflections !



- We want to express in one number how much voltage is reflected, and not only the **magnitude**, but also the **phase** : the **reflection coefficient** : Γ_x (gamma)

- $\Gamma_x = \frac{E_r}{E_i}$ It is a **complex** number : $|\Gamma_L| = 0$ to 1 (**0,05 is GOOD**)
and $\angle \Gamma_L = 0^\circ$ to 360°

Reflection Coefficient

- At the load Z_L we have : $\Gamma_L = \frac{Z_L - Z_0}{Z_L + Z_0}$
- For the same example as before : $\Gamma_L = \frac{150 - 50}{150 + 50} = \frac{100}{200} = 0,5 \angle 0^\circ$
or 50% of the voltage is reflected, and in phase
- Some special cases :
 - Short circuit** : $Z_L = 0 \rightarrow \Gamma_L = -1$, all voltage is reflected , 180° out of phase
 - Open circuit** : $Z_L = \infty \rightarrow \Gamma_L = +1$, all voltage is reflected , in phase
(and the LOAD will have DOUBLE voltage !)
 - Matched condition** : $Z_L = Z_0 \rightarrow \Gamma_L = 0$, no reflected voltage at all
- The reflection coefficient will be the basis for the **Smith Chart**

Measuring in dB ? ... the Return Loss (RL)

- We send a wave along a TL ... some of it will return, we hope it is LESS than what we sent, hi ...

How many **dB** will that reflection be LOWER than the incident wave ?

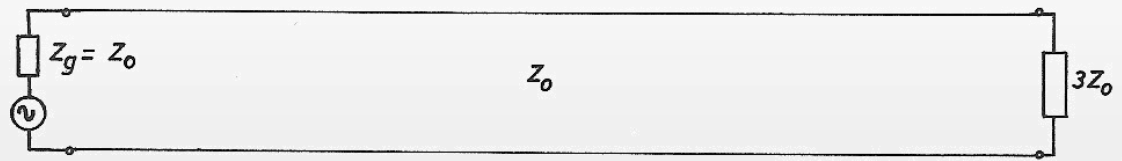
This is the RETURN LOSS $RL = 20 \cdot \log (|\Gamma_x|)$

- NOT a complex number, and always **negative** !
(Some (e.g. HP ;-) may say it's *positive ... well, tomato - tomato*)
- At full reflection : $RL = 0$ dB
- No reflection : $RL = -\infty$ dB
- Who can measure $= -\infty$ dB ?
Not possible \rightarrow limit = internal equipment noise
- **RL = -26 dB is GOOD**
- For our example : $RL = 20 \cdot \log (0,5) = -6$ dB



Amateurs are most familiar with „SWR“ , but what is it ?

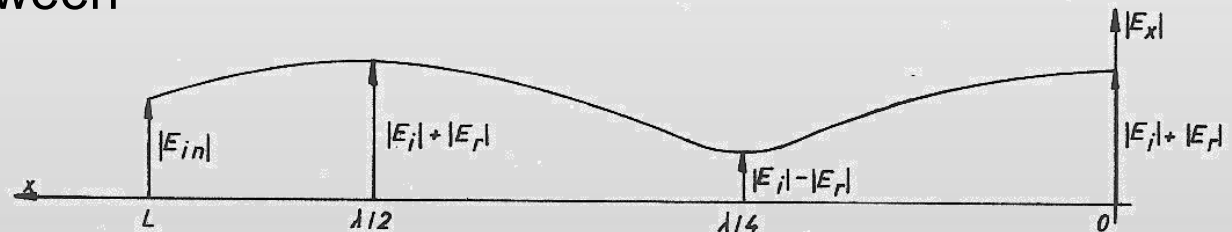
- “**Standing Waves**” are a misnomer , our waves are always on the move ! (E_i and E_r are both **travelling** waves)
BUT ... the combination of two travelling waves makes a **stationary** “**voltage pattern**” with nodes and anti-nodes in fixed locations
- Total voltage is always ‘maximum’, ‘minimum’ or something in between
e.g. $Z_L = 3 \cdot Z_0$
then $\Gamma_L = 0,5$
(50% reflects, in phase)



here : vector →

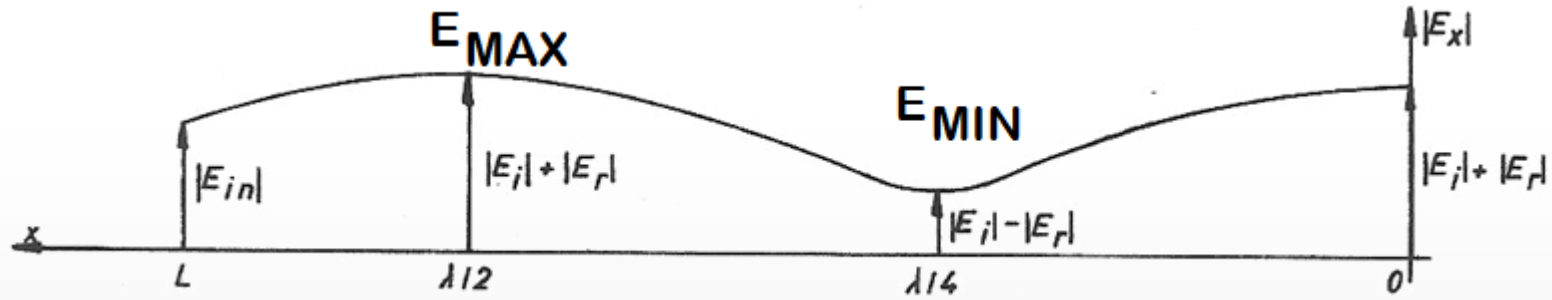


- the **sum** E_x varies between $0,5 \cdot E_i$ and $1,5 \cdot E_i$
e.g. if $E_i = 1V$, then $E_x = 0,5$ to $1,5 V$
here : modulus →



- Note : E_i rotates CCW, E_r rotates CW, when moving from load to source

The Standing Wave Ratio or VSWR or for short : SWR



(Voltage) Standing Wave Ratio or $SWR = \sigma = \frac{E_{MAX}}{E_{MIN}}$ ($\sigma = \text{sigma}$)

In our example $E_{MAX} = 1,5 \text{ V}$, $E_{MIN} = 0,5 \text{ V}$, **SWR = 3** (NOT 3:1 ... who invented that ?)
 SWR is always a REAL number, varies from 1 (no reflection) to ... $+\infty$ (full reflection)
 (and 1,11 is GOOD)

Now have you ever ... our “SWR meter” does NOT measure SWR at all !!
 It would require measuring voltage at two separate locations along the line
 (it can be done with a “slotted line”)

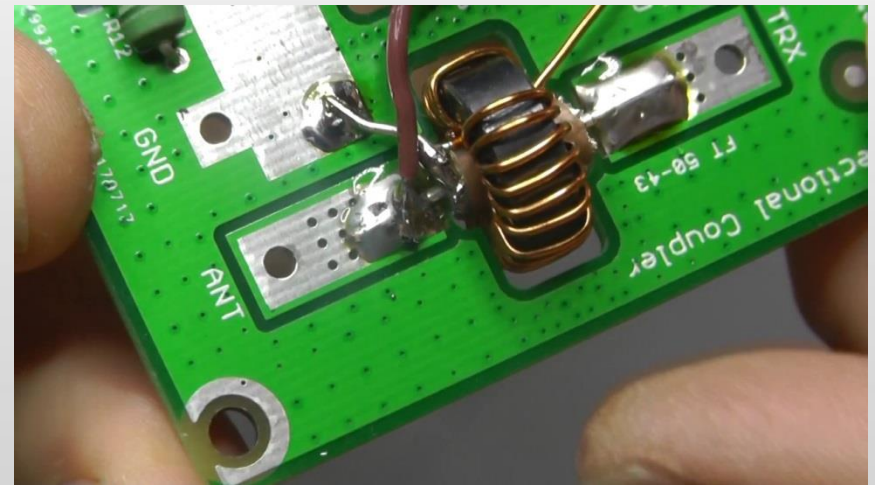
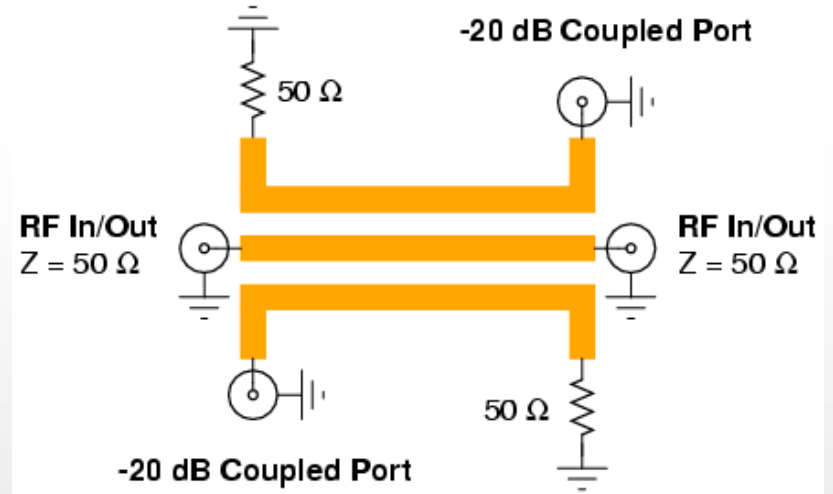
We actually measure the *modulus* of the reflection coefficient ($|\Gamma_L|$) with a “directional coupler” or a resistive “bridge” ... and have a **scale** calibrated for SWR

(with this formula : $SWR = \frac{1+|\Gamma_L|}{1-|\Gamma_L|}$)

Typical SWR meter ...

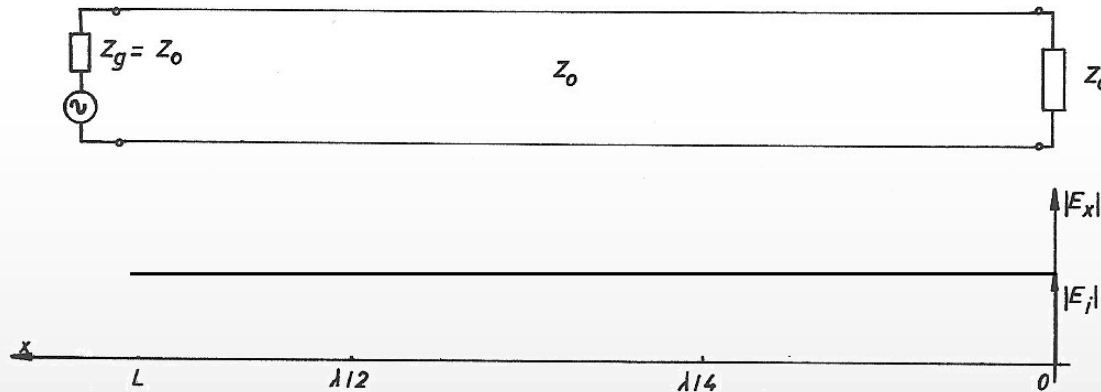


and some directional couplers



e.g. Google “Bruene bridge” ... ←

SWR at matched condition ... $Z_L = Z_0$



No reflection , and no maximum or minimum voltage
or $E_{MAX} = E_{MIN} = E_i$ and so **SWR = 1**

Another handy trick ... IF Z_L is **purely resistive** (and only then !)

$$SWR = \frac{Z_L}{Z_0} \quad \text{or} \quad SWR = \frac{Z_0}{Z_L} \quad (\text{largest one is on top})$$

In our example : $SWR = 150/50 = 3$

Reflection Coefficient – Return Loss – SWR relations ?

Print this handy table – see link at the end (here RL is positive)

Return Loss to VSWR Conversion Table

Return Loss (dB)	VSWR	Reflection Coefficient, Γ	Mismatch Loss (dB)	Reflected Power (%)	Through Power (%)
1	17.39	0.891	6.868	79.43	20.57
2	8.72	0.794	4.329	63.10	36.90
3	5.85	0.708	3.021	50.12	49.88
4	4.42	0.631	2.205	39.81	60.19
5	3.57	0.562	1.651	31.62	68.38
6	3.01	0.501	1.256	25.12	74.88
7	2.61	0.447	0.967	19.95	80.05
8	2.32	0.398	0.749	15.85	84.15
9	2.10	0.355	0.584	12.59	87.41
10	1.92	0.316	0.458	10.00	90.00
11	1.78	0.282	0.359	7.94	92.06
12	1.67	0.251	0.283	6.31	93.69
13	1.58	0.224	0.223	5.01	94.99
14	1.50	0.200	0.176	3.98	96.02
15	1.43	0.178	0.140	3.16	96.84
16	1.38	0.158	0.110	2.51	97.49
17	1.33	0.141	0.088	2.00	98.00
18	1.29	0.126	0.069	1.58	98.42
19	1.25	0.112	0.055	1.26	98.74
20	1.22	0.100	0.044	1.00	99.00
21	1.20	0.089	0.035	0.79	99.21
22	1.17	0.079	0.027	0.63	99.37
23	1.15	0.071	0.022	0.50	99.50
24	1.13	0.063	0.017	0.40	99.60
25	1.12	0.056	0.014	0.32	99.68
26	1.11	0.050	0.011	0.25	99.75
27	1.09	0.045	0.009	0.20	99.80



S-Parameters (scattered parameters)

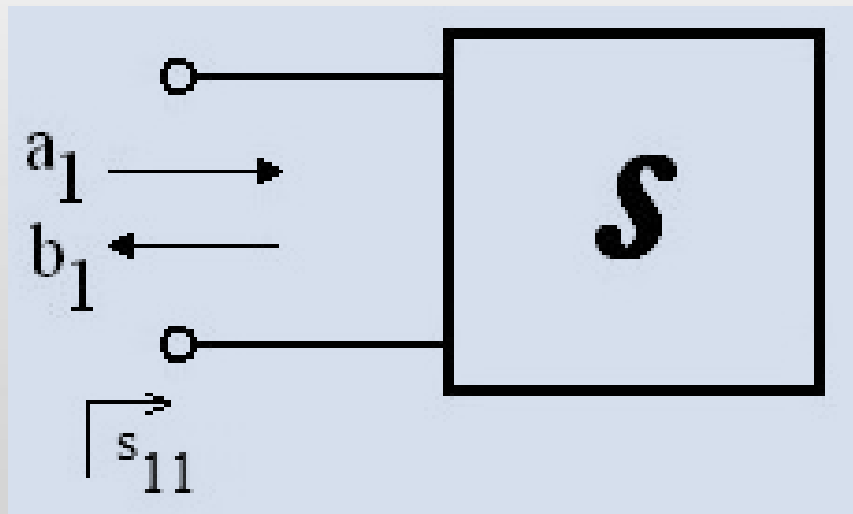
a = wave incident to the network

b = wave reflecting from the network

ONE-PORT : only one S-parameter : **S₁₁**

e.g. Antenna, Dummy Load, Component

$b_1 = S_{11} \cdot a_1$ or $S_{11} = b_1/a_1 = E_r/E_i =$ the complex reflection coefficient !



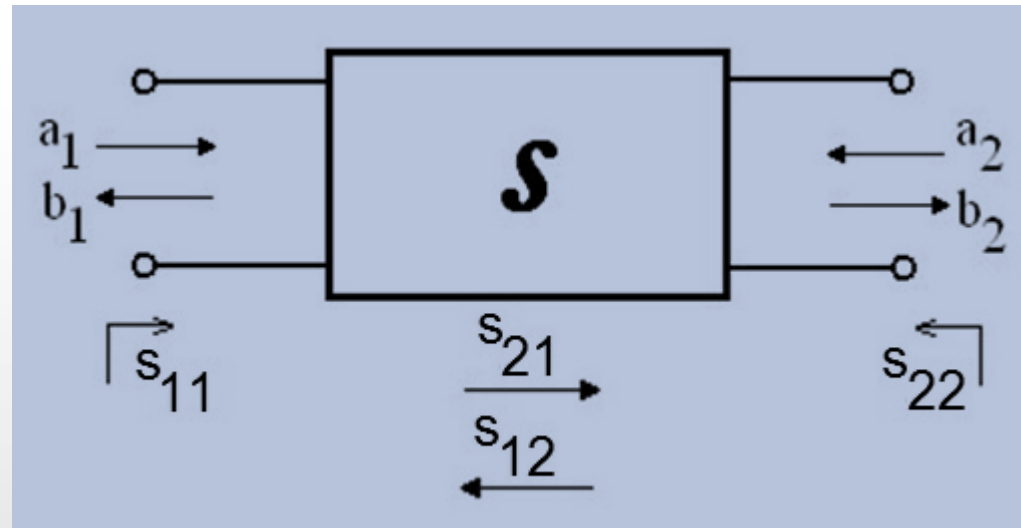
S-Parameters (scattered parameters)

TWO-PORT :

now we have 4 S-parameters !

$$b_1 = s_{11} \cdot a_1 + s_{12} \cdot a_2$$

$$b_2 = s_{21} \cdot a_1 + s_{22} \cdot a_2$$



Wat do they mean ?

S₁₁ = reflection coefficient at PORT 1 (while PORT 2 has a matched load)

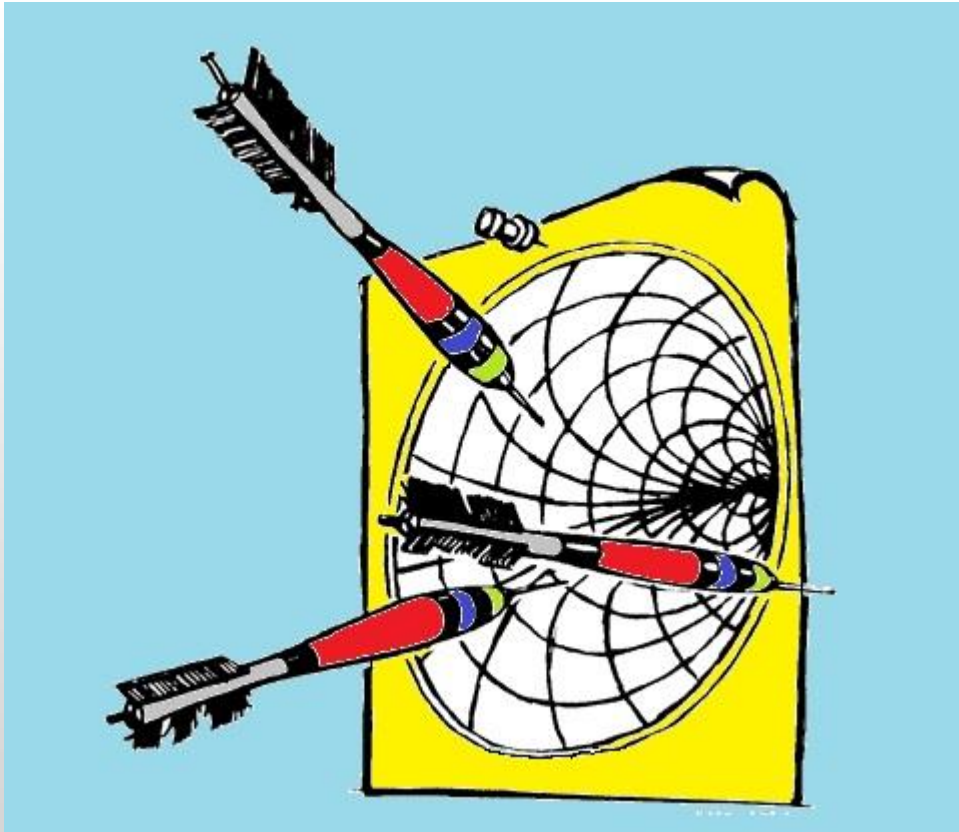
S₂₂ = reflection coefficient at PORT 2 (while PORT 1 has a matched load)

S₂₁ = the forward GAIN (but can be < 1, and always is for passive circuits)

S₁₂ = the reverse GAIN (most often < 1, and we hope so for amplifiers ;-)

Smith Chart

Is a graphical representation of Γ , impedances and admittances, and is a handy complex calculator



In the old days :

Paper chart, not easy to learn and use

Now :

Very easy to use program with an appropriate name :
SMITH !

Smith Chart

It will help us in designing a **MATCHING NETWORK**

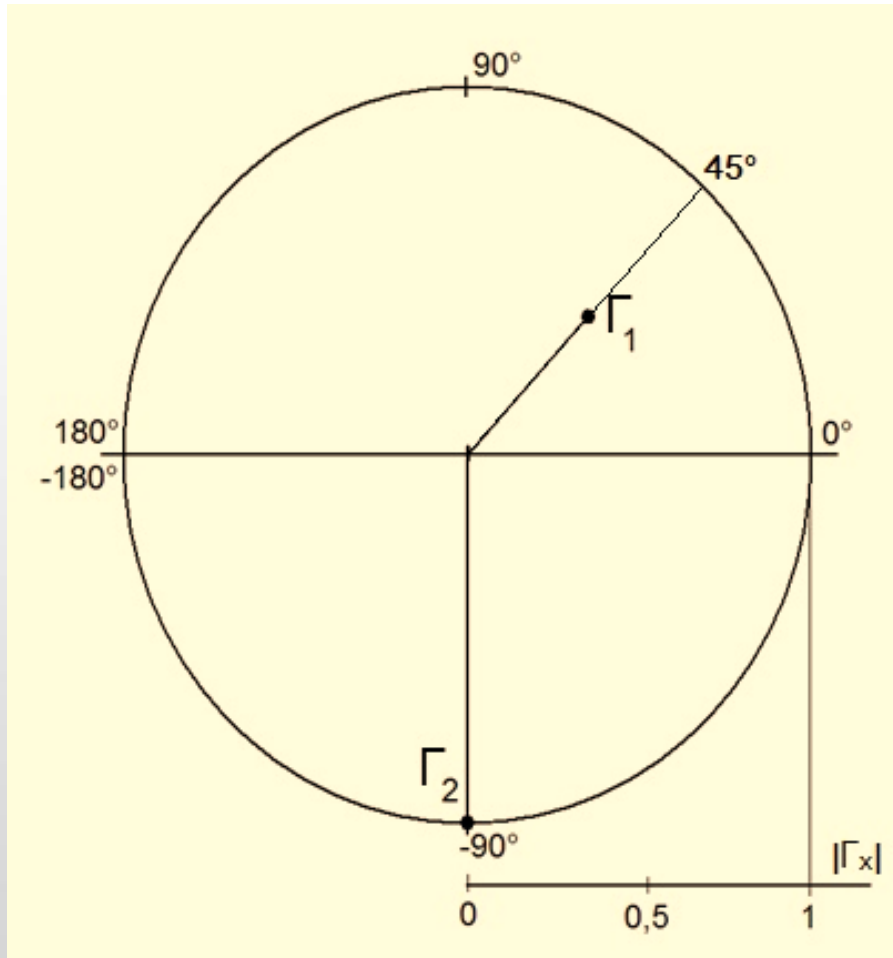
Why would we want to MATCH anyway ?

- Maximum power transfer
- Reflections disturb the stability of amplifiers, distort signals, etc.
- Standing Wave pattern may cause a breakdown in the dielectric at E_{MAX}
- Constant impedance along the line : lets you connect the source at any point

Possible techniques

- **lumped components (L/C)**, in series or in parallel → one example given
- $\lambda/4$ transformer (not now)
- TL in series (not now)
- stubs (not now)

Smith Chart is a reflection coefficient plane



We want to graph ALL possible values of the reflection-coefficient Γ_x

This results in a CLOSED DISK with radius = 1

$|\Gamma_x| = 0 \dots 1$ and $\angle \Gamma_x = 0 \dots 360^\circ$

e.g. $\Gamma_1 \cong 0,5 \angle 45^\circ \rightarrow$ SMITH

$\Gamma_2 = 1 \angle -90$

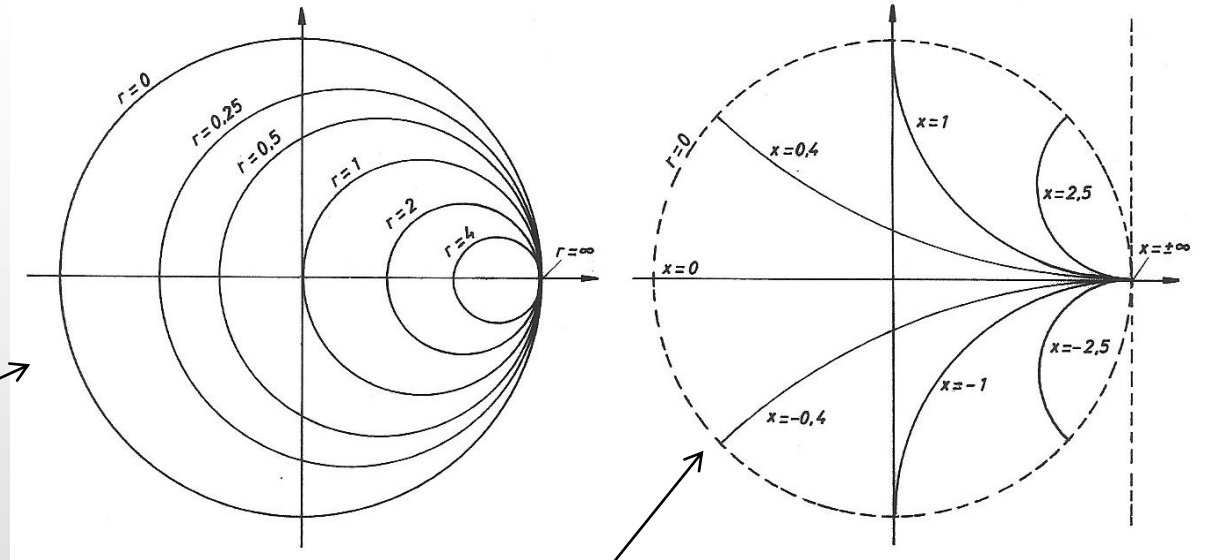


Smith Chart is also an impedance plane

To be able to plot all possible impedances, we use **NORMALIZATION**

Normalized impedance
(z in lower case)

$$\mathbf{z_L} = \frac{Z_L}{Z_0} = r_L + j.X_L$$



R-circles : all points having the same r-value

X-circles (arcs) : all points having the same x-value

Smith Chart : impedances

Special values on the Smith Chart :

The outside border, where $|\Gamma_L| = 1$, is where all purely inductive (upper half) or all purely capacitive (lower half) impedances are (and $r = 0$)

Horizontal axis is the r -axis
= all purely resistive impedances

On this line :

Left = short circuit

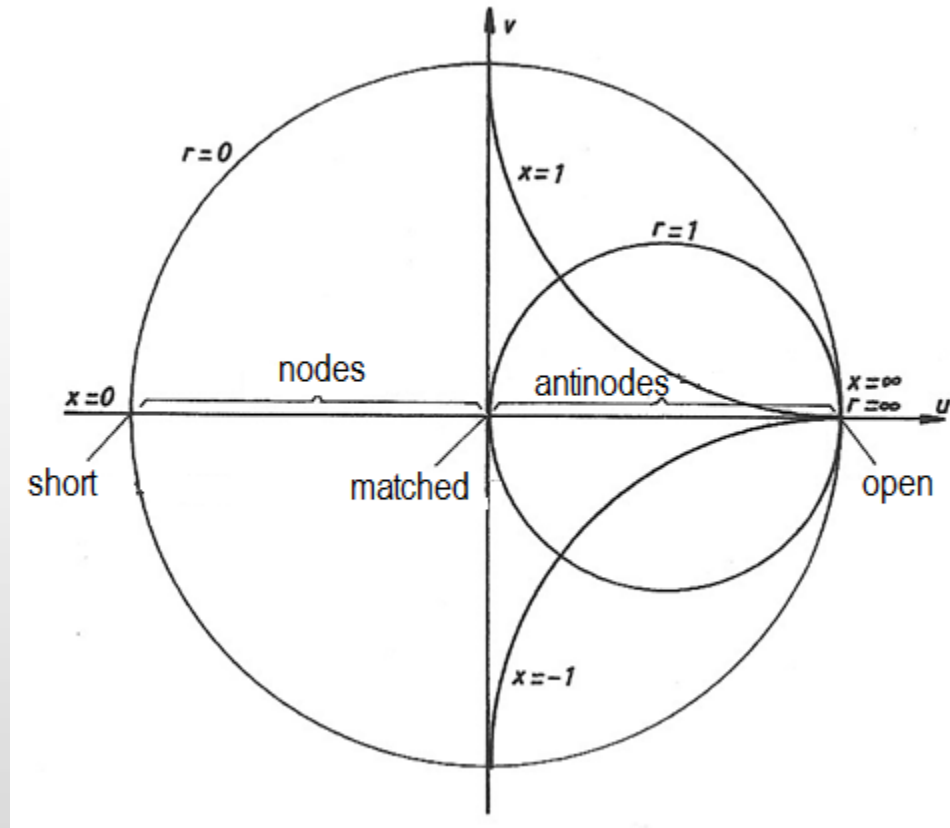
Right = open circuit

Center = matched, $Z_L = 1$

Nodes and antinodes :

NODE = lowest z or minimum voltage

ANTINODE = highest z or maximum voltage



Smith Chart : impedances

Why use normalization ?

Makes us independant of the “system” impedance

e.g. 100 Ω in a 50 Ω system ... $z = 100/50 = 2$

600 Ω in a 300 Ω system ... $z = 600/300 = 2 =$ the same point on chart !

e.g. : given : $Z_0 = 50 \Omega$, load $Z_L = 50 + j.70 \Omega$

where is this on the Smith Chart ?

→ SMITH



The SMITH program does all the normalization/de-normalization for us !

(see : SETTINGS → Default Z_0)

And now for that **1000 + j.500 Ω** ... no longer a problem ! → SMITH



Smith Chart : moving along the line

Moving along a TL, going from load \rightarrow source , E_i and E_r will have different phases with respect to each other (see standing waves slide).

In a lossless line, only phase of Γ_x will change, modulus remains constant
We make a **clockwise ROTATION** around the center point (z_0)

e.g. we move a quarter wave from the load Z_L

E_i and E_r will each change over 90° , and Γ_x will change a 180° , this is half a turn on the chart.

\rightarrow A full turn around the chart is ? ... **half wavelength** !

\rightarrow Application : use a **$n \times \lambda_g/2$** cable to measure an antenna : Z_{in} is again = Z_L

e.g. an antenna was measured as $Z_L = 50 + j.70 \Omega$ (INDUCTIVE),
what is the impedance at $\lambda_g/4$ away from the antenna ?

(note : now the velocity factor and the frequency are important)

Solution : $Z_{L2} = 17,2 - j.23,5 \Omega$

\rightarrow SMITH



And conclusion : now the impedance is CAPACITIVE !

Smith Chart : even more CIRCLES ?

In SMITH, make the **ADMITTANCE plane** visible

(Tools → Settings → Y-Plane (on/off))

Now we see the g-circles (conductance) and b-circles (susceptance)

BEWARE : an inductive impedance IS STILL an inductive admittance, but the sign for the reactive part will change ! ($+j \rightarrow -j$ or $-j \rightarrow +j$)

Constant **SWR Circles** : concentric circles around z_0

(Tools → Circles → SWR → tick the required boxes)

→ see SMITH



Smith Chart : add L or C, in series or in parallel

→ We do a **SHIFT** along an **r** (in series) or a **g** circle (in parallel)

Remember : L = “eLevate” = move UP (tnx W2AEW for this trick)
C = “Crash” = move DOWN

Example from a few slides ago :

R = 150 Ω , in parallel with C = 100 pF , at 28 MHz

Y was = 0,0066 + j.0,0176 S

But how to calculate Z = 1/Y ? It's really simple now → SMITH

Solution : Z \approx 19 - j.50 Ω



(see later : my “DUT” measures as 17,7 – j.47,6 Ω)



Let's make a matching network to 50 Ω , shall we ?

It's “poepsimpel”* with SMITH ! (solution : Lseries = 420 nH**, Cparallel 148 pF)

[* that's Dutch, try translating it with Google Translate, hi]

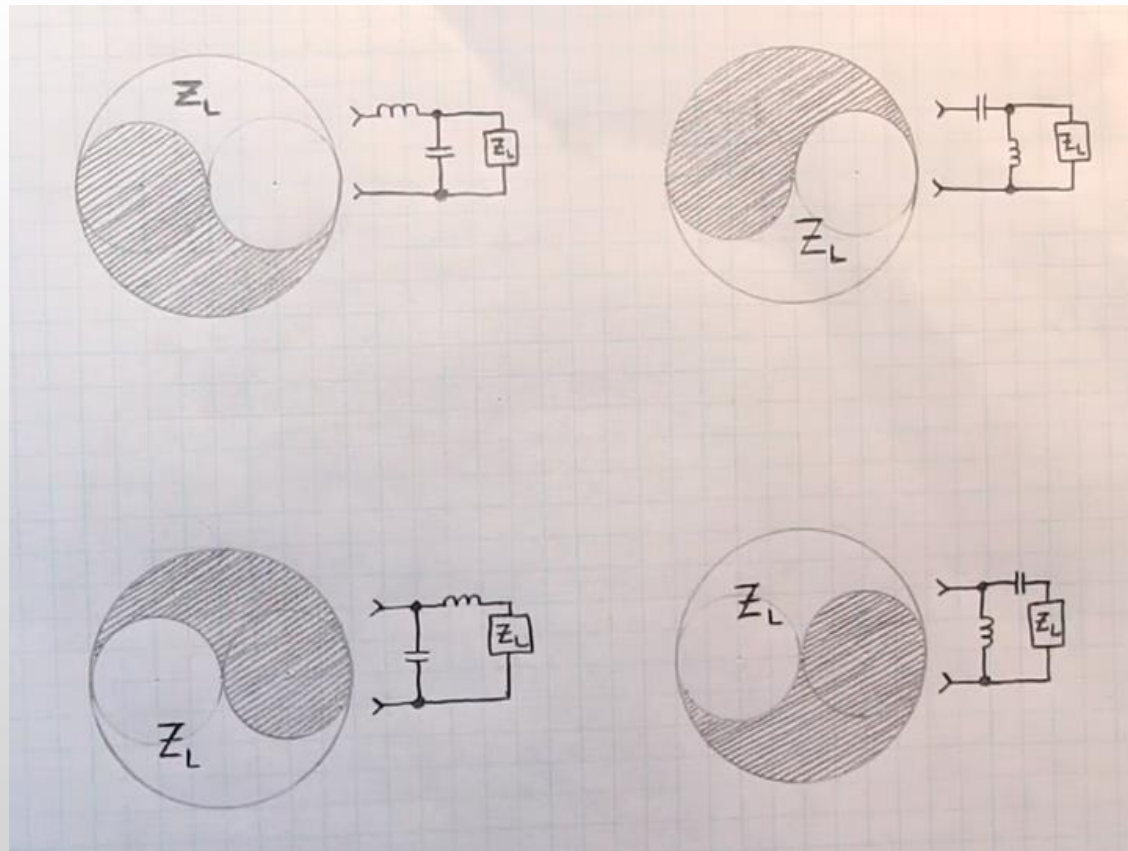
[** without further details : 9 turns on a T50-6 core , see excellent program Mini Ringcore Calculator]

EXTRA : add L or C

There are 8 possible L/C combinations

What impedances can be matched with what circuit ?

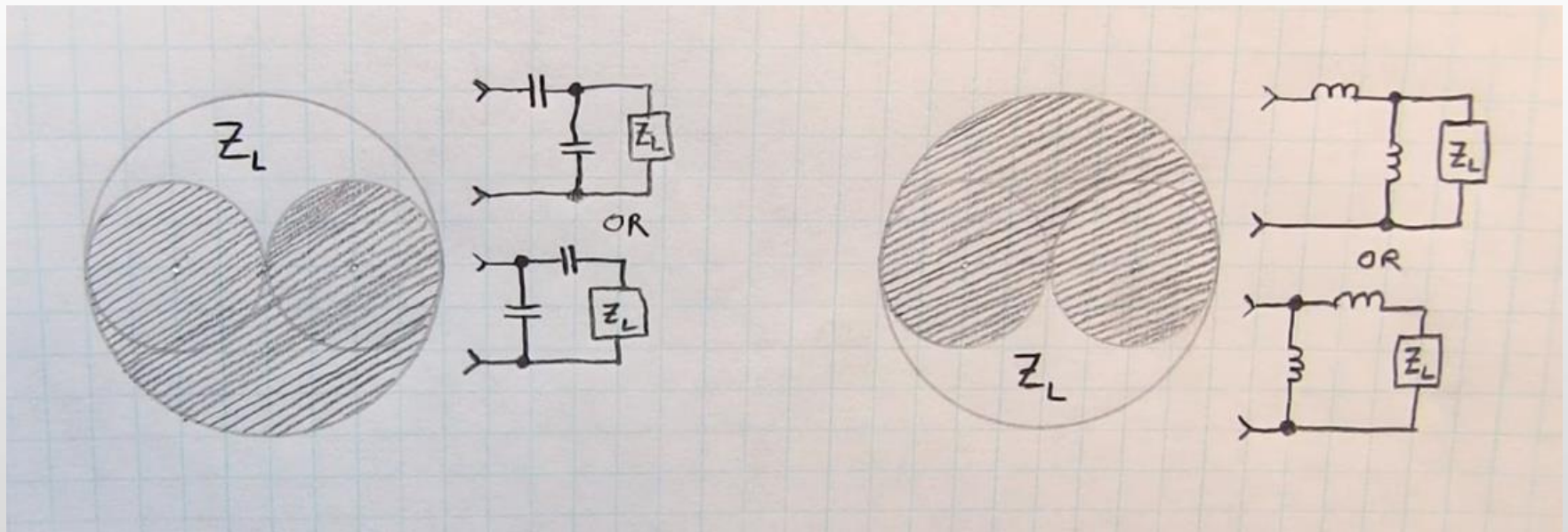
The first 4 :



source W2AEW video

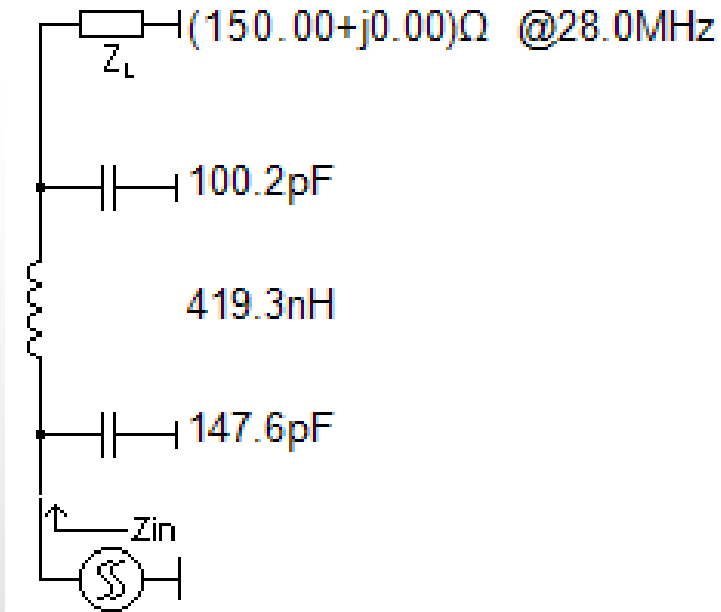
EXTRA : add L or C

And four more networks, now C/C or L/L configurations :



source W2AEW video

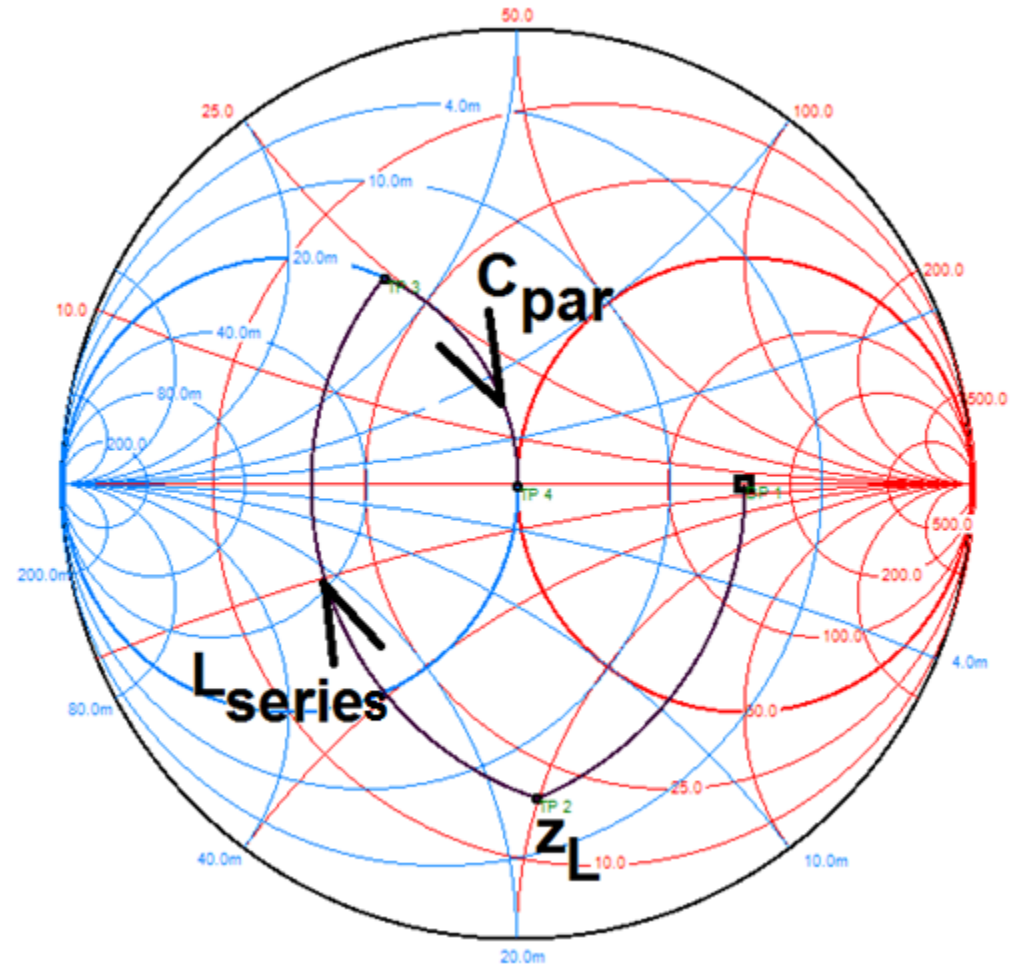
Smith Chart : add L or C, series or parallel



Nice !

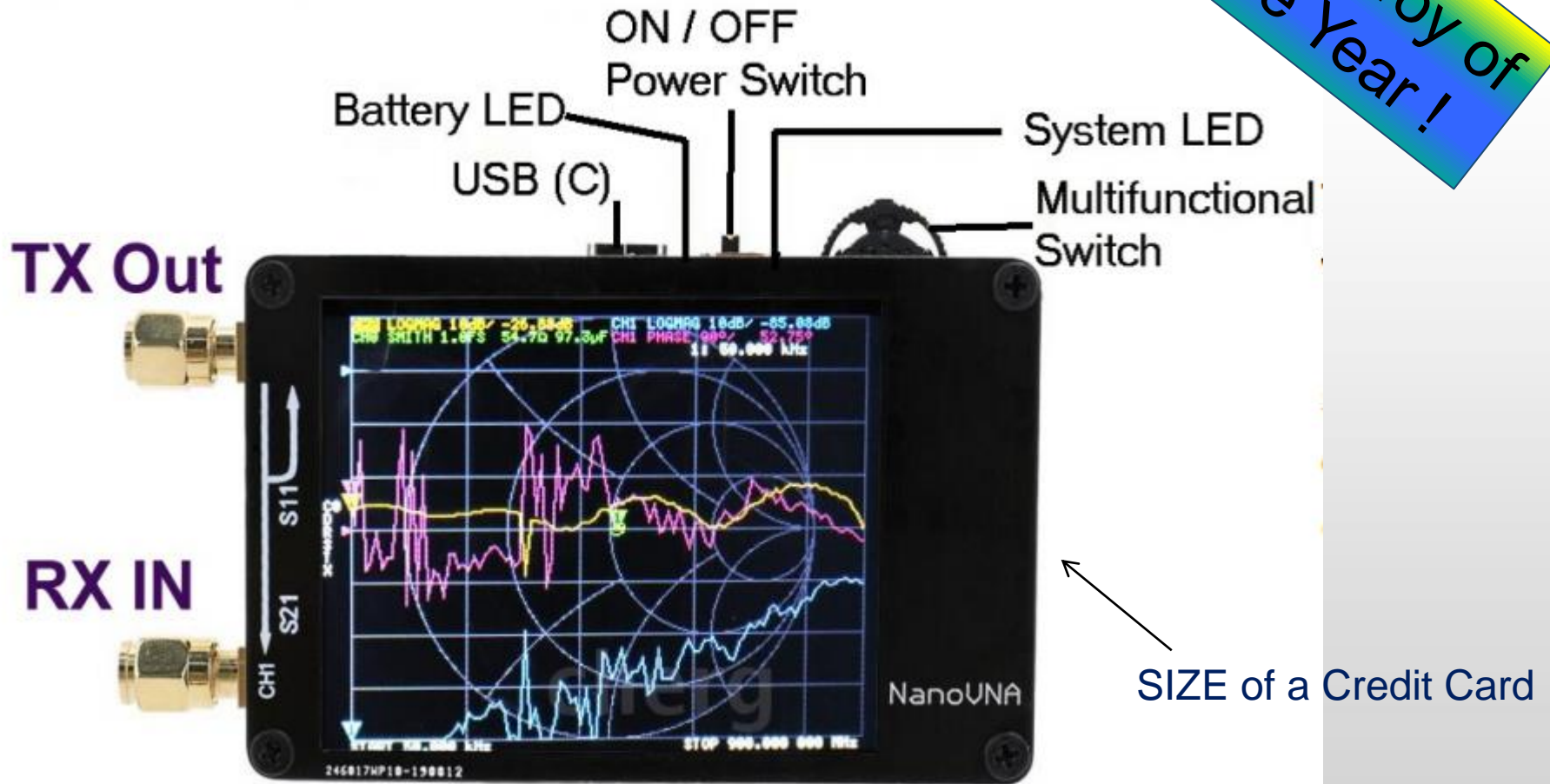
But will this be true in practice ?
the nanoVNA will tell it ...

after the BREAK !

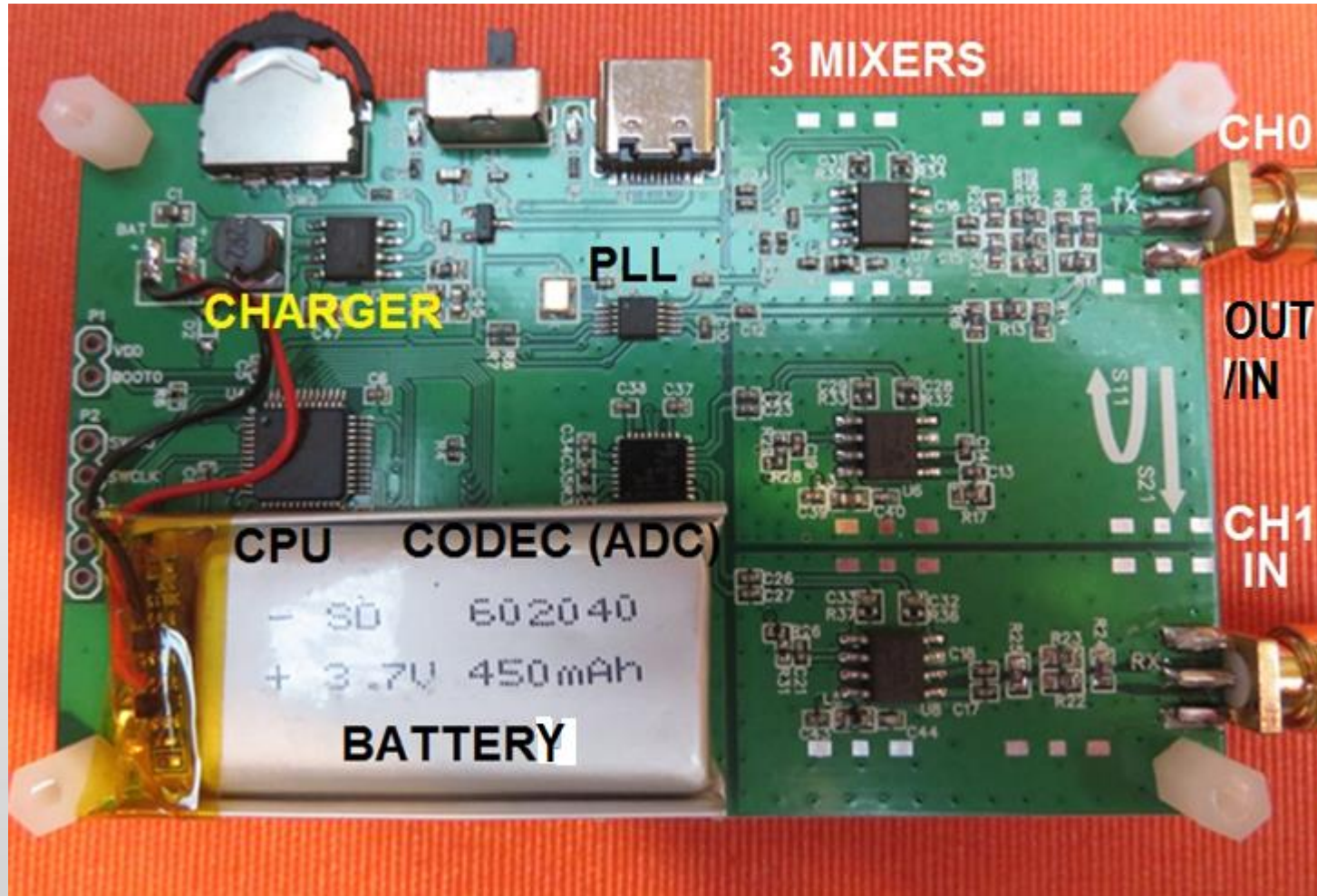


Measuring is Knowing ... the nanoVNA !

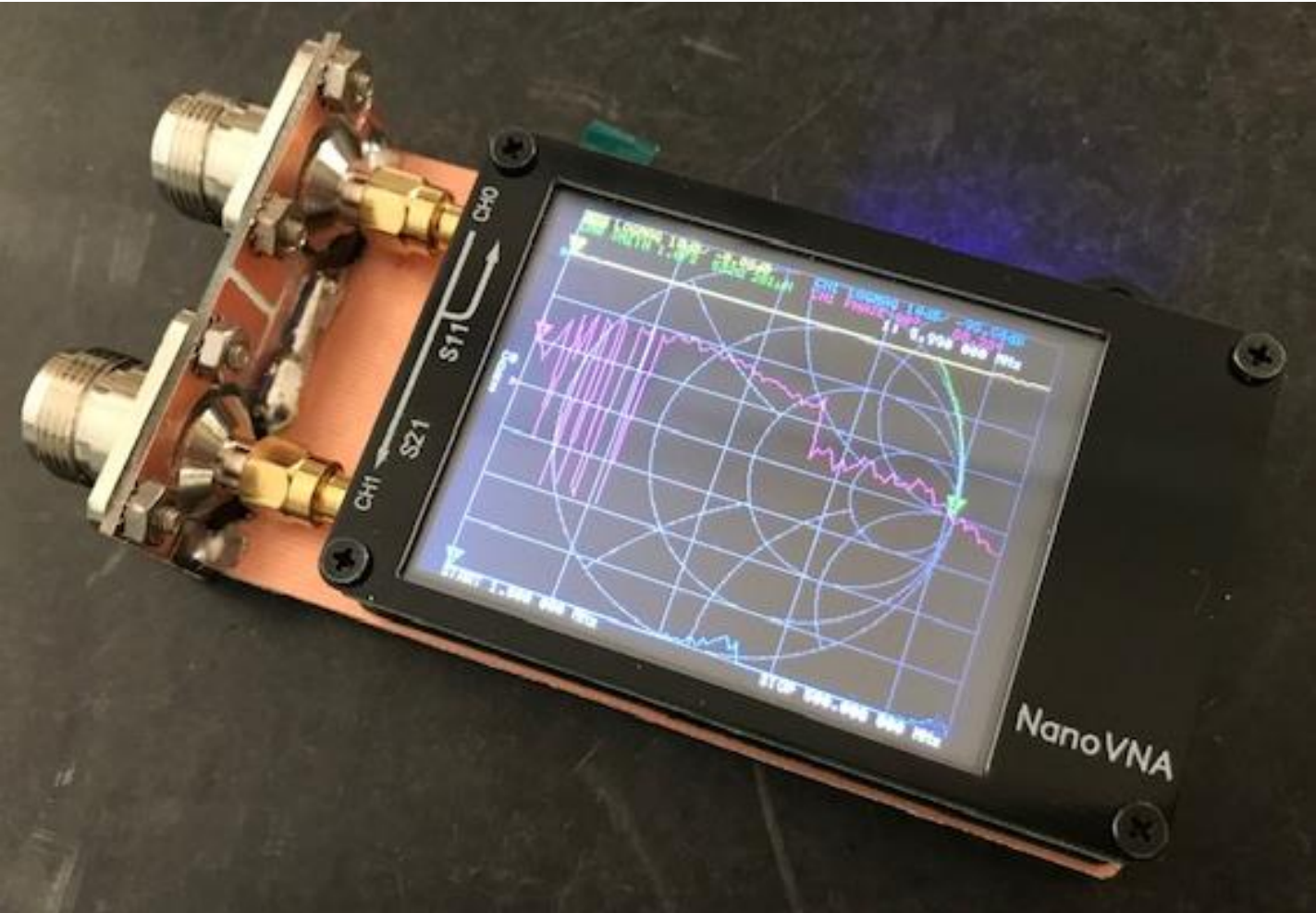
Nerd-Toy of the Year !



nanoVNA inside



nanoVNA with N-connectors



Source K6JCA

Scalar Network Analyzer

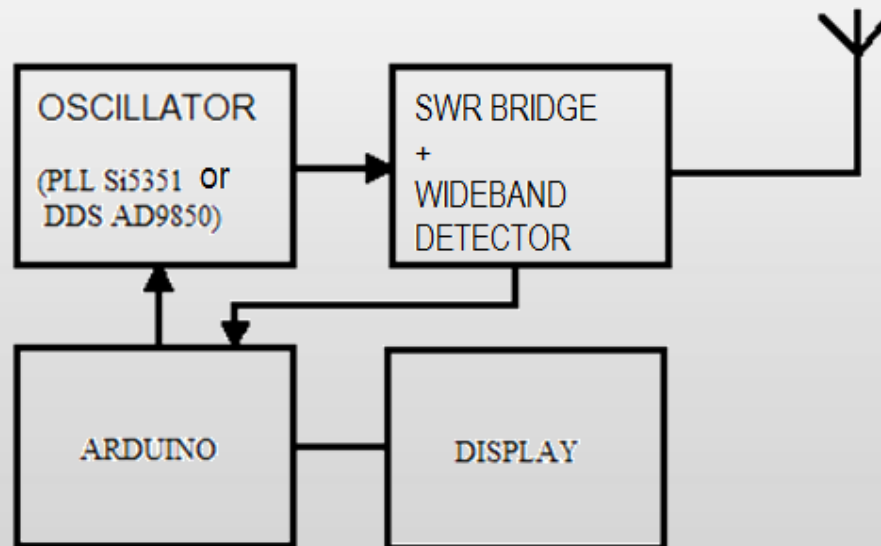
Only measures the magnitude of reflection

Can not measure complex impedance

Wideband detector measures any signal picked up by the antenna

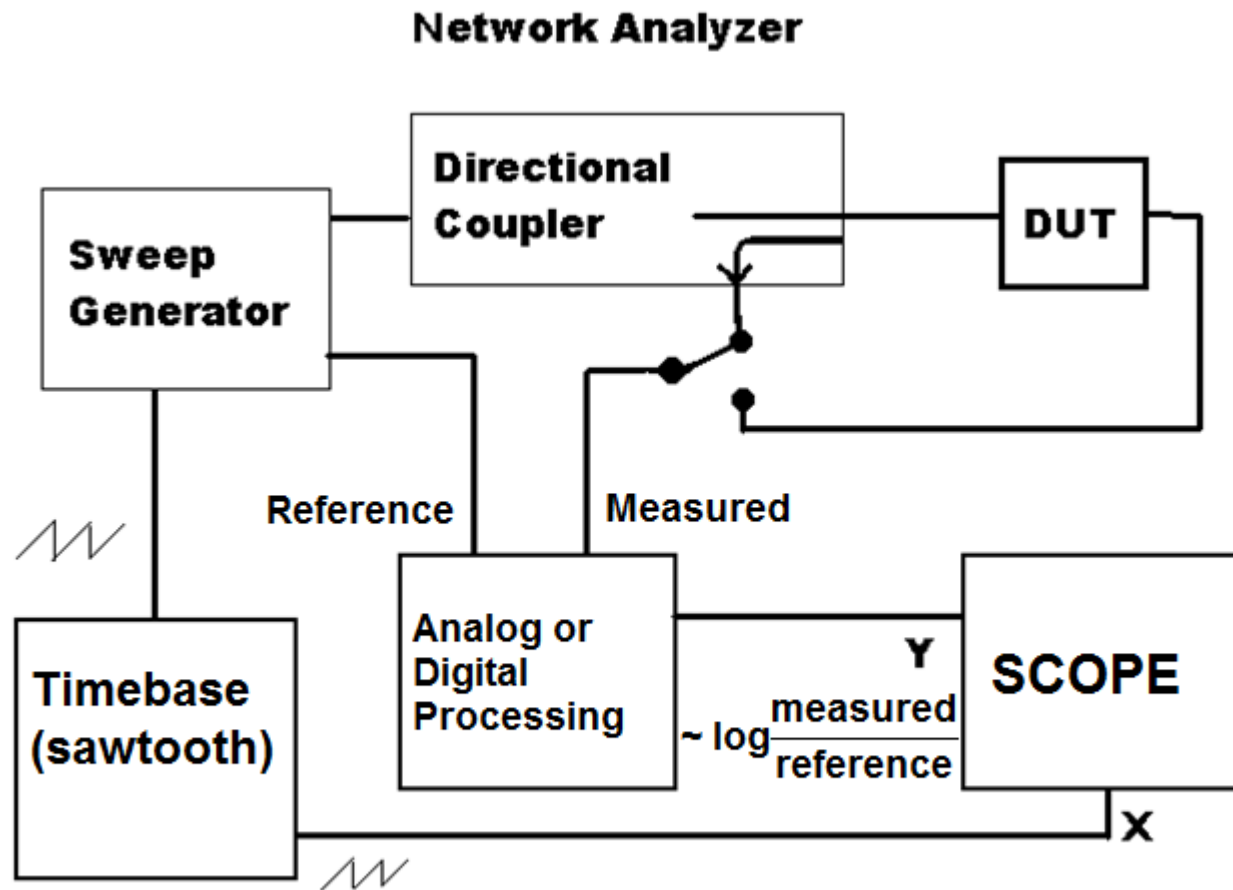
>> used in most simple antenna analyzers & Arduino projects (e.g. K6BEZ)

>> a bit better : the ANTUINO by HF SIGNALS (from India, see Bitx40 & μ Bitx)

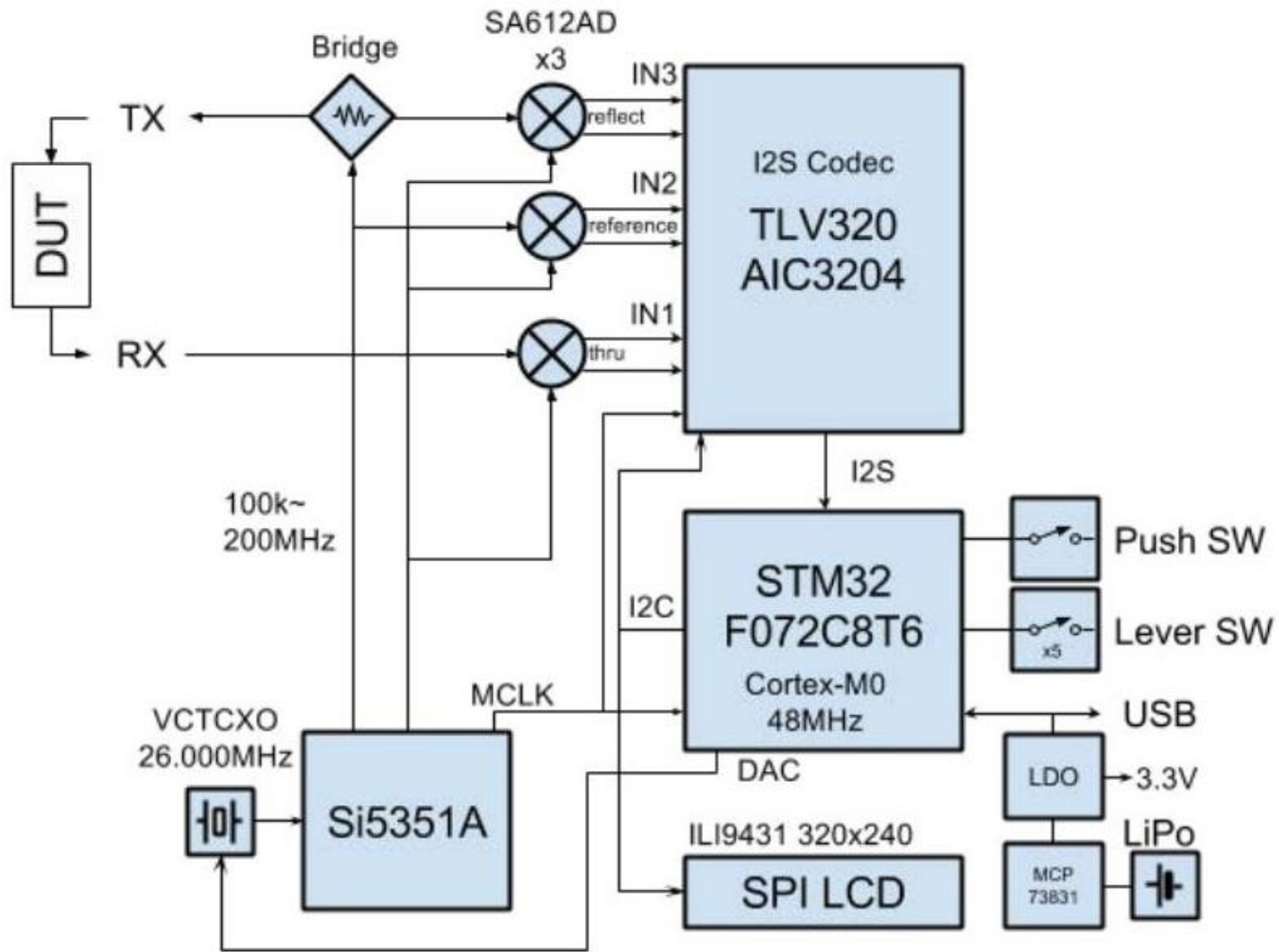


VNA = a Vector Network Analyzer

Classic setup



nanoVNA block diagram - operation



nanoVNA specifications

Frequency range : 50kHz to 900MHz (300 - 900MHz with harmonics)

RF output: -13dbm (maximum -9dbm) , so approx. 0.1 mW

Dynamic range : 70dB (50kHz - 300MHz), 60dB (300MHz - 600MHz), 50dB (600MHz - 900MHz)

Display: 2.8 inch TFT, resolution 320x240 ... like the “new” Nokia 3310 !

USB interface: USB type C (power/charging + data connection to PC)

Power: USB 5V 120mA , LiPo battery +/- 500 mAh

Number of points : **101 (fixed) ← biggest disadvantage !**

Display : 4 traces, 4 markers + **5 memories for calibration & settings (C0-C4)**

Frequency error : < 0.5 ppm (e.g. 50 Hz error at 100 MHz)

nanoVNA Manual ?

Gunthard Kraus, DG8GB, wrote a nice manual in German **and in English**

54 pages, lots of nice examples ... and it's FREE!

NanoVNA

A Vector Network Analyser covering 50kHz to 900MHz for under 50 Euros

„Getting Started Manual“ in three parts:

Part 1: The device

Part 2: Operation using a PC with the Software

„NanoVNA - saver V0.2.0.“
(including practical examples)

Part 3: stand-alone operation

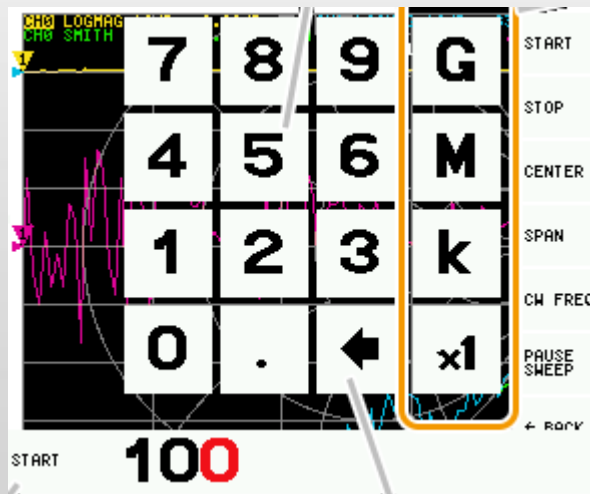
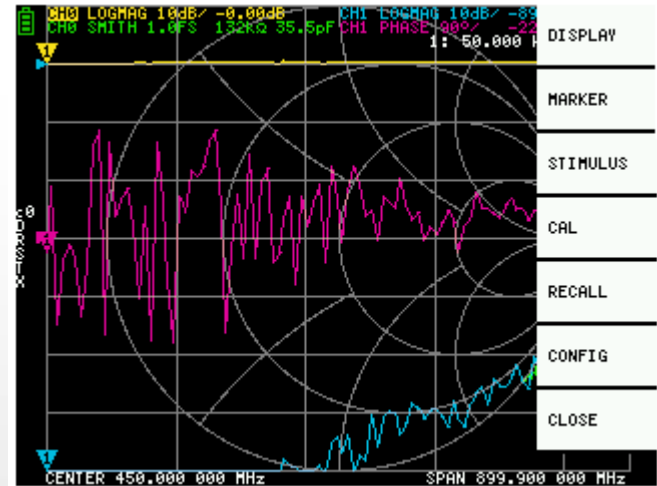
Version 1.4.2.

Author: Gunthard Kraus, DG8GB

Tettngang, 3rd December 2019

nanoVNA „standalone“ : basic controls

- “Rocker switch” is of little use ...
→ use a PalmPilot or Nintendo DS stylus !
- Tap the screen to see the menu →
- Display > Trace > T0 – T4 >
the selected TRACE stays active for other operations like FORMAT, SCALE, PORT ...
- Enter numbers : e.g. STIMULUS > START
then tap the “white zone” near the frequency
then tap 145.400 and M = 145.4 MHz →
- CALIBRATION : first do a RESET !
then CALIBRATE with “SOLT “ (see manual)
then SAVE in C0 to C4
(C0 loads as the default at startup)



nanoVNA „standalone“ : the MENU Structure

MAIN MENU

DISPLAY

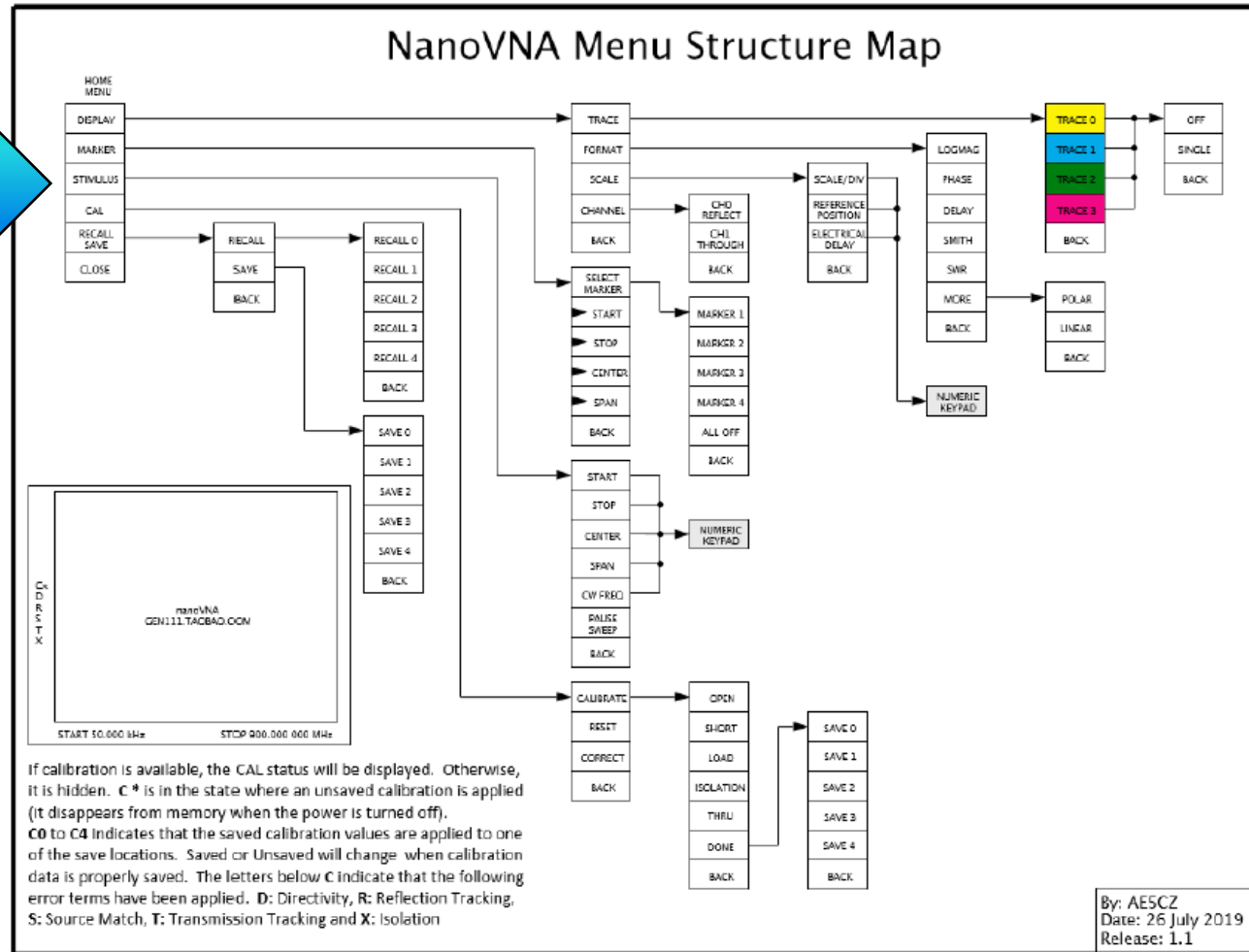
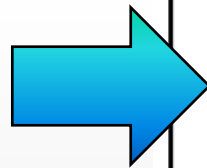
MARKER

STIMULUS

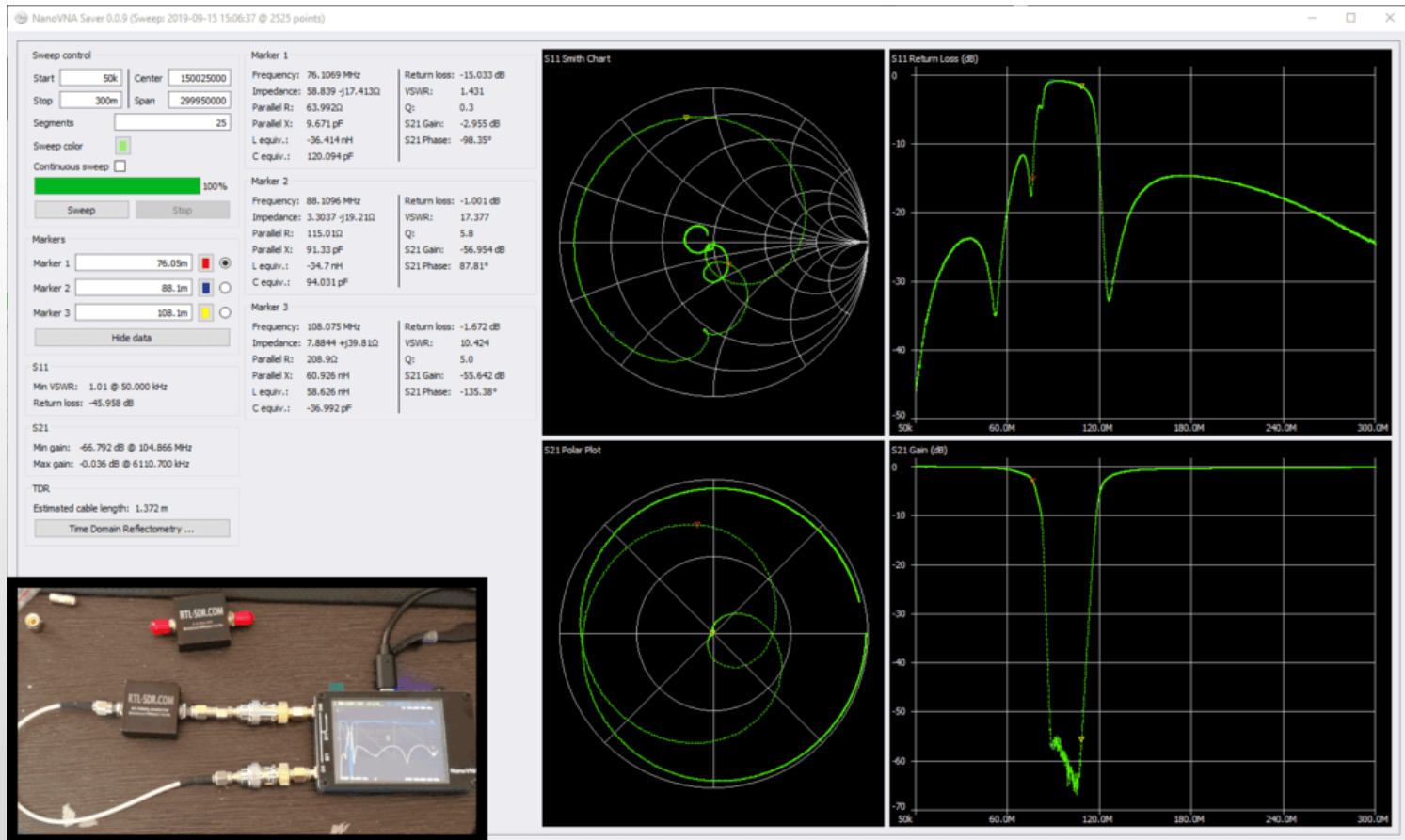
CAL

RECALL/SAVE

CLOSE



More versatile with PC software : nanoVNA Saver



Regular updates ... always use the latest one !

Just do it ! ... the nanoVNA in practice !

FIRST : Calibrate !

50 kHz – 900 MHz calibration is the default (in C0), but is only 101 points !

e.g. We want to measure an 80m antenna :

first point is at 50 kHz, second point is at **8,9 MHz** ! No calibration point in 80m !

BETTER : do a calibration over a limited range

or even better : do it on the PC, where you can use “segmented” scanning, and a large number of points, and you can **SAVE** as many calibration files as you like

Measuring cables should be included in the calibration !

And finally : check your calibration by connecting the SOL elements again !

e.g. Lets measure some 50 Ω resistors

(commercial load, homebrew loads : carbon, wirewound ...)

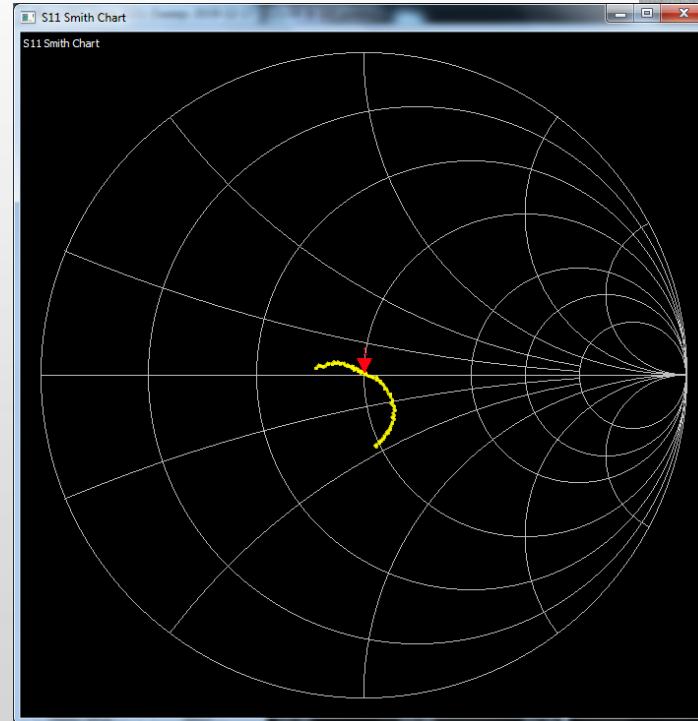
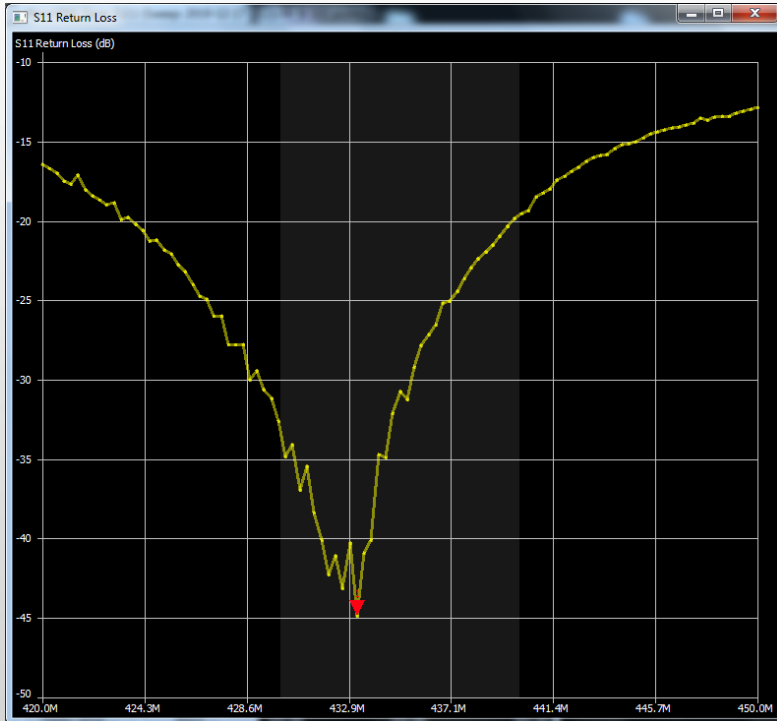
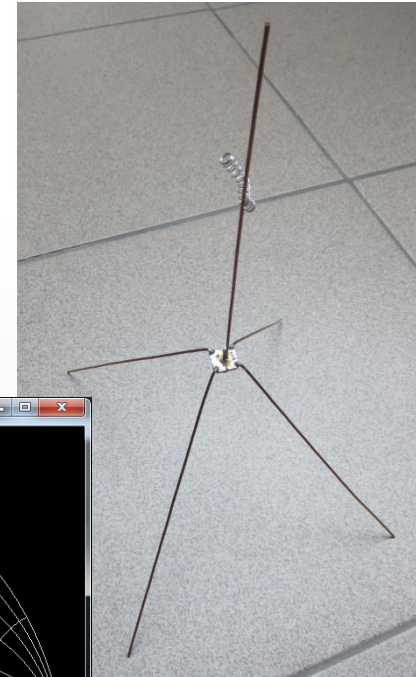


Just do it ! ... the nanoVNA in practice !

An ANTENNA !

e.g. Groundplane for 70 cm, copper wire 1,5 mm²,
+ a ballpoint “spring” to tune it, see the effect →

Demo “continuous sweep” , best: narrow band + 1 segment



nanoVNA ... in practice

Measuring at the antenna ?

the nanoVNA is very portable ... so you can take it up to your antenna ?

At HF not a good idea (RF ingress into the nanoVNA or other unwanted coupling)

Also see the many demo's on YouTube, flapping about a VHF whip on a cable (and no ground) near the nanoVNA ... useless !

Use a cable with a "Common Mode Choke" , and calibrate at the antenna end



Source : DF9CY

Common-Mode Choke
of 4+4 Turns RG58 on
2*70mm Ferrite Core (RK1)

W6LG



nanoVNA ... in practice : a MATCHING network !



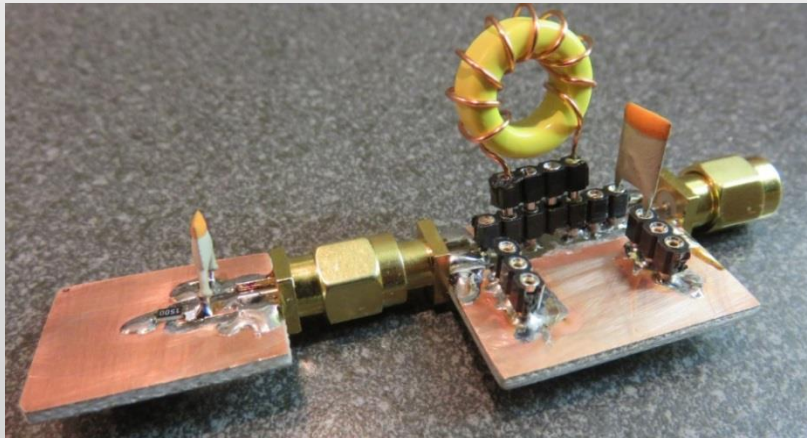
Previous example : match a load of $150 \Omega // 100\text{pF}$ at 28 MHz

Measure the load : $Z_L = 17,75 - j.47,6 \Omega$ - Match with $L = 420 \text{ nH}$ in series,
then $C = 150 \text{ pF}$ in parallel (@28 MHz : my values were $L = 438 \text{ nH}$, $C = 165 \text{ pF}$)

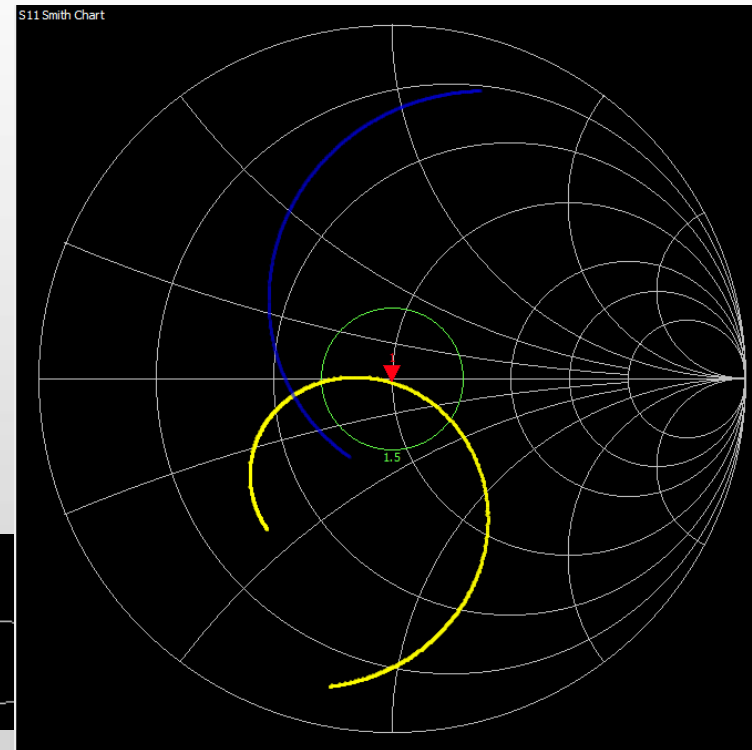
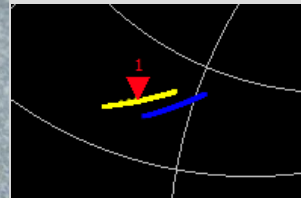
After matching : **$Z = 58,09 - j.5,62 \Omega$** ...

We're a little bit "off", but it's good for CB ! ;-)

- TIP** : "Set current as Reference" to compare with previous measurement
→ blue line = without the C
+ add SWR circle (e.g. $\text{SWR} = 1.5$)



effect of
extra board

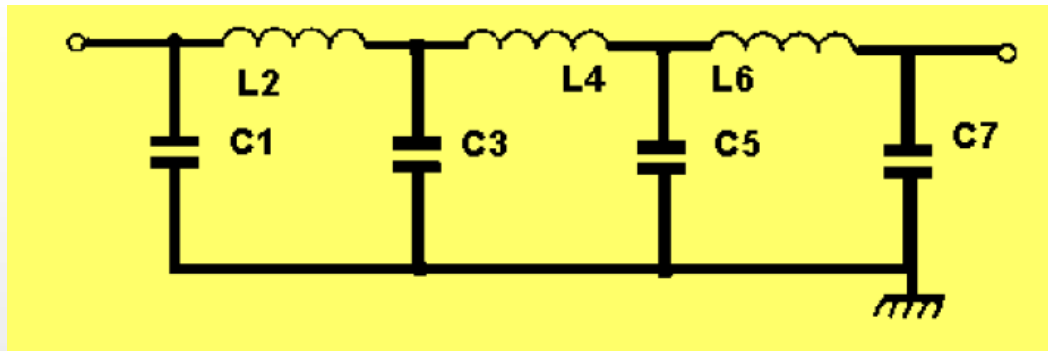


nanoVNA ... in practice : a FILTER !

e.g. a **LOW PASS FILTER** for 30m

Design it with ELSIE* , or use the tables by W3NQN* (* see links)

Circuit :



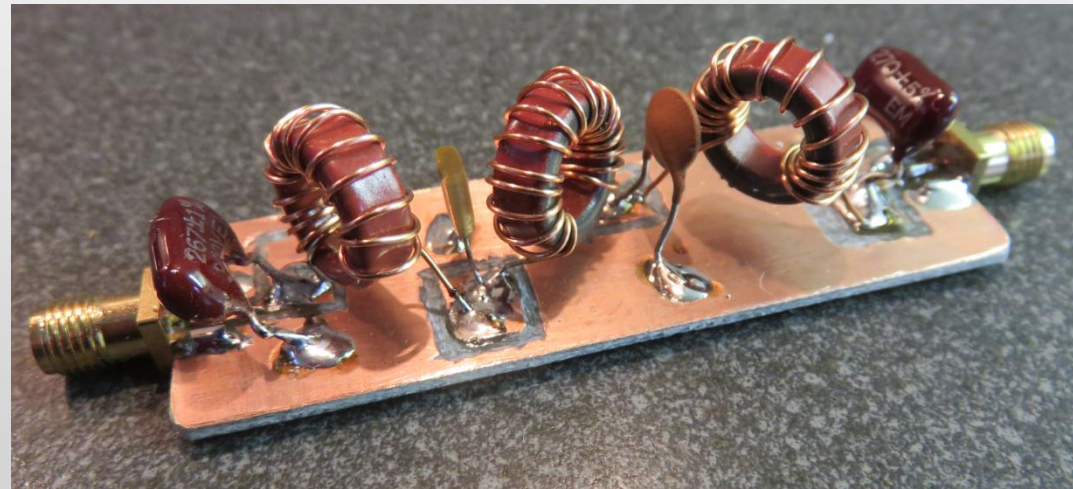
Realisation :

$C1, C7 = 270 \text{ pF}$

$C3, C5 = 560 \text{ pF}$

$L2, L6 = 1,09 \text{ } \mu\text{H}$ (T50-2, 15t)

$L4 = 1,26 \text{ } \mu\text{H}$ (T50-2, 16t)



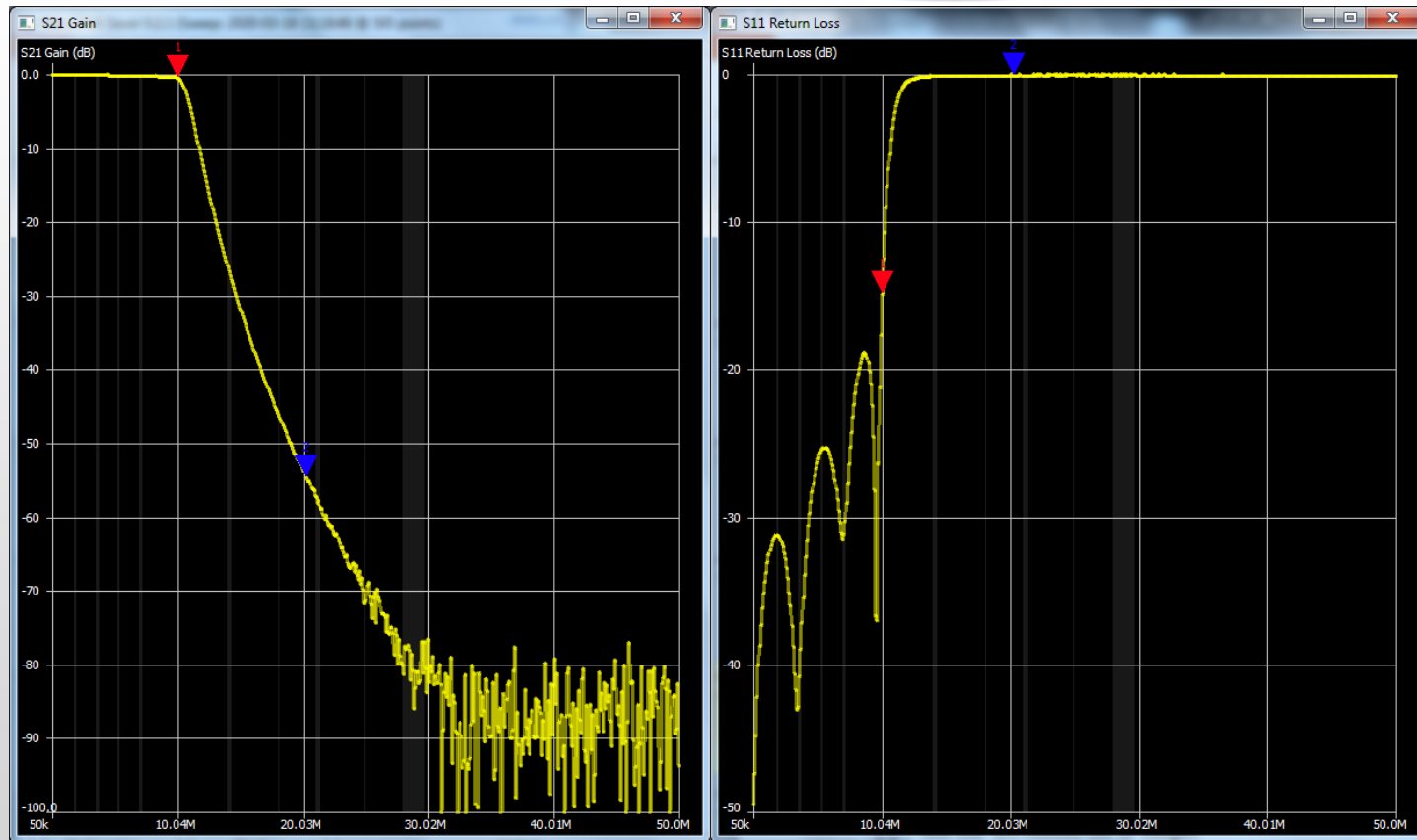
nanoVNA ... in practice

LOW PASS FILTER for 30m
+ CALIBRATION at **505 points** with nanoVNA Saver →



@10.1 MHz:
S21 = -0.55 dB
RL = - 12 dB
(could be better)

@20.2 MHz
S21 = -54.5 dB



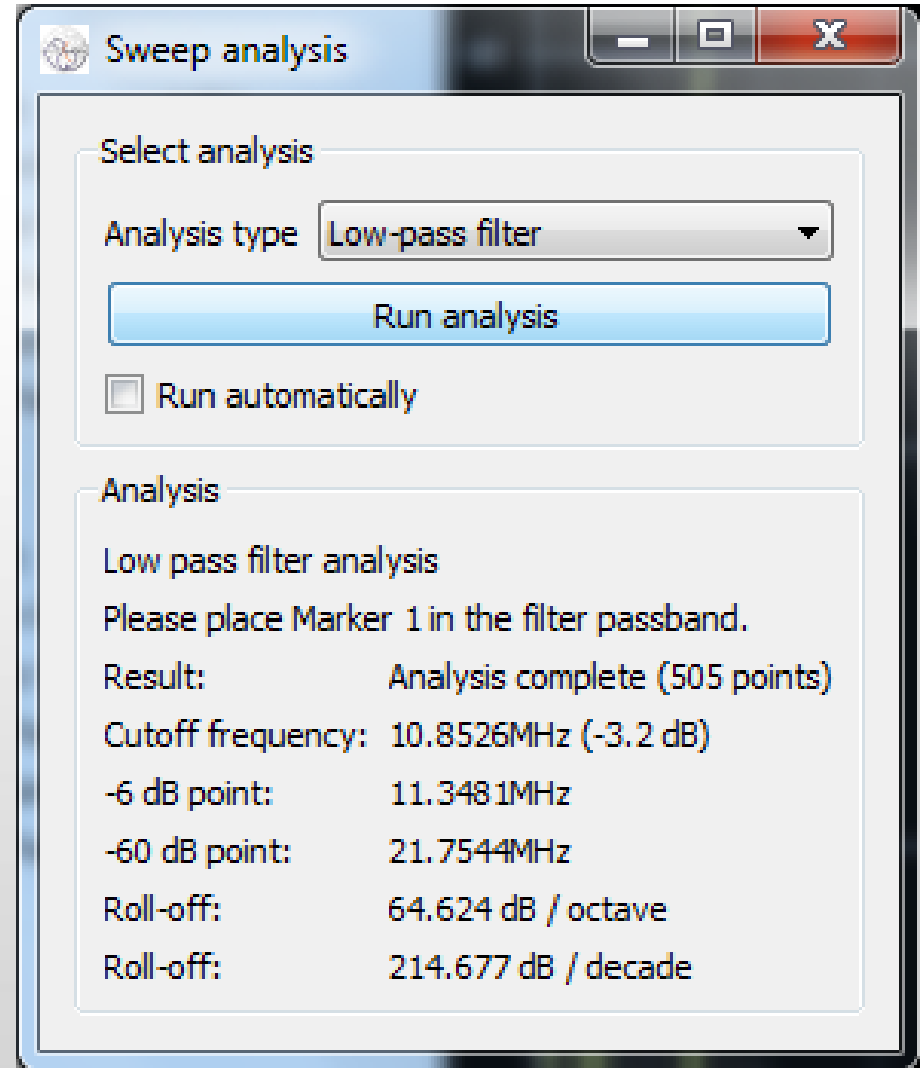
nanoVNA ... in practice

LOW PASS FILTER for 30m

Another handy function :

Automatic Analysis of filters →

(the “Analysis ...” button is at the bottom of the Marker Data pane)

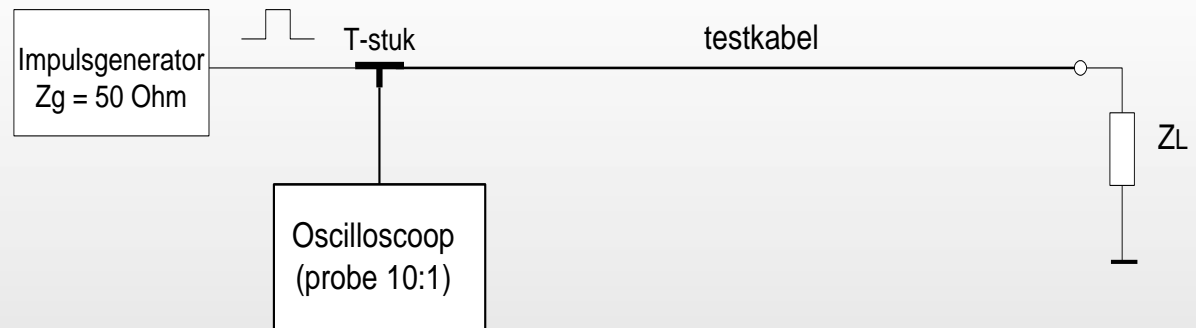


nanoVNA ... TDR measurement

TDR = TIME DOMAIN REFLECTOMETRY

2 principles :

- The old IMPULSE method = in the low frequency spectrum (~100 kHz)



- Calculate the response from S_{11} at several frequencies

From frequency domain to time domain using **Inverse Fast Fourier Transform***
A peak in the time response relates to the PLACE of the discontinuity !
Maximum length that can be measured is determined by the frequency step and the velocity factor (not essential to know this, but here's the formula anyway ...)

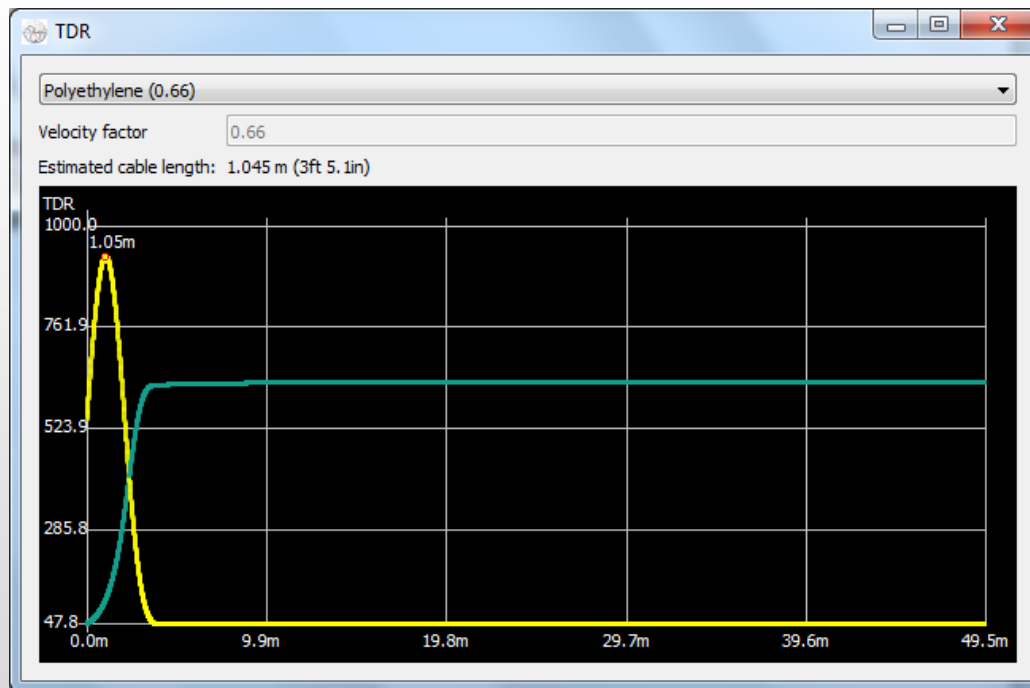
$$L_{MAX} = \frac{k \cdot v_0}{\Delta f} \quad \text{e.g. } k=0,66, \text{ step} = 1 \text{ Mhz} \rightarrow L = 0,66 \cdot 3 \cdot 10^8 / 1 \cdot 10^6 = \mathbf{198 \text{ m}}$$

nanoVNA ... TDR measurement

nanoVNA Saver does all the work ...

e.g. cable RG223 measured as 1,05 m, $k = 0,66$

Length measured by nanoVNA Saver = 1,045 m



Also handy : Z_0 of the cable is also shown (not very accurate, but good enough to distinguish between a 50 or 75 Ω cable)

nanoVNA ... other method to measure Z_0 of a cable

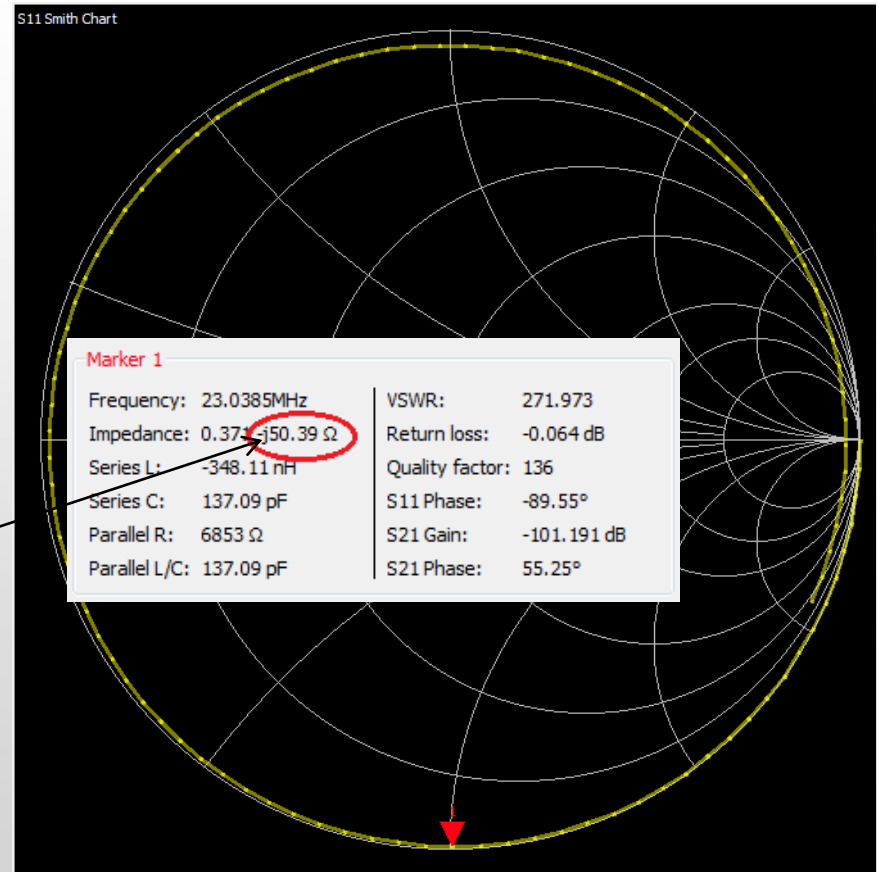
The $\lambda/8$ method

A short TL (called a “Lecher line”), length = $\lambda/8$, is left open at its LOAD end.
Input Impedance will be : $-j.Z_0$

So on the chart, starting from OPEN,
find the frequency where $Z =$ a SHORT
There the line is a $\lambda/4$
Now measure Z at **half that frequency**
The reactance will be $-j.Z_0$

e.g. the same cable of 105 cm, $k=0.66$
At 23,038 Mhz it is a $\lambda/8$, the reactance
is $-j.50,39 \Omega$, so **$Z_0 = 50,39 \Omega$**

A 75Ω cable will not show at -90° ,
but at it's normalized impedance of
 $0 - j.1.5$ (or -67°), which equals $0 - j.75 \Omega$

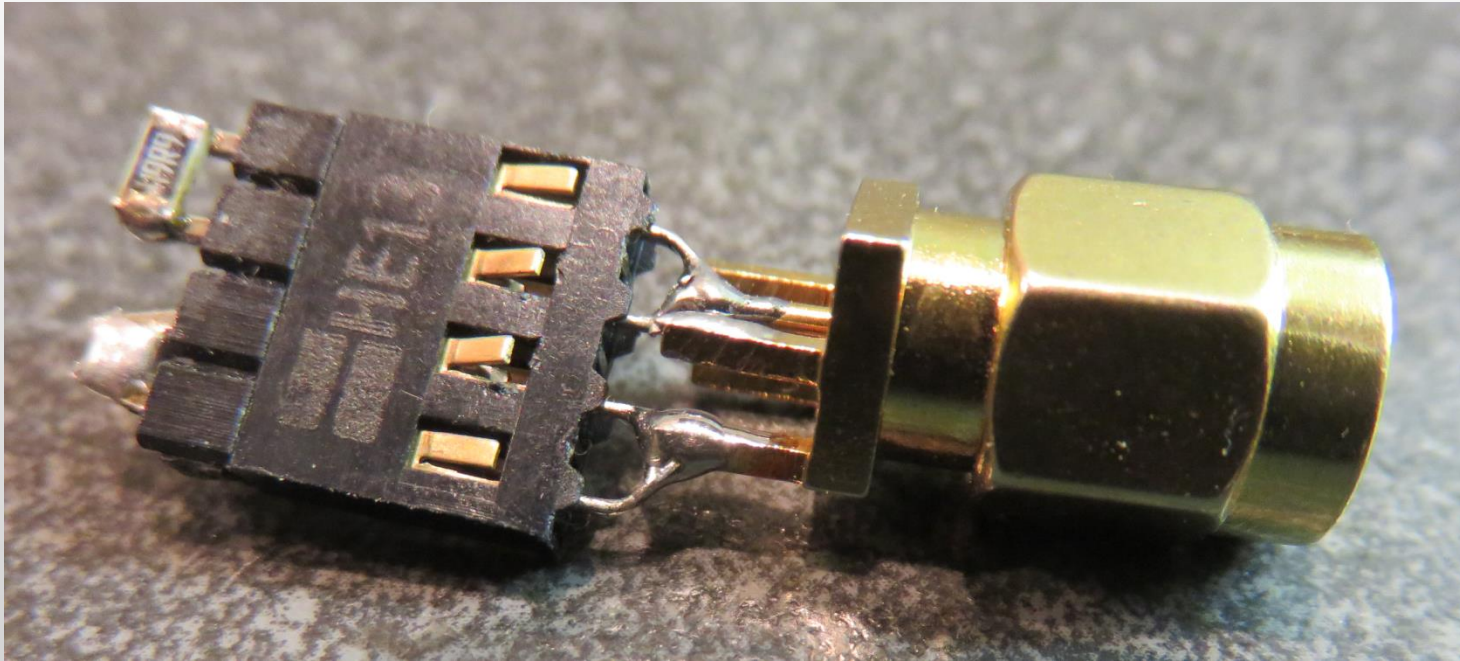


nanoVNA as a Component Tester

Menu STIMULUS > CW FREQ > 50 kHz (or your actual “working frequency”)

Component adapter + SOL calibration + two prongs bent out for SMD's
L, C, R are calculated from measured impedance →

Also *(loss) resistance*, *Q factor*, *etc* can be measured ... see manual



nanoVNA as a Signal Generator

- Antenna or cable on CH0
- Menu STIMULUS > CW FREQ > enter frequency
- Output is a SQUARE wave (with harmonics)
- Level can not be adjusted, it varies between -7 dBm ... - 19 dBm
- No modulation possible (e.g. VNWA3E has AM, FM and level adjust)
- You can set a small sweep range
... hear some “ticking” in the receiver
- RF generators from China ? ... e.g. →
more expensive than a nanoVNA !



nanoVNA as a Spectrum Analyzer ?

CH1 is an **INPUT**, so it should be possible !

Connect an antenna or probe to CH1

Put Trace 1 or 3 on LOGMAG = spectrum display, but it can not be calibrated

+ “images” at 10 kHz (twice the IF of 5 kHz), so just good enough to “have a look”

NOTE : only 101 discrete frequencies with a 1 kHz bandwidth : what you see is

NOT what you get ! (signals not on one of those 101 frequencies are not shown !)

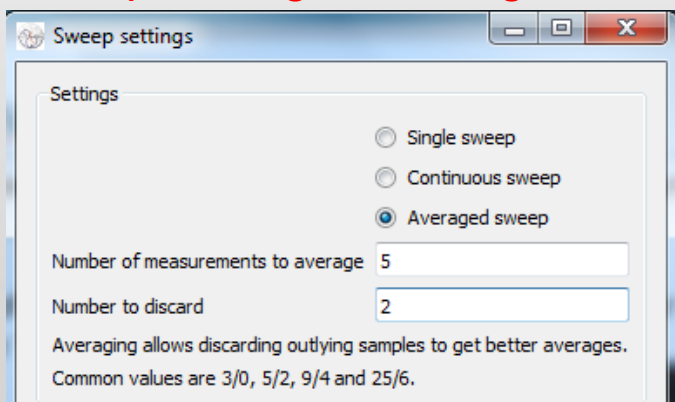
e.g. view of the **40m band**

- In nanoVNA:

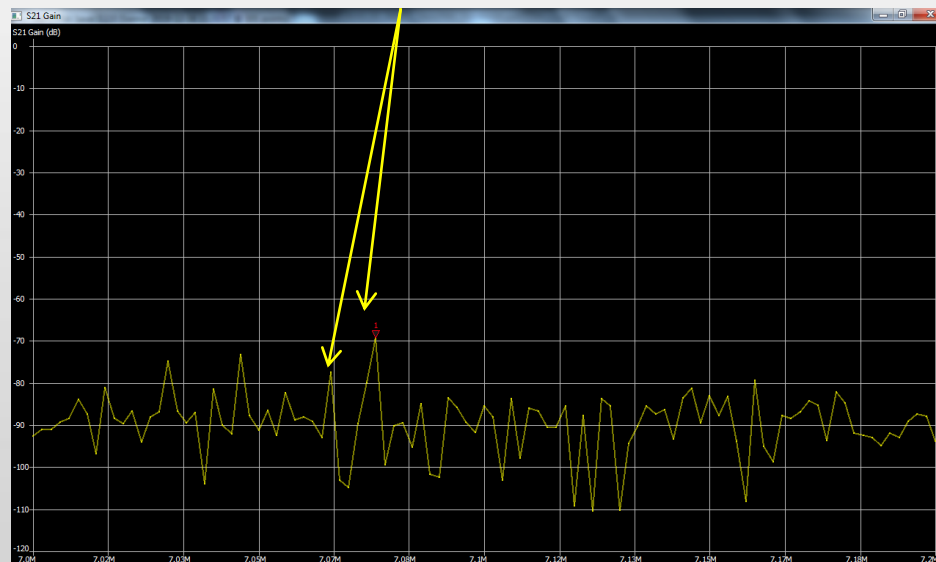
Display > Scale > Ref. Pos. = 15

- In nanoVNA Saver :

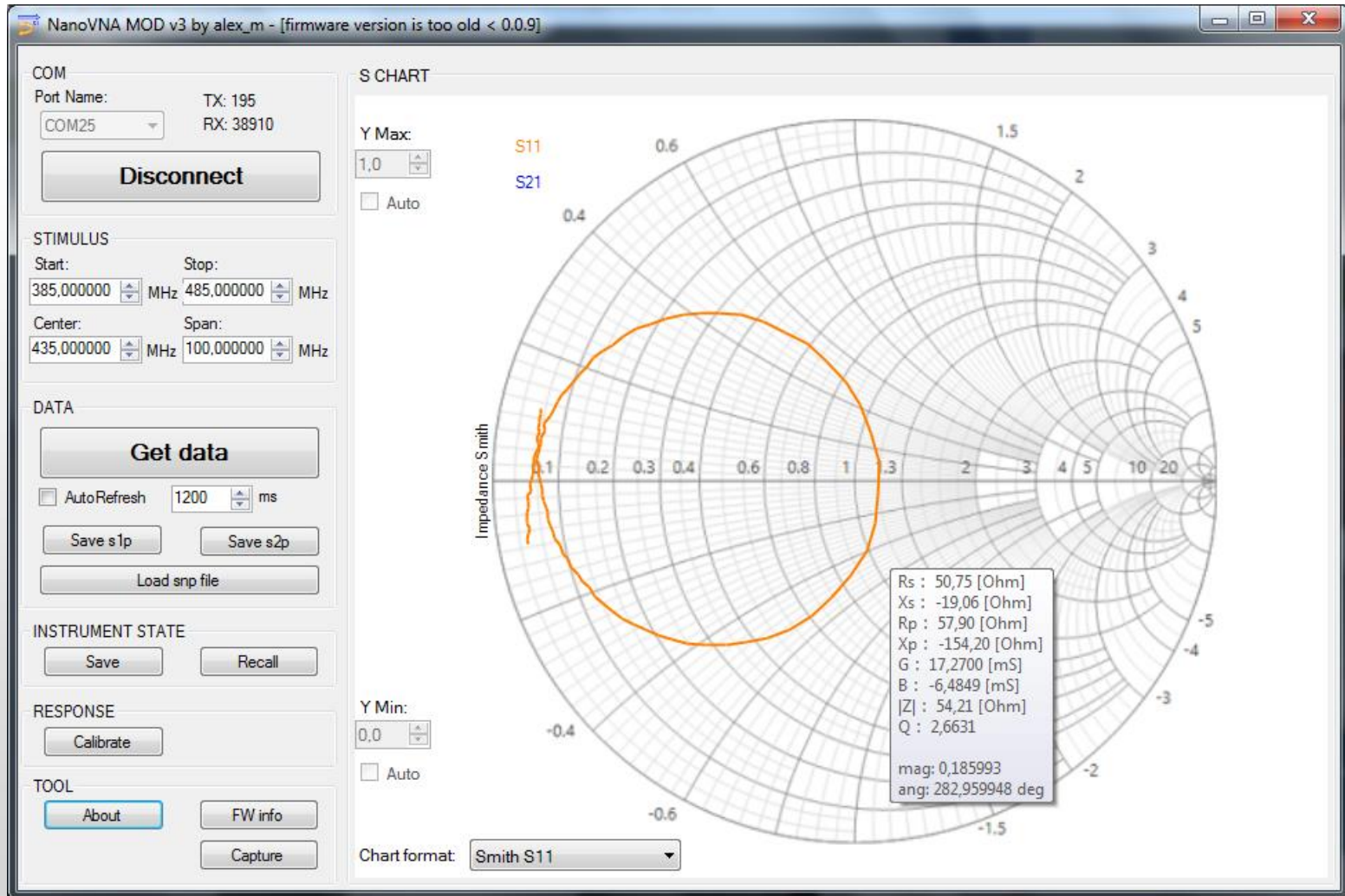
Sweep settings > Average sweep 5/2



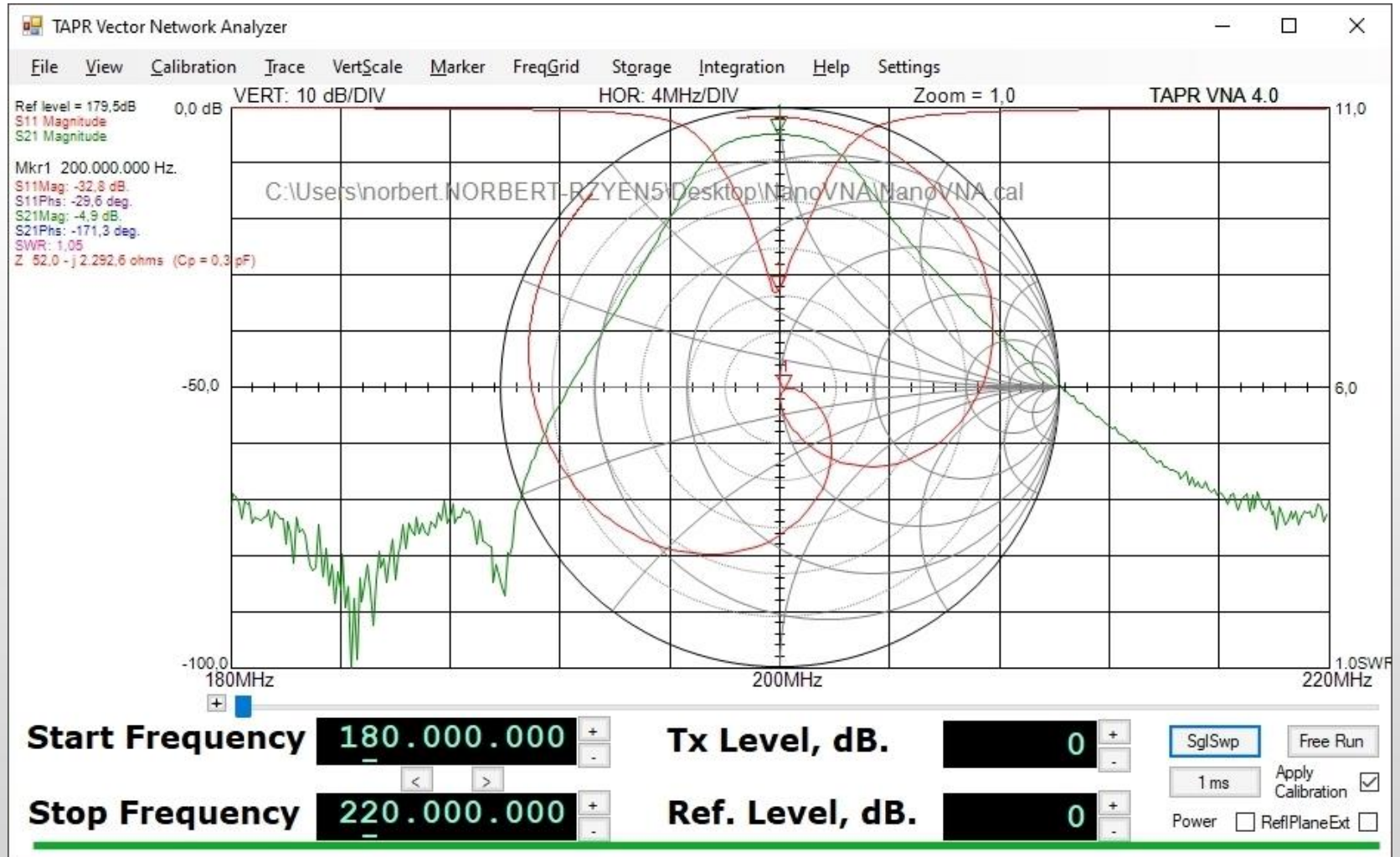
7.074 MHz (FT-8) shows up twice



Finally ... some alternative software : nanoVNA Sharp



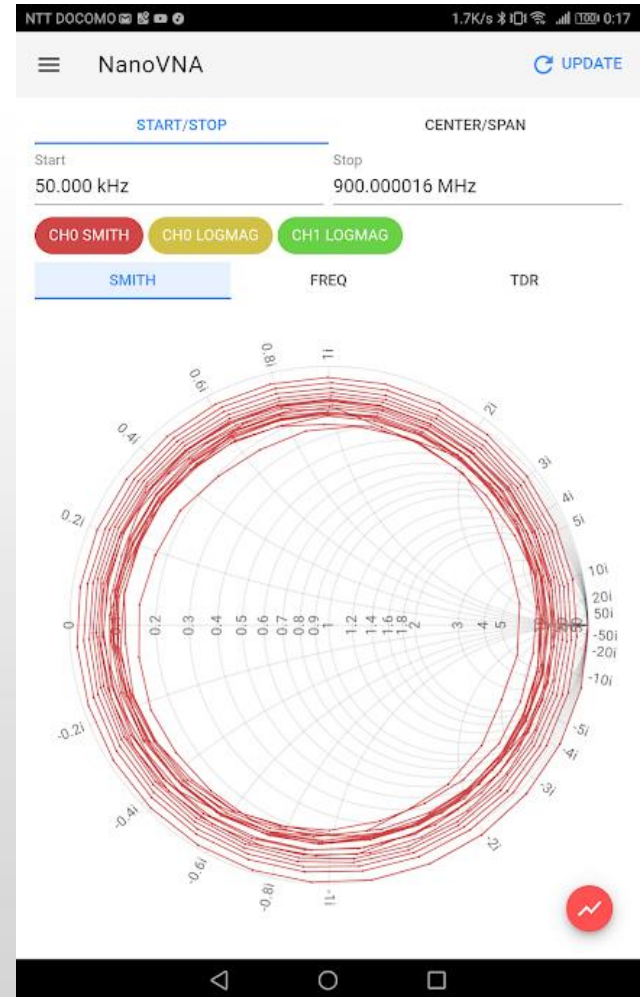
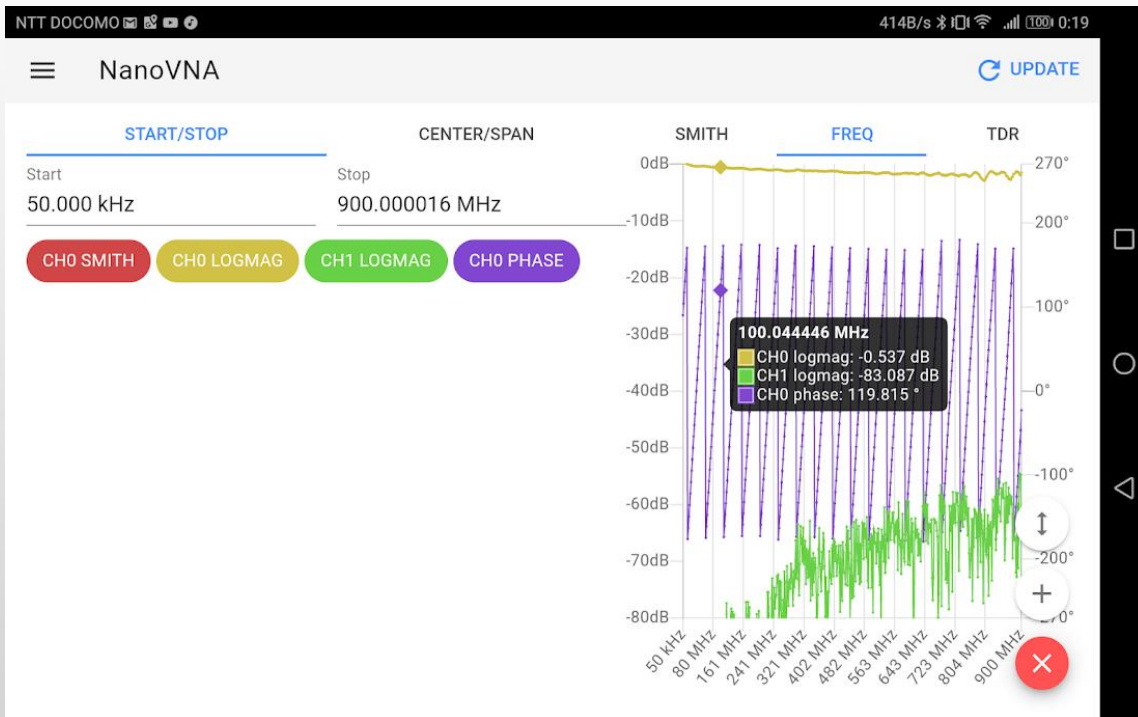
Alternative software : TAPR VNA





Software for Android : nanoVNA WebApp

→ Needs a USB OTG cable



Other FIRMWARE ?

Have not tested this , so not much to tell ... do it at your own risk

Use a pincet to short two contacts and Power ON, nanopVNA will enter DFU mode (“Device Firmware Update”)

Then using PC software, load the new Firmware ... it sounds simple !

Many versions around

- Only the function Antenna Analyzer
- Only 2 traces , but a larger font
- Only the basic frequency range (50 kHz – 300 MHz)
- With built-in TDR function
- With menu item for voor DFU mode
- Etc ...

Still a lot to explore and learn !

nanoVNA Forum + Wiki = All you wanted to know but ...



The screenshot shows the Groups.io website for the 'nanovna-users' group. The browser address bar shows 'groups.io/g/nanovna-users'. The page header includes the Groups.io logo, a search bar, and links for Help, Log In, and Sign Up. The left sidebar has links for Home, Messages, and Hashtags. The main content area features a photo of a NanoVNA device displaying a Smith chart on its screen. Below the photo, the group name 'nanovna users' and email 'nanovna-users@groups.io' are listed. The 'Group Description' section states 'Users of nanovna small VNA' and provides links for files and a wiki. The 'Group Information' section shows 2,605 members, 726 topics, and a start date of Jun 3. The 'Group Settings' section lists various options, including that all subscribers can post, posts do not require approval, and the wiki is visible to subscribers only.

nanovna users nanovna-users@groups.io

Group Description

Users of nanovna small VNA
Files: <https://groups.io/g/nanovna-users/files>
Wiki: <https://groups.io/g/nanovna-users/wiki>

Group Information

- 2,605 Members
- 726 Topics, Last Post: 8:42am
- Started on Jun 3
- Feed

Group Settings

- All subscribers can post to the group.
- Posts to this group do not require approval from the moderators.
- Messages are set to reply to group.
- Subscriptions to this group require approval from the moderators.
- Archives are visible to anyone.
- Wiki is visible to subscribers only.
- Members can set their subscriptions to no email

Sources / Links

THEORY

Smith Chart <http://k6jca.blogspot.com/2015/03/a-brief-tutorial-on-smith-charts.html>

Video on L/C matching networks

<https://www.youtube.com/watch?v=lgeRHDI-ukc>

Table Reflection Coefficient - RL - SWR <https://www.markimicrowave.com/blog/wp-content/uploads/2016/11/return-loss-to-vswr.pdf>

Arduino Antenne Analyzer by K6BEZ

http://www.hamstack.com/hs_projects/k6bez_antenna_analyzer.pdf

A better Antenne Analyzer : the Antuino

<http://www.hfsignals.com/index.php/antuino/>

W3NQN Basic LPF tables (from GQRP club)

http://www.gqrp.com/harmonic_filters.pdf

W3NQN Improved “CWAZ” LPF article

<https://www.arrl.org/files/file/Technology/tis/info/pdf/9902044.pdf>

TDR theory on Inverse Fourier Transform

<https://nuclearrambo.com/wordpress/accurately-measuring-cable-length-with-nanovna/>



Sources / Links

nanoVNA

nanoVNA best video ! <https://www.youtube.com/watch?v=mKi6s3WvBAM>

nanoVNA Forum <https://groups.io/g/nanovna-users>

Original manual for standalone use <http://nanovna.com/>

The menu structure <https://oristopo.github.io/nVhelp/html/Menu.htm>

A more comprehensive manual, many good examples & use of nanoVNA Saver
http://gunthard-kraus.de/fertig_NanoVNA/English_NanoVNA_V1.4.2_final.pdf

Idea for mounting N-connectors <https://groups.io/g/nanovna-users/files/Housing%20and%20Case%20Designs/N%20connectors%20for%20the%20NanoVNA%20-%20k6jca.pdf>

Sources / Links

SOFTWARE

Program SMITH <https://www.fritz.dellsperger.net/smith.html> , the site has also a good introduction on the Smith Chart (ppt) and many examples

ELSIE Filter Design <http://tonnesoftware.com/elsie.html>

Mini Ringcore Calculator : all calculations for coils with iron powder, ferrite and air cores <http://www.dl0hst.de/mini-ringkern-rechner.htm>

nanoVNA Saver download <https://github.com/mihtjel/nanovna-saver/releases>
+ good introduction on its use <https://zs1sci.com/blog/nanovnasaver/>

nanoVNA Sharp <https://drive.google.com/drive/folders/1-JViWLBOIzaHTdwdONX2RP8S4EgWxoND>

nanoVNA WebApp (Android)

<https://play.google.com/store/apps/details?id=net.lowreal.nanovnawebapp&hl=nl>



Any questions ?



You can wake up and go home now !