MegiQ VNA-Sandbox

User Guide

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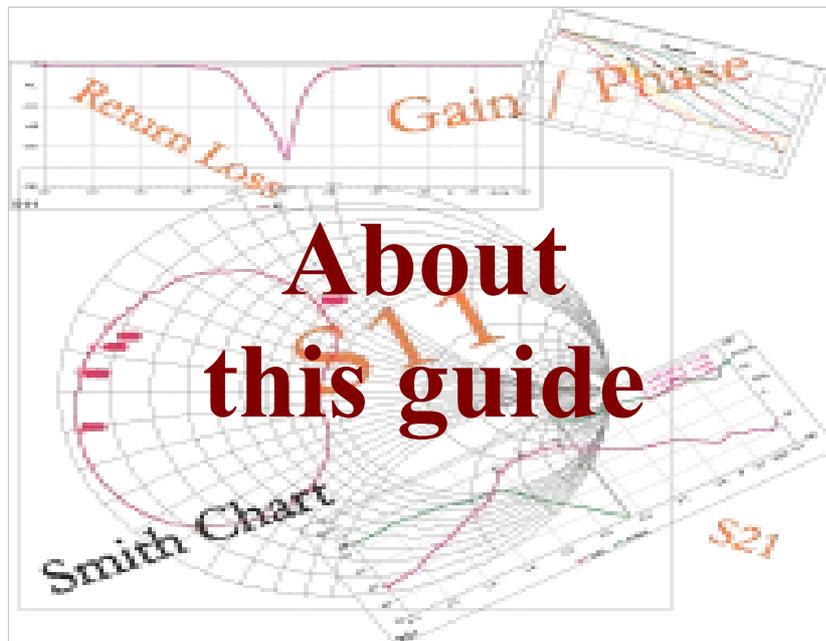
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general practice

Vector network analysis is for electronic engineers and designers. The apparatus needs special care, it is by no means comparable to the robustness of most multimeter and oscilloscopes. If you are acquainted with the use of spectrum analysers you probably are on the safe side, since the vulnerabilities of spectrum analysers are in the same order as VNAs.

Misuse might damage the instrument or lead to nonsense results. Therefore you'll find a list below with suggestions to be on the safe side.

- Beware of the maximum input signals. With a VNA these are, just as with spectrum analysers, much lower then with e.g. an oscilloscope.
  There is often a difference between allowable AC and DC input. With the MegiQ VNA maximum DC input is 20 V and maximum AC input is +20 dBm (100mW into 50Ω -> 2.2V rms)

- Keep connectors clean and mate them carefully, not too tight or too loose.

- Be careful with cables:
  - If you use the 'real ones', the ones intended for measurement purposes:
    - realize that they are very expensive
    - that mating them too often will wear them down.
  - If you use inexpensive "standard" cables:
    - make sure not to move or bend them too much after calibrating the set-up. This way you can make good measurements with those inexpensive consumer grade cables.
    - check them before using them, specially look for good, stable contact.
    - throw them away every now and then, and use a fresh new one.

- Calibrate the whole set-up each time you make a change. Even if you change a cable with an other "same" cable. Most cables, although looking the same, are different, except the ones specially made to be the same. But those specials are very expensive.

- Use "SMA-savers" on the input connectors to the SMA, (a simple male-female adapter, or an adapter to an other standard, such as UFL).
  By using adapters, you (un)screw connectors at the "output side" of the adapter and not directly on the front panel. This way you make sure not to wear down the front panel SMA to much.
  The adapter itself is easily "calibrated-out", so it will not spoil the measurement.

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about this guide

This guide serves two goals. Because you might be new to vector network analysis, or you might be new to the MegiQ VNA models.

Learning a new instrument can be challenging, and although the MegiQ VNA has a very intuitive user interface, it still *is* a full blown VNA, with the many different features that make sense if you use them in the right way.

Therefore this Getting started helps you through both: getting used to the actual instrument *and* hands on training with vector network analysis.

Fore this you will use the MegiQ VNA-Sandbox, a PCB with several easy demo circuits, but well chosen in order to present you with *both* the many features of the MegiQ VNA *and* the use of vector network analysis in every day life of an RF-engineer / -designer.

In principle you can use the MegiQ VNA-Sandbox with other VNAs in order to get accustomed to vector network analysis in case you do not have a MegiQ VNA available. In that case the buttons to push on the VNA will be different. And several measurements will be unavailable, because the MegiQ VNA -how simple it may look- has a lot to offer other instruments don't.

set-up

In this Getting Started we shall describe the set-up with the MegiQ VNA. You will need the following hardware / software:

- MegiQ VNA-0440 (standard or e-version) with USB cable and power adapter
- MegiQ VNA-Sandbox
- Windows XP or Win7 PC with the MegiQ VNA software installed
- SMA (f) to UFL (f) converter (3 times)
- coaxial cable UFL(m)-UFL(m) (3 times)

We presume the MegiQ VNA software has been installed. If not so, please refer to the Installation Guide.

Note that for some measurements, the ones using the internal bias generator or the third port, you will need the VNA-0440e.

the use of getting started

You can start with circuits on the MegiQ VNA-Sandbox where you want in this document, but if you are new to vector network analysis, we suggest to follow the order of this Getting Started manual. In all cases you should always start calibrating the set-up.

performing a VNA measurement

Performing a measurement with a Vector Network Analyser is not very difficult, as long as you do the right steps in the right order. These steps are independent of the kind of VNA measurement you want to do. It all just has to do with the use of the high frequencies, which makes it different from many other, lower frequency measurements.

- Think it all well over: what do you want to know, what do you want to do with the results, etc.?

- Choose the point where you want to measure. It is RF, so every millimetre counts: run length transform impedances, so choose this point carefully.

- Make sure you use the right cables, connectors.

- Power up the instrument and let it warm up. (the MegiQ VNA is very temperature stable, so in most cases you do not have to wait)

- Make the right measurement set-up (hardware) and the set-up of the instrument. (using the PC software)

- Perform the calibration. (see "calibration")

- Perform the measurements.

- Interpret and save the results.
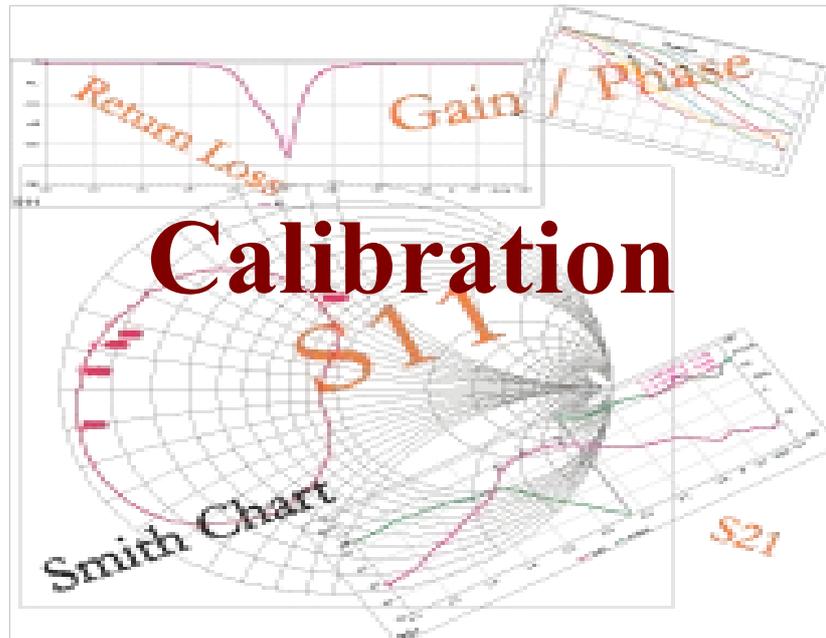
Calibration

calibration

In vector network analysis you are interested in impedances of components and circuits. At high frequencies almost any length of cable will act as an impedance transformer, thus altering the impedance you actually see. Furthermore at even higher frequencies many cables become lossy, which influences gain *and* impedance plots.

Luckily these cables act as linear elements and can be 'calibrated-out' by linear algebra. Do not be afraid, the instrument will do this for you, but it should be fed with some well known impedances for every frequency of interest before you start the actual measurement. Therefore before using the instrument you should perform a calibration on the whole set-up, including the cables, connectors, etc. for the frequency range you want to use in your measurement.

Point of calibration: at the EUT

The instrument stores this set of calibration data, and since the MegiQ VNA is very temperature stable, you will not have to perform this calibration routine very often.

But, changing cables, connectors or frequency range means that you most renew the calibration. Avoid bending cables to much after calibration. (depending on the quality of the cable of course)

The well known impedances the MegiQ VNA uses for this are an Open Connection (O) a Short Circuit (S) a load resistor of 50Ω (L) a Through (T) and a "No Connection" in order to calibrate the insulation between ports (I).

On the MegiQ VNA-Sandbox the calibration circuits are 11 (open), 12 (short), 13 (load and insulation) and 14 (through).

typical calibration setup

The calibrating process is straight forward, you will find it step by step below. You will find the process for the 1-port and the 2-port measurements. You will need cables with UFL connectors when using the MegiQ VNA-Sandbox.

Again: during the calibration process, use the very same cables and connectors you are going to use in the actual measurement! Not calibrating the whole set-up will lead to very confusing results!
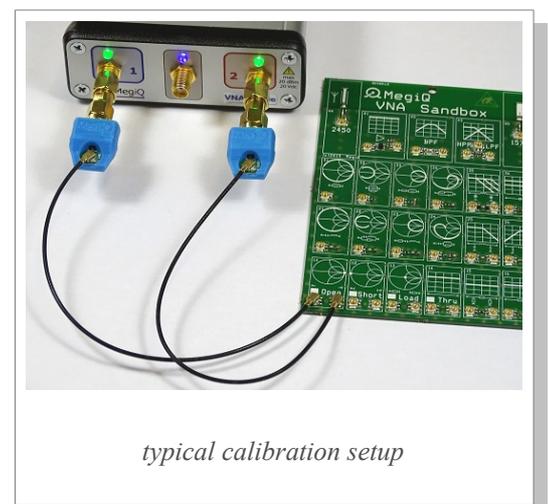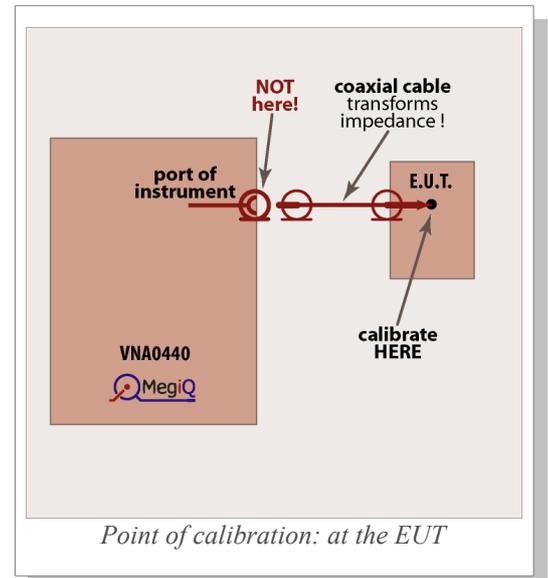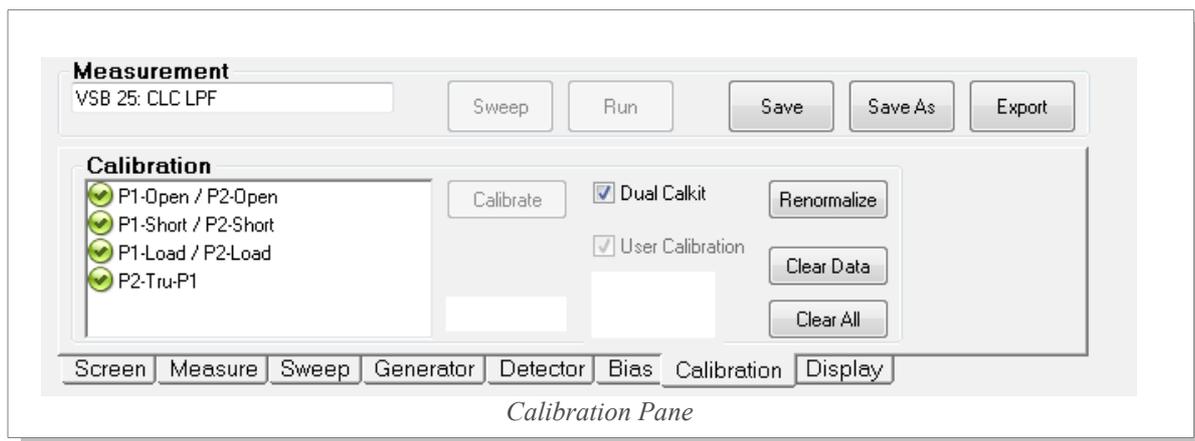
Calibration Pane

the calibration pane

By selecting the calibration tab you get the calibration pane.

In the list "**Calibration**" you see what calibrations are needed. You can select a calibration you want to perform in this list and then press the button "Calibrate". Of coarse after you made the right connections to known impedances. (The OSLT-kit)
Green says the calibration has been done, red means there is no data.
Note that the instrument does not know whether or not you changed anything since you last calibrated the set-up, so green does not always mean you've got a valid calibration!

check boxes

There are several check boxes.

- Dual Calkit: On the sand box, there are two of each calibration impedance (O, S, L,) This way you speed up calibration by doing two calibrations (both ports) at the same time, in case of a 2-port measurement.

- User Calibration: tells the instrument to use the calibration you perform with the OSLT kit.
  When this box is not checked the instrument will use the factory calibration at the SMA connectors of the instrument. You do not need to perform your own calibration now. But remember, the instrument will also measure any cable length, connectors, etc. that is in between the SMA of the instrument and your EUT. These will not be calibrated-out.

buttons

There are several buttons in the Calibration Pane:

- Calibrate: The instrument will calibrate what you just selected in the list. (double clicking in the list has the same effect)

- Renormalize: The instrument will apply the last calibration you made to the measurement data in the graphs. You can use this when you want to calibrate *after* you made your measurements, even on save data.

- Clear Data: This will clear the measurement data.

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- Clear All: This will clear the measurement data and the calibration tables.

single-port calibration (OSL)

If you are performing a 1-port measurement, you only need the O,S and L, because there is no "through" to an other port and also the "insulation" between ports is of no importance. First in the GUI, load the session file "VSB Measurements.vns" and select the measurement "VSB21/22:LCR series" This will pre-set the instrument and the display, which is handy if you are an new-comer to the MegiQ VNA-0440. Later on you can do all these, or different settings yourself, depending on the measurement.

1. GUI, Tab Generator: choose frequency range & generator power as appropriate.

   open

2. Connect the VNA to the "Open" circuit on the Sandbox (*circuit 11*)

3. GUI, Tab Calibration: select P1-Open
   and press Calibrate.

   short

4. Connect the VNA to the "Short" circuit on
   the Sandbox (*circuit 12*)

5. select P1-Short and press Calibrate.

   load

6. Connect the VNA to the "Load" circuit on
   the Sandbox (*circuit 13*)

7. select P1-Load and press Calibrate.

   final check

Press Sweep. In the Smith chart all measurement points should now be close to the centre (50Ω) and in the Return Loss chart all points should be better then 45dB.
(50 is better then 40 when it comes to Return Loss)

You are ready to go now, but remember, after changing cables, connectors or frequency range you'll have to renew the calibration!

2-port calibration (OSLTI)

If you are performing a 2-port measurement, you need the O, S and L on both ports, *plus* the "*through*" (T) from one port to the other and the "*insulation*" (I) between both ports.

First in the GUI, load the session file "VSB Measurements.vns" and select the measurement "VSB25: CLC LPF" This will pre-set the instrument and the display, which is handy if you are a new-comer to the MegiQ VNA-0440. Later on you can do all these, or different settings yourself, depending on the measurement.

instrument set-up

1. GUI, Tab Generator: choose frequency range & generator power as appropriate.

open

2. Connect *both* ports to the "Open" circuits on the Sandbox (*circuit 11*)

3. GUI, Tab Calibration: select P1-Open / P2-Open and press Calibrate.

short

4. Connect *both* ports to the "Short" circuits on the Sandbox (*circuit 12*)

5. select P1-Short / P2-Short and press Calibrate.

load

6. Connect *both* ports to the "Load" circuits on the Sandbox (*circuit 13*)

7. select P1-Load / P2-Load and press Calibrate.

insulation

8. The insulation between the two ports will be calibrated together with the load calibration above, so you do not need to perform any special action for that.

through

9. Connect *both* ports to the "Through" circuit on the Sandbox (*circuit 14*)

10. select P2-Tru-P1 and press Calibrate.

final check

Connect both ports to the "Load" circuit on the Sandbox (*circuit 13*).

Press Sweep. In the Smith chart all measurement points should now be close to the centre (50Ω) and in the Return Loss chart all points should be below 40dB.

You are ready to go now, but remember, after changing cables, connectors or frequency range you'll have to renew the calibration!

saving your calibration

You can press the button "Save As" and give your configuration a name. Specially the 2-port calibration is quiet some work. After saving the configuration, you also save the calibration tables and thus you'll have the saved configuration to go back to. Of coarse this only gives you a valid calibrated set-up as long as you change nothing.
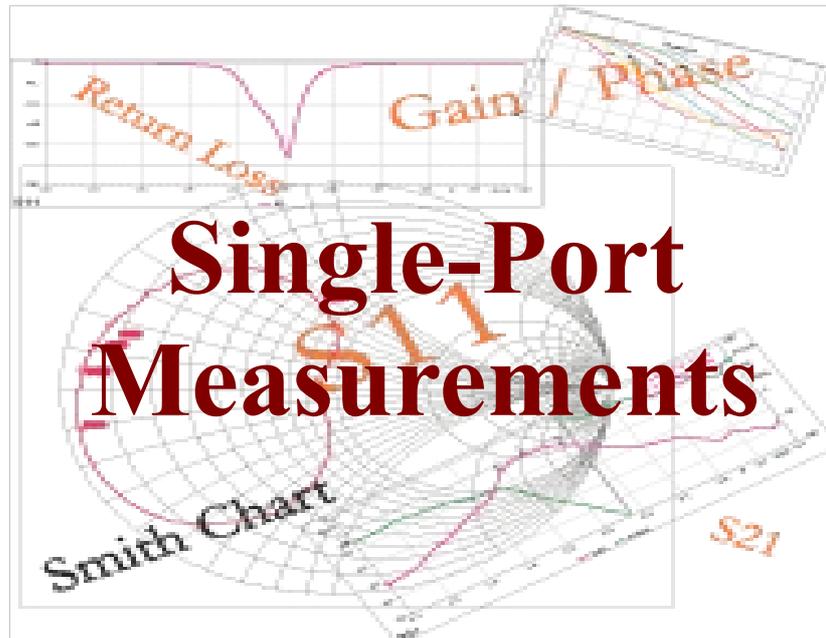
Single-Port Measurements

Single port measurements

Now you are ready to start performing actual measurements on the MegiQ VNA-Sandbox. RF in real Life! You will find a description of every circuit on the Sandbox together with an explanation what you see on the VNA display, and more important: "*What does it mean*".

real life circuits!

No, do not be afraid, these RF circuits are not "life" in the sense of dangerous voltages. No, the VNA uses low signal levels which are not dangerous. With *Real Life Circuits* we mean: circuits you are likely to encounter in your day-to-day work as an RF-engineer.

experiment!

You can experiment freely with the circuits on the MegiQ VNA-Sandbox. Feel free to watch the effects of a loosely connected cable, of changing one cable by a slightly longer one without recalibrating. Also the effects of touching the circuit under test, or in case of the antenna experiments, just putting your hand in the neighbourhood of the circuit.

using the sandbox

This is very easy. Every circuit has a number, one or more UFL connectors and a small graph of the expected results. Connect the instrument to the connectors of the circuit of your choice, do the right settings on the instrument and perform the measurement.

The circuits and the measurements on it are explained in this document, one chapter per circuit You can start with any circuit at will. But if you are a new-comer to vector network analysis, we suggest you start in the order of this manual.

calibration

Of course, you have already calibrated the set-up with connectors and cables you are going to use in the real measurements. If not so, see the previous pages under "calibration". The instrument is very stable, so once calibrated you can go on for quiet some time.

enjoy!

It is not for an exam. So play around and learn, learn and learn. And do no forget to enjoy, because learning RF is fun!

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series resonant circuit (21)

An ideal series resonant circuit consist of a pure capacitor in series with an inductor and is therefore a pure imaginative impedance, except at resonance where the capacitive and the inductive part cancel each out resulting in a short circuit, which is a 'zero-vector' in the origin so you cannot define it being real or imaginative at resonance.

circuit 21:
series LC

schematic

what do you see

All pure imaginative impedances reside on the outer rim of the Smith chart. At very high frequencies the impedance is very high due to the inductor. on the low side of the spectrum it is very high due to the capacitor. In between the impedance goes from high through zero, to high again.

As soon you see the graph of a series resonant circuit leave the outer rim going a bit to the middle it tells you that the circuit is not that ideal at all (which is with anything in real life)

Anything within the Smith chart is lossy, so there are pure resistive ('real') elements in the circuit. This has to do with the circuit-Q. Affecting this are resistance of the inductor (plus the skin effect), dielectric losses in the capacitor and PCB material.

You also see that these losses increase at higher frequencies.

Note: losses in the cables are NOT contributing to this effect. You've calibrated these out.. (You *do have* calibrated the whole set-up including cables and connectors, haven't you?)

All points outside the graph indicate a negative real resistance, e.g. an active circuit, like an oscillator, but this is not the case with circuit 21.

explanation of the display

typical measurement display

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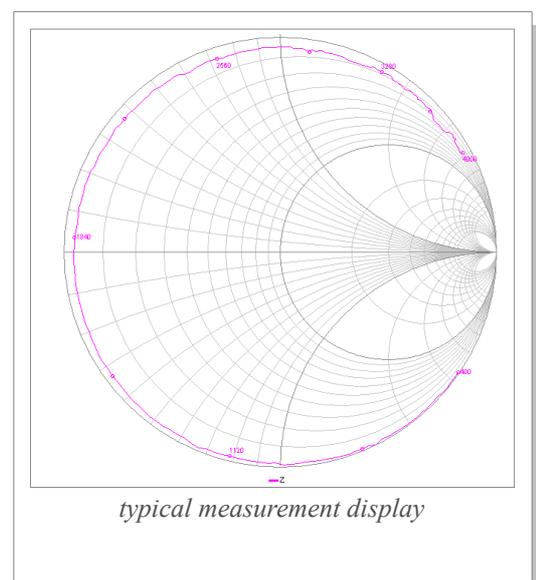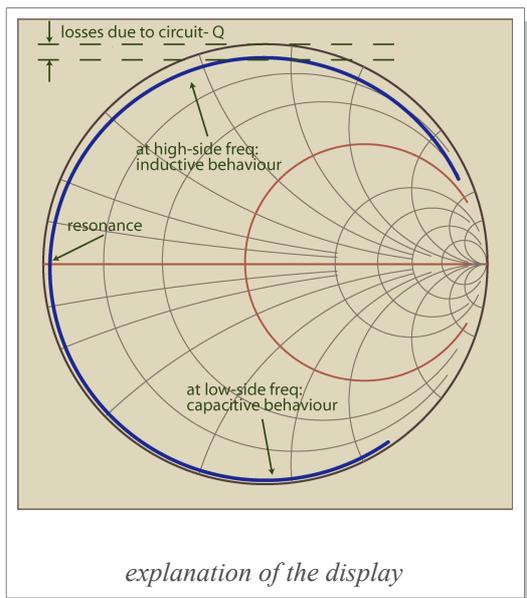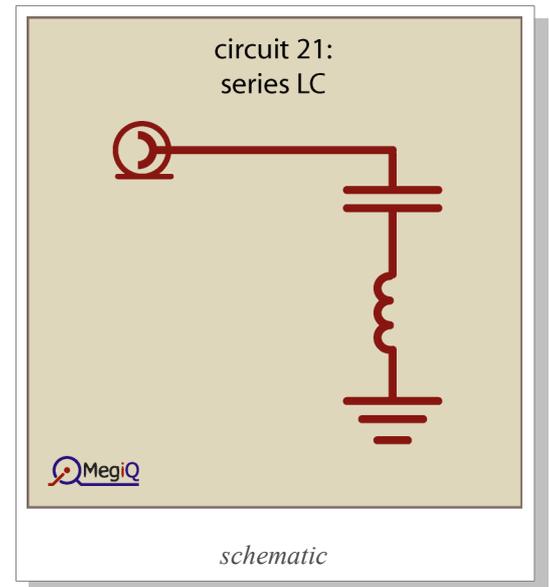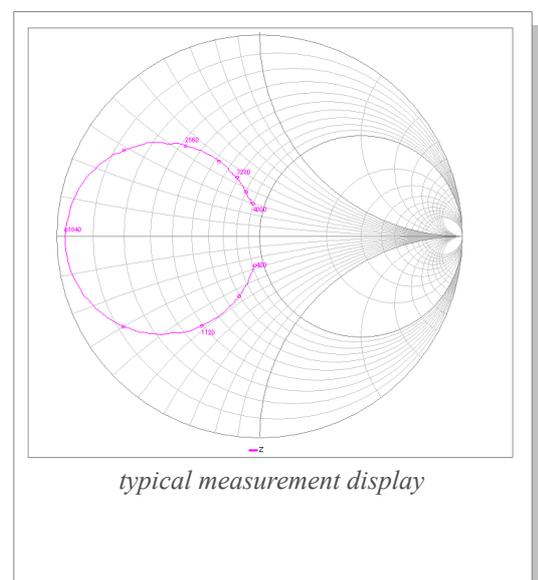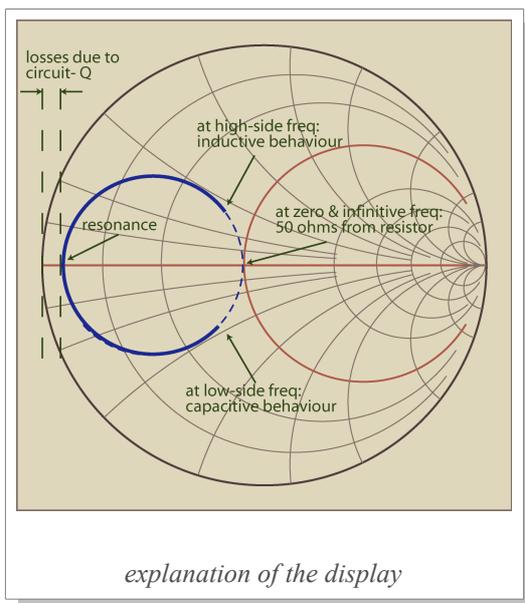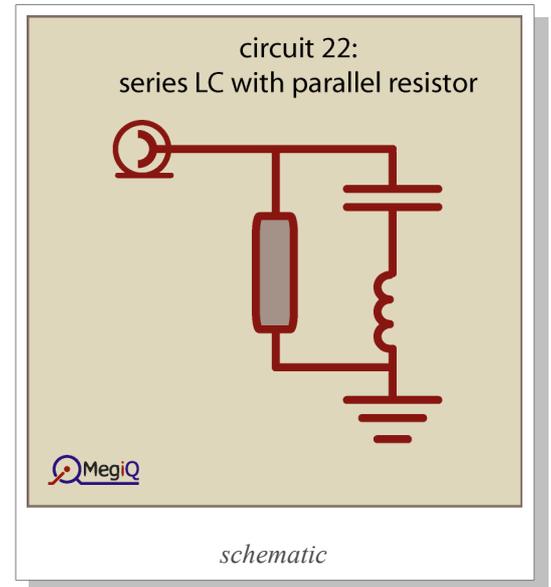
series resonant circuit with parallel resistor (22)

Here the series resonant circuit is bypassed by a pure resistor, introducing a reel part in the impedance.

what do you see

Near to resonance you will see about the same behaviour as with the previous circuit, because the impedance of the LC is very low at those frequencies, thus shorting out the resistor.

But, when you move away from resonance, the impedance of the LC will go way up and the influence of the parallel resistor will be greater, until finally, you only "see" this resistor (50Ω). Above resonance the circuit is more like a lossy inductor and on below resonance it looks like a very lossy capacitor.

Here the curve is much more to the inner of the chart, indicating a "lossy circuit". Note that the word "lossy" only applies to the port you are looking into. It means there is less power "coming back".

circuit 22:
series LC with parallel resistor

schematic

explanation of the display

typical measurement display

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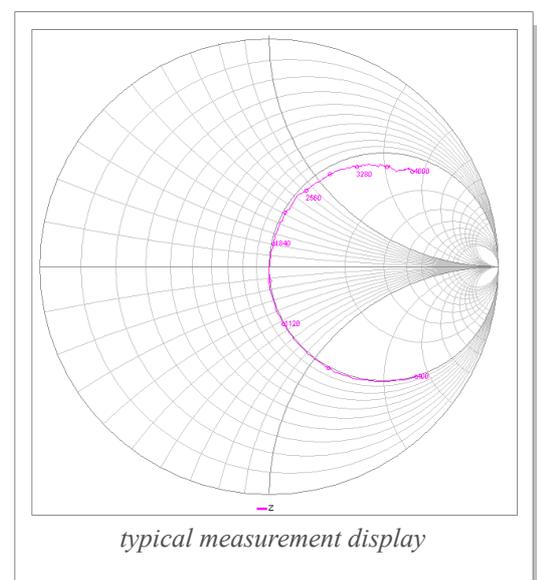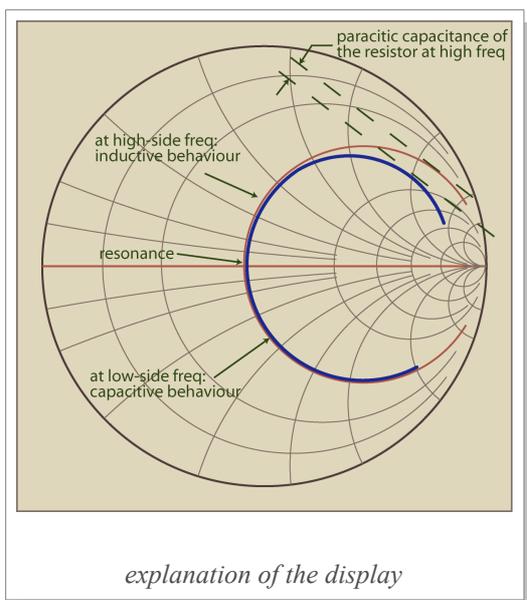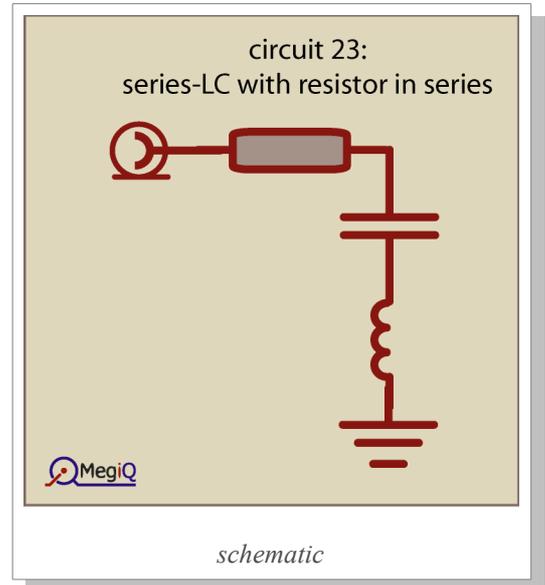## series resonant circuit with resistor in series (23)

Now you find a resistor in series with the series LC-circuit, again introducing a reel part tot the imaginary impedance of the LC-resonant circuit.

what do you see

At very low frequencies the capacitor introduces the bulk of the series impedance, while at very high frequencies you will almost only see the inductor. In both cases the resistor does not contribute a lot to the total impedance. But around resonance the LC part shows very low impedance and then the resistor (50Ω) has a big influence.

The line does slightly go to the inner of the chart at very high frequencies. This is caused by the by the parasitic capacitance shunting the resistor and also by increased circuit losses at higher frequencies.

So way off resonance the circuit shows the same behaviour as the simple series LC-circuit (circuit 21) and close to resonance the circuit acts as a 50Ω resistor, yielding points very close to the middle of the Smith chart. (Yes, in this case very lossy *and* dissipative)

circuit 23:
series-LC with resistor in series

schematic

explanation of the display

typical measurement display

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series resonant circuit with resistor parallel with inductor (24)

Again a series LC-circuit, but now with a 50Ω resistor parallel to the inductor. This simulates a very lossy coil at high frequencies.

what do you see

At very low frequencies the capacitor takes care of the bulk of the impedance: it shows a high capacitive impedance very alike circuit 21, the first LC-circuit. The resistor is of almost no importance. But when frequency goes up the capacitive impedance goes down and the RL-part gets more influence.

At resonance the line crosses the reel line (the horizontal line in the chart) much closer to the middle then in the case of circuit 21. Indeed, the circuit is much more lossy then the (almost) pure LC-circuit so the line *got to be* closer to the middle.

circuit 24:
series-LC with resistor parallel
with inductor

schematic

At very high frequency the capacitor has a very low impedance and the inductor a very high one, so the 50Ω of the resistor dominated the graph at high frequencies.
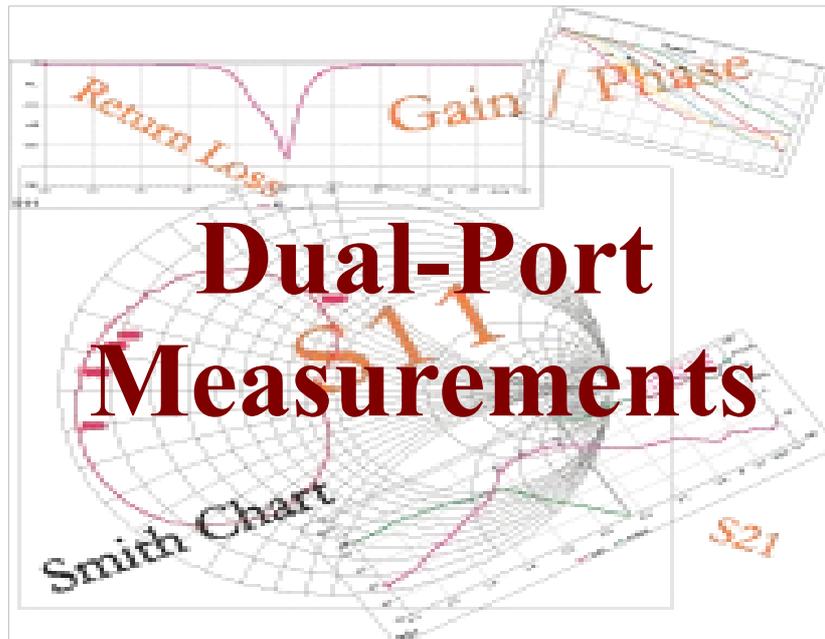
explanation of the display

typical measurement display

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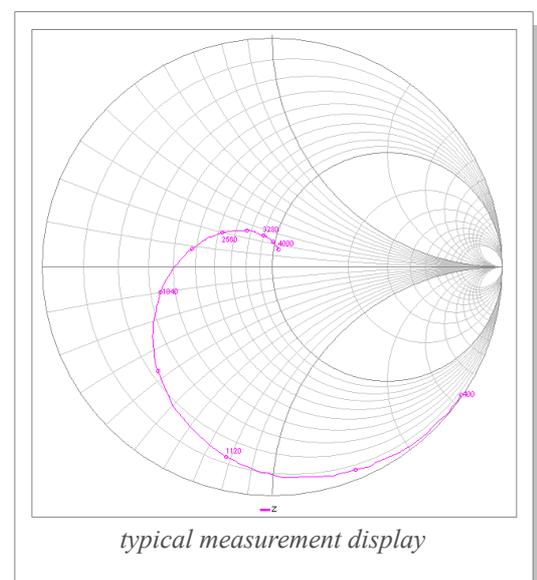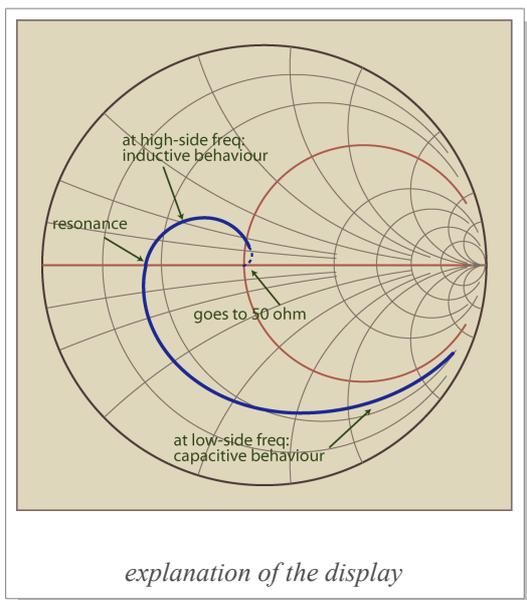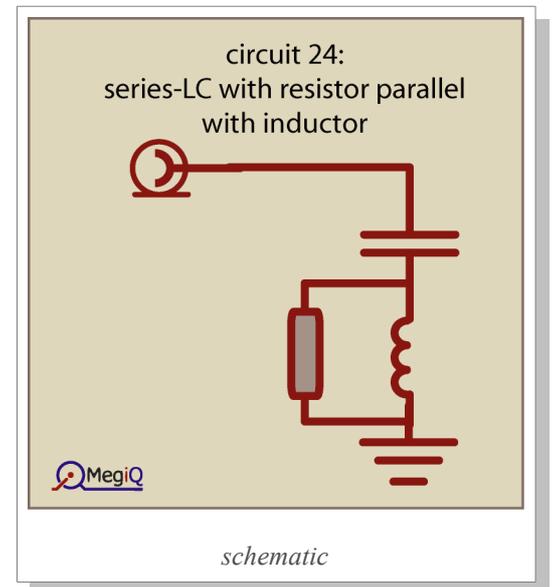
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Please contact MegiQ for more information about the VNA-Sandbox that includes the full version of this tutorial.

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