

## about the MegiQ VNA Sandbox

The MegiQ VNA Sandbox is a small educational kit, featuring 22 circuits, including a calibration kit. It serves two goals:

**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.

**Learning new kind of measurements,** and Vector Network Analysis is new to many Engineers has not just to with pushing buttons. You must know what you see, interpret the data and pictures and translate that to engineering decisions.

**The MegiQ VNA Sandbox helps you through both:** getting used to the instrument *and* hands on training with vector network analysis.



*The MegiQ VNA Sandbox*

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.

### Simple Connect and Go

you will find the calibration tools and the “circuits under test” on one PCB. There are a lot UFL coaxial connectors on this board so that you can easily connect the circuit you want to evaluate. The MegiQ VNA and the Sandbox comes with UFL cables and UFL to SMA converters, so you are ready to go.

A step by step guide explains you how to calibrate, you to use the instrument, how to interpret the data and graphs you get from the Sandbox-circuits, etc, etc.

### Preview

As a preview, you will find on the next pages an abstract of the educational material that comes with the MegiQ VNA Sandbox.

## there we go

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 VNA 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.

### configuration files

There are some pre-set configuration files you can load, that will set the instrument in the right set-up. With each measurement we shall note what configuration file you can use. Of course, you can make your own settings, which we strongly recommend, but perhaps you can wait to do this after you've become acquainted with vector network analysis on the VNA-Sandbox.

But in first instance, using the configuration files give you a good head start, since these not only set the right setting of the instrument, but also the right choice of graphs on the screen.

### 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 not forget to enjoy, because learning RF is fun!

## 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.

### measurement

In the GUI, load measurement **1PortResonance**, connect port-1 to the circuit and press sweep on the Screen-tab.

### what do you see

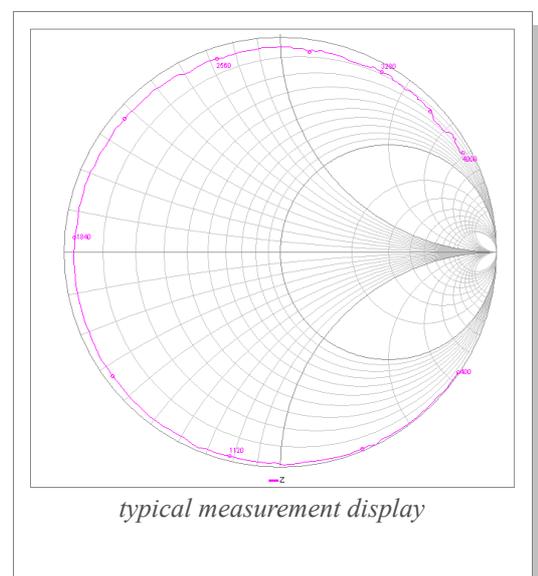
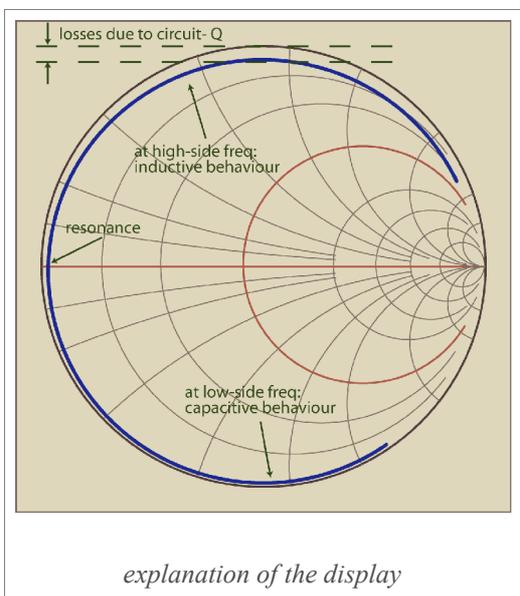
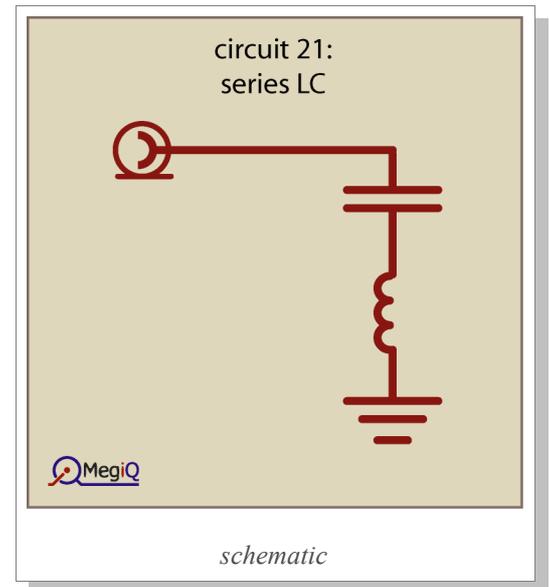
All pure imaginative impedances reside on the outer rim of the Smith chart. At very high frequencies the impedance is very high due to the inductor. on the low side of the spectrum it is very high due to the capacitor. In between the impedance goes from high through zero, to high again. As soon you see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



abstract

## series resonant circuit with parallel resistor (22)

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

### measurement

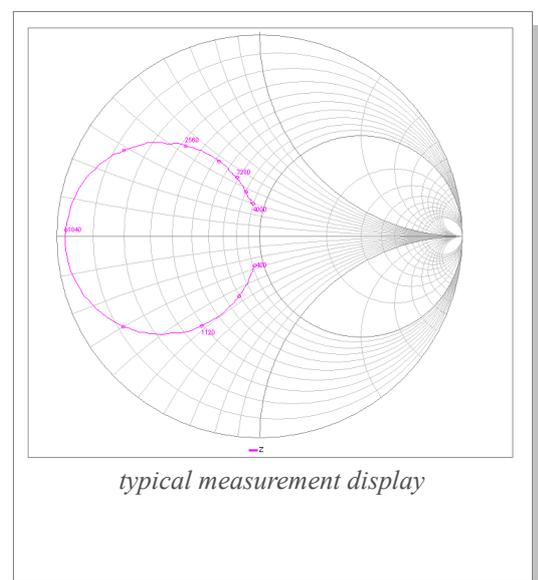
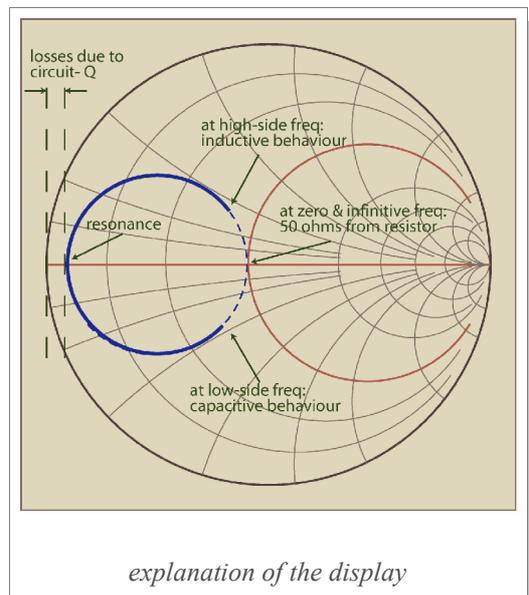
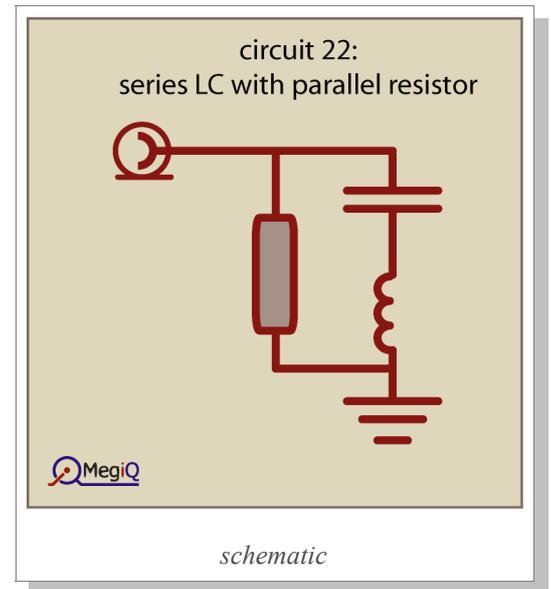
In the GUI, load measurement **1PortResonance**, connect port-1 to the circuit and press sweep on the Screen-tab.

### 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”.



abstract

## resistive $\Pi$ -attenuator (15)

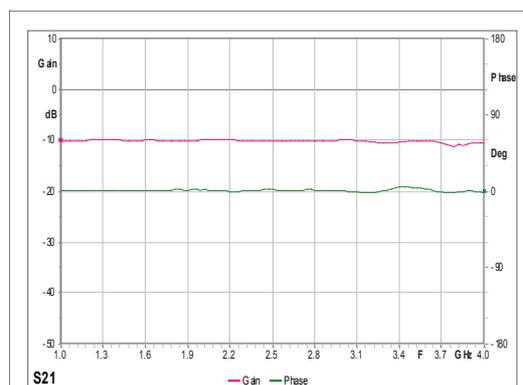
A resistive  $\Pi$ -attenuator consists of three resistors and should give good match on both ports, is fully bi-directional if is symmetrical and should give a fixed attenuation over the whole frequency range.

### measurement

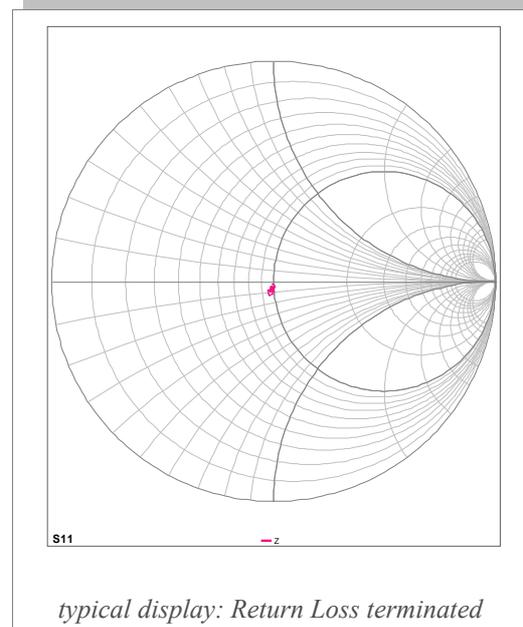
In the GUI, load measurement **2Port**, connect port-1 and port-2 to the circuit and press sweep on the Screen-tab.

### what do you see

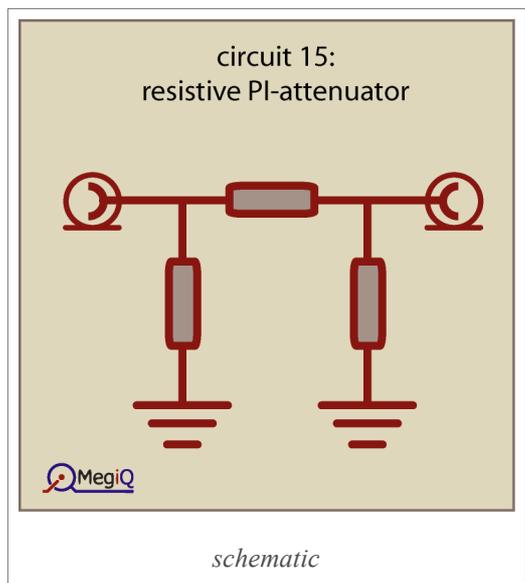
Main goal of resistive  $\Pi$ - (and also T-) attenuators is guaranteeing a good match, i.e. high Return Loss / low SWR and also attenuating the signal, although often the



typical measurement display (gain/phase)



typical display: Return Loss terminated



schematic

attenuation is not the main goal and even not wanted. But well, you get nothing for free...

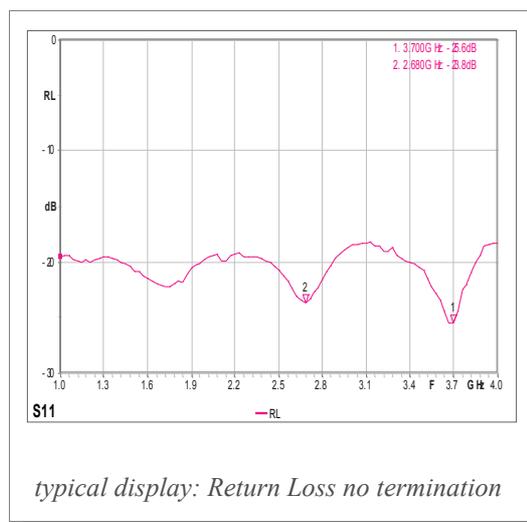
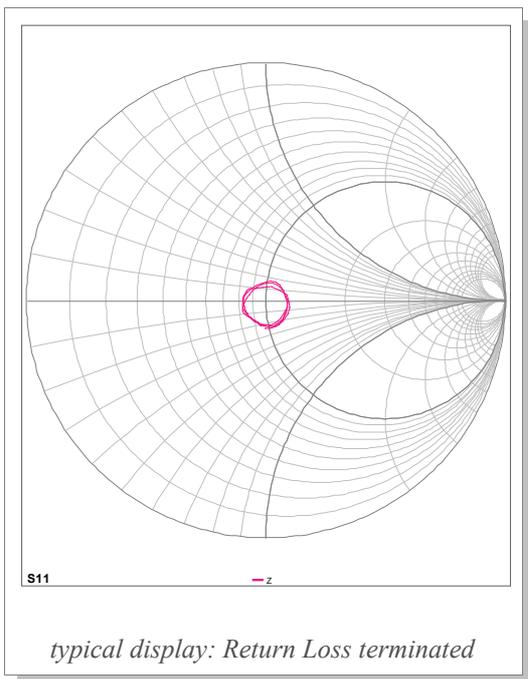
Resistive attenuators should be broadband and should not exhibit any phase shift: they are not filters.

Well, from the gain/phase plot you can read that the attenuator is broadband indeed, doing 10 dB of attenuation and that phase shift is zero. There are some small anomalies at the high end of the spectrum, but for such a simple attenuator on epoxy and using standard components it is not bad at all!

As you would expect, in the Smith chart all measurement points are close to the middle, indicating a very good match. There is some anomaly though, they all lie a bit below the resistive line, they are a bit capacitive. This is most probably due to parasitic capacitances of pads or components.

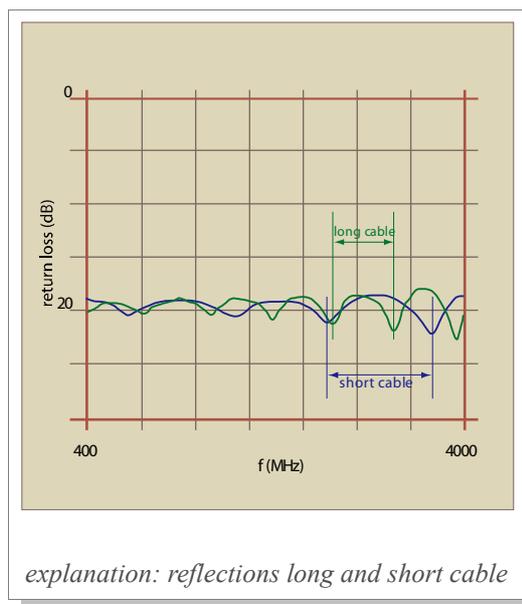
Now an interesting experiment: disconnect the output cable from the attenuator at the end of the VNA. You get a Smith chart with all points in a circle-like pattern closely around the middle, and indeed, this is a SWR-circle, indicating a fixed (quiet good) Return Loss. If you express this in a Return Loss graph in dB, you can look more into detail and see some wavelike patterns.

abstract



These wave are caused by reflections in the cable. You could try a long and a short cable and see the with longer cable the “wave-length” in the graph gets shorter. This has to do with the fact that the cable is in fact a transmission line transformer and that circles around the middle point of the Smith chart, thus transforming the mismatch at the far end of the cable in a repetitive way. A longer cable has a lower resonance frequency, i.e. it “turns around the middle” faster introducing more (and shorter) waves.

Furthermore the average of the Return Loss is around 20 dB, what you would expect from a 10dB attenuator.



abstract

## voltage controled low-pass filter (35)

Again a simple CLC low-pass filter configured as a  $\Pi$ . But now the capacitors are varactor diodes, so you can adjust the cut-off frequency of the filter by applying a DC voltage on the varactors.

Here you use the internal bias generator and the internal bias-Tee's of the VNA as a programmable voltage generator. This is not incorporated in the standard version, you should have the extended version, the VNA-0440e. You recognize this version by the third SMA (generator output) on the front panel.

### measurement

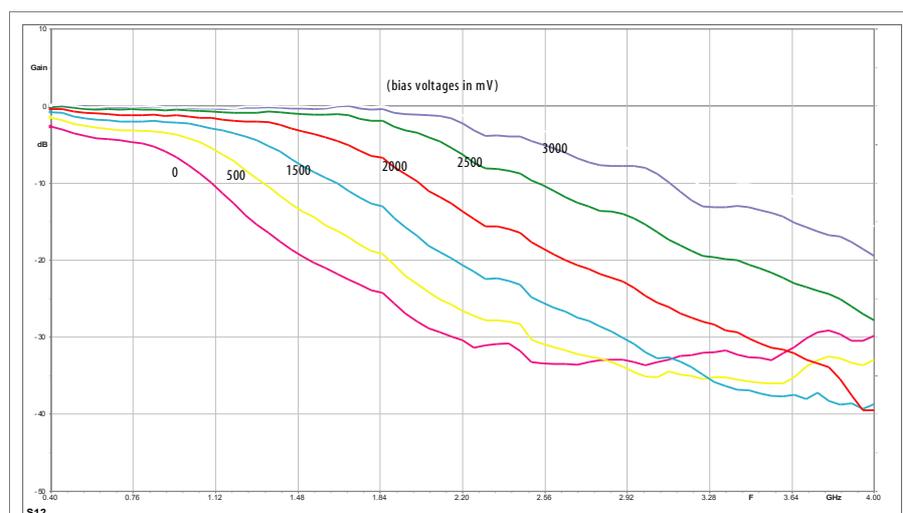
In the GUI, load measurement **2PortVaractor**, connect port-1 and port-2 to the circuit and press sweep on the Screen-tab.

### the bias generator

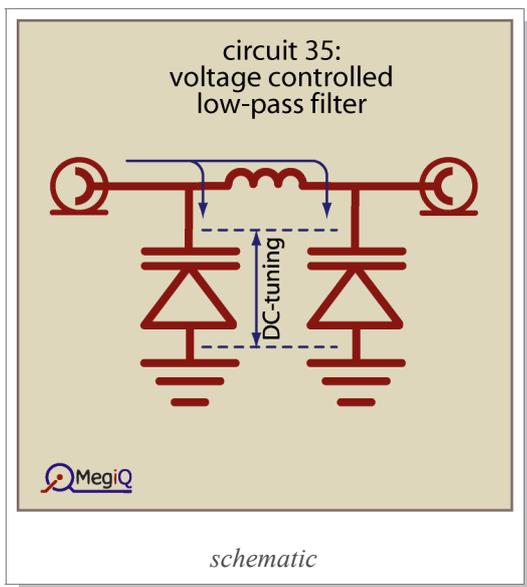
The programmable bias generator can make steps in voltage and in current. You can select on which port the bias generator acts, via a bias-Tee. You can also ground a port for DC or leave it open. In the case of this filter you can apply the DC tuning voltage to port 1 or port 2 as long as you leave the other port open, because you should apply DC-voltage across the varactor diodes.

You can choose to step the bias generator or leave it at a fixed level (I or V). You can also choose the order, so sweep the bias for each step in frequency, or make multiple frequency sweep with a different bias setting each. The latter is what we do here in this example.

### what do you see



typical measurement display (gain)

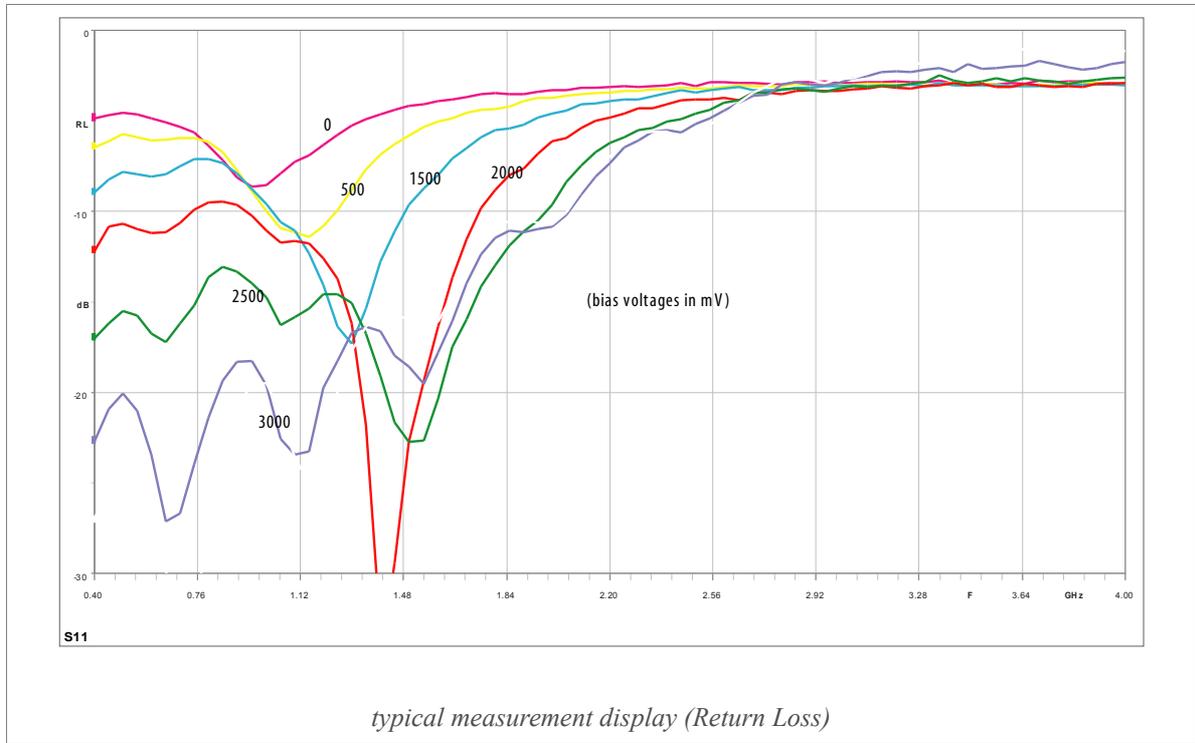


In one overview you see the frequency response at different tuning voltages, and see how the cut-off frequency changes.

All in one press of the sweep button!

abstract

You can also draw the graph where you see the Return Loss at several DC-bias settings. Watch how the Return Loss is heavily affected by the DC-bias.



abstract

## Concluding

Well this was a quick introduction to the MegiQ VNA Sandbox, a tool to play with in order to get accustomed to Vector Network Analysis pretty fast.

## Contact us

For more information on the Sandbox, or on other products, please contact us or your local representative.

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