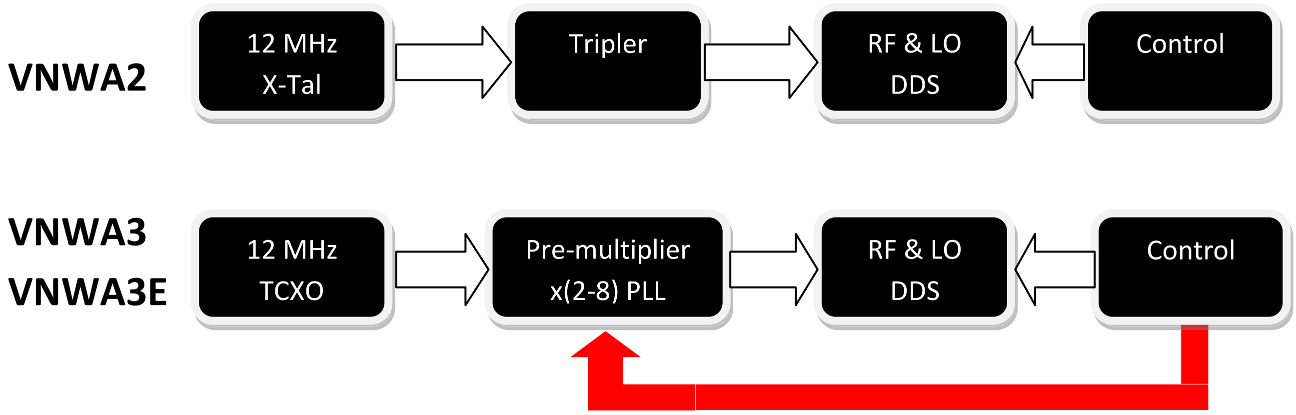
Why VNWA2 and VNWA3 does not show correct attenuation of high and low pass filters or what limitation exist for the VNWA design compared to a professional R&S or HP VNA

Preface:

1. **Some basic information about VNWA2, VNWA3 and VNWA3E**



For VNWA2 the Clock frequency is fixed 36MHz (35.9MHz) and internally in the DDS there is a facility for further multiplication of the 36MHz clock.
During a sweep the multiplication factor is changed by the Control circuit for both the RF and LO DDS but not by the same factor. The user can select whether the shall happen automatic (mode Auto) in the VNWA software - menu Options/Setup/Instrument Setting – or the RF or LO DDS shall run with fixed and independent multiplication factors.
For the VNWA3 and VNWA3E there has been added a controllable PLL Pre-multiplier which can multiply the clock with a factor 2 to 8. Thus the RF and LO DDS can be clocked in dependable from 24 to 288MHz. However the internal multiplier of the DDS is set accordingly, not to run the RF & LO DDS beyond safe limits.
If running the VNWA3 with Auto and pre multiplier set to 3 instead of Auto then the VNWA3 behaves exactly as VNWA2.
The Auto switching schema in this special case is as seen below:

For the VNWA2

Auto Clock Multiplier Settings: Base-Clock = 35.9 MHz

File

Seg.#	start f	f/Base-Clock	n LO	n RF
1	0 MHz	0	10	9
2	107.675 MHz	3	20	19
3	574.266 MHz	16	10	11
4	610.157 MHz	17	11	13
5	663.995 MHz	18.5	14	13
6	717.832 MHz	20	15	14
7	771.669 MHz	21.5	17	15
8	825.507 MHz	23	17	15
9	897.29 MHz	25	18	17
10	969.073 MHz	27	19	18
11	1040.856 MHz	29	20	19
12	1292.097 MHz	36	14	15
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For the VNWA3/VNWA3E

Auto Clock Multiplier Settings: Base-Clock = 3 · 12 MHz

File Options

Seg.#	start f	f/Base-Clock	n LO	n RF
1	0 MHz	0	10	9
2	108 MHz	3	20	19
3	576 MHz	16	10	11
4	612 MHz	17	11	13
5	666 MHz	18.5	14	13
6	720 MHz	20	15	14
7	774 MHz	21.5	17	15
8	828 MHz	23	17	15
9	900 MHz	25	18	17
10	972 MHz	27	19	18
11	1044 MHz	29	20	19
12	1296 MHz	36	14	15
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As seen identical switching for VNWA2 and VNWA3. The first frequency any change takes place is 108 MHz which we later shall see playing an important role.

For the VNWA3 when Auto mode selected for both the RF and LO DDS as well the Pre-Multiplier PLL.
In the following this mode called **VNWA3 Auto Auto mode**
A far more complex switching takes place, and already from 47.1 MHz.
As seen the max. clock is constantly close to the DDS limit 675 MHz.

Auto Clock Multiplier Settings: Base-Clock = 12 MHz

File Options

Seg.#	start f	f/Base-Clock	n LO	n RF	premult.	max. clock
1	0 MHz	0	5	7	8	672.000201901616 MHz
2	47.1 MHz	3.925	9	7	6.25	675.000202802962 MHz
3	72.2 MHz	6.016667	11	10	5.3125	701.250210689744 MHz
4	94.9 MHz	7.908333	7	9	6.25	675.000202802962 MHz
5	111.3 MHz	9.275	10	9	6	720.00021632316 MHz
6	140.2 MHz	11.683333	10	11	5.3125	701.250210689744 MHz
7	189.1 MHz	15.758333	18	17	3.125	675.000202802962 MHz
8	220.6 MHz	18.383333	10	9	6	720.00021632316 MHz
9	223.9 MHz	18.658333	10	11	5.3125	701.250210689744 MHz
10	252.7 MHz	21.058333	20	19	3	720.00021632316 MHz
11	281.9 MHz	23.491667	18	19	3.125	712.500214069794 MHz
12	288.2 MHz	24.016667	11	10	5.3125	701.250210689744 MHz
13	302.6 MHz	25.216667	11	10	5	660.00019829623 MHz
14	326.1 MHz	27.175	10	9	6	720.00021632316 MHz
15	352.5 MHz	29.375	10	11	5.3125	701.250210689744 MHz
16	378.8 MHz	31.566667	20	19	3	720.00021632316 MHz
17	394.3 MHz	32.858333	18	19	3.125	712.500214069794 MHz
18	409 MHz	34.083333	20	19	3	720.00021632316 MHz
19	413.3 MHz	34.441667	18	19	3.125	712.500214069794 MHz
20	433 MHz	36.083333	20	19	3	720.00021632316 MHz
21	457.1 MHz	38.091667	10	9	6	720.00021632316 MHz
22	488.1 MHz	40.675	19	18	3.125	712.500214069794 MHz
23	524.8 MHz	43.733333	14	15	4	720.00021632316 MHz
24	525.2 MHz	43.766667	19	18	3.125	712.500214069794 MHz
25	543.5 MHz	45.291667	14	15	4	720.00021632316 MHz
26	544 MHz	45.333333	19	18	3.125	712.500214069794 MHz
27	562.3 MHz	46.858333	14	15	4	720.00021632316 MHz
28	573.5 MHz	47.791667	19	18	2	456.000137004668 MHz
29	599.7 MHz	49.975	11	13	3	468.000140610054 MHz
30	608.3 MHz	50.691667	13	11	3.125	487.500146468806 MHz
31	617.3 MHz	51.441667	18	17	2	432.000129793896 MHz
32	622.3 MHz	51.858333	13	11	3	468.000140610054 MHz
33	626 MHz	52.166667	13	11	3	468.000140610054 MHz
34	627.5 MHz	52.291667	10	9	4	480.00014421544 MHz
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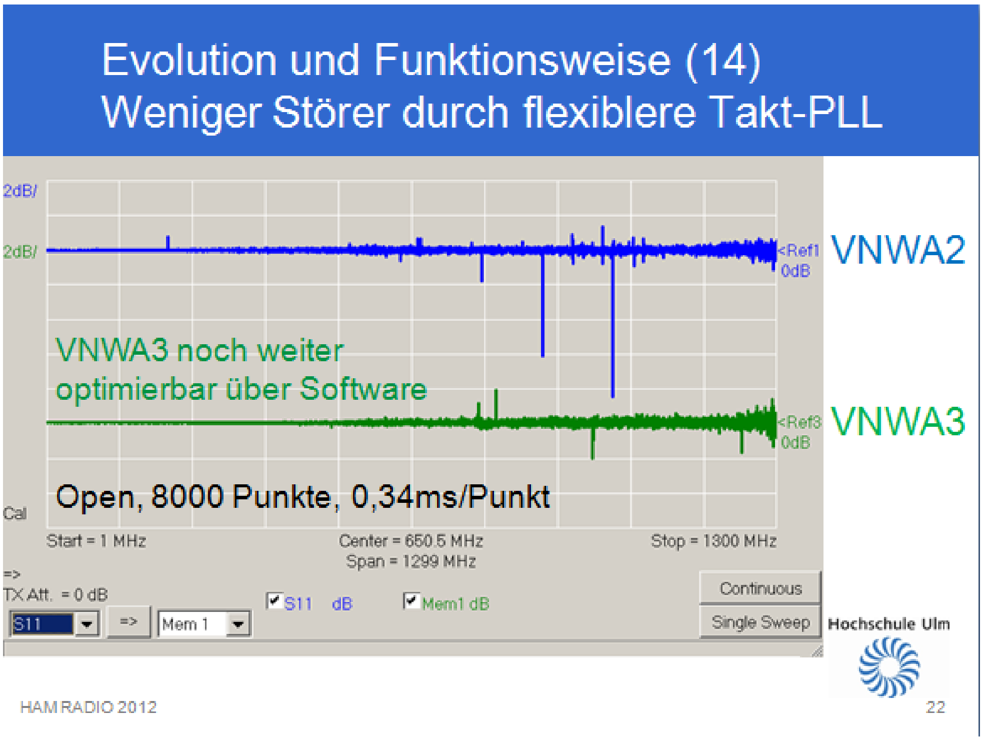
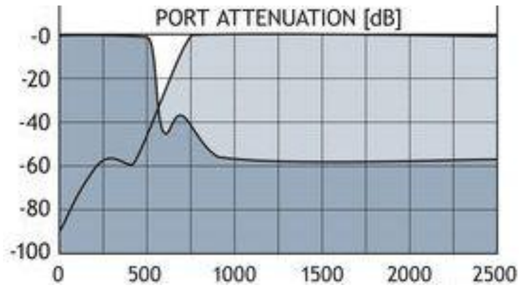
The benefit of this more aggressive switching is the possibility to reduce spikes as below slide from Tom Baier's presentation at HAMRADIO 2012 shows (see below) but any "medal has a backside" as the measurement to follw demonstrates.

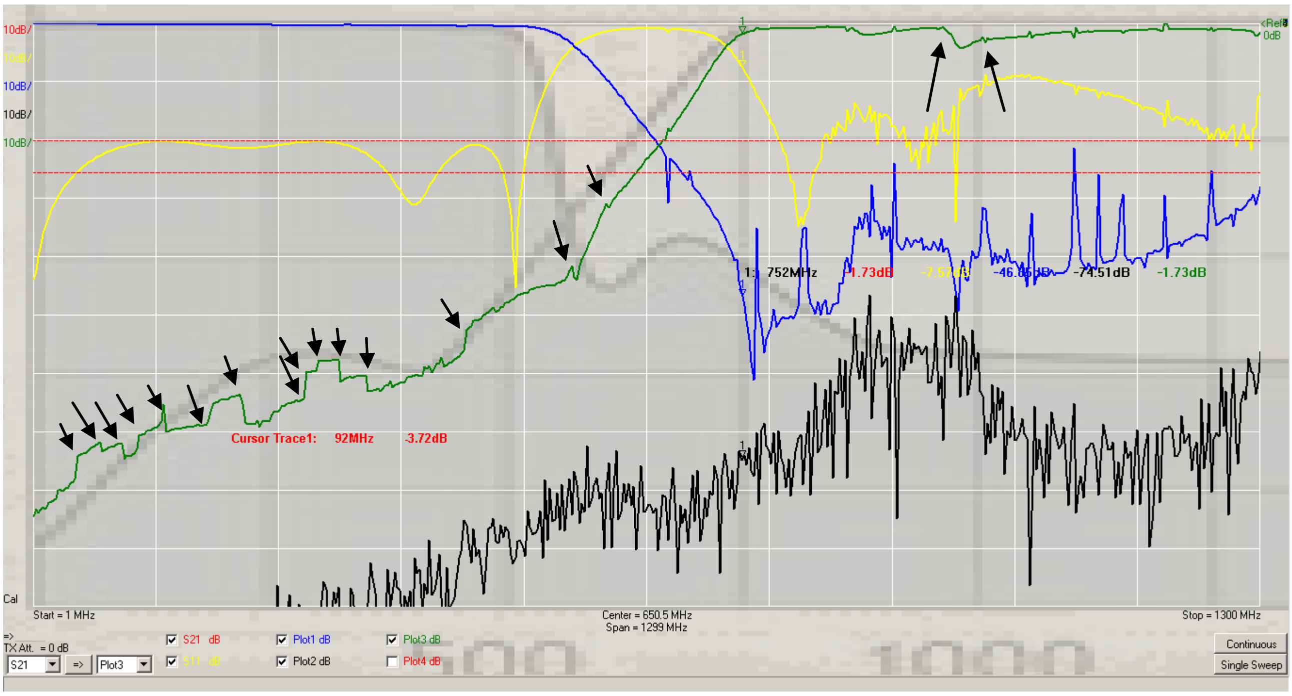


Measurements on a diplexer from Procom which has a change over frequency of 550MHz and provides a low pass filter of 500MHz and a High Pass filter of 800-1300MHz

DIPX500/800



In all cases I use the manufacturers specification as background (light Gray trace) using the nice VNWA feature for such purposes. The sweep is with 500 point and time per point 100mS both during calibration and sweep. The unused port always terminated with 50 ohm. Calibration is with crosstalk cal. in use (just in case) even if it reduces the dynamic range by 3dB where no crosstalk exist (according to info from DG8SAQ Tom Baier).



In above picture I am running the VNWA3 in Auto Auto Mode.

Black Trace is the Noise floor when RX port left open (actually terminated with 50 ohm).

Yellow Trace S11 measure at the diplexer input but not relevant for this discussion

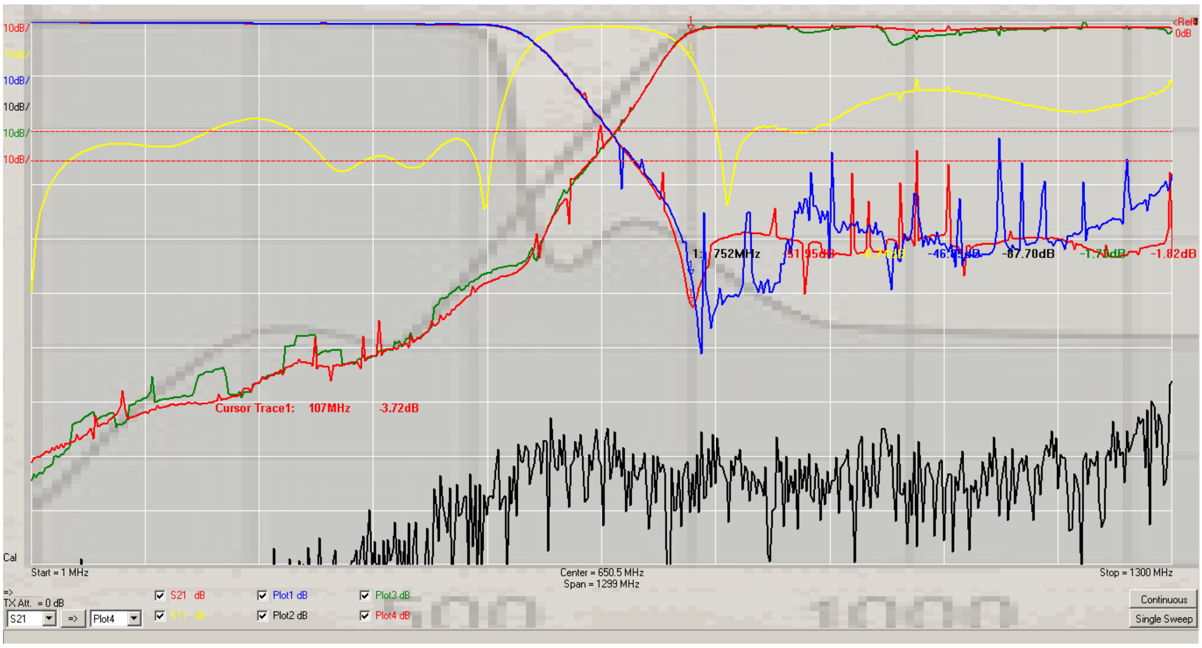
Blue Trace the Lowpass Filte

Green Trace the Highpass filter.

For both the Low pass and High pass measurements the traces are quite “jumpy” (see arrows for the High Pass filter)

All these “jumps” are caused by the VNWA3 Auto Auto mode aggressive switching scheme and is causing a lot of Beyond UHF frequency components which exist both for the LO and RF signal and while sweeping below 600MHz these components just passes from the VNWA TX port through the Highpass filter without any attenuation. Remember that during the calibration all this “noise” is removed during the S21 calibration and so to say part of the calibration. During a sweep where we expect to measure attenuations beyond 30 to 40dB these side effect has to expected in the VNWA Auto Auto Mode when measuring over so wide a frequency range or if the filter we measure, such as an notch filter, have little attenuation outside the “notchband”. Even a band pass filter with limited attenuation outside the passband might leak this kind of “noise” disturbing the test result. What exactly goes in greater details requires a “Tom Baier brain”.

Let’s now see what happen if we use the VNWA2 Auto x 3 mode



Hopla !! The Noise floor when RX port left open (actually terminated with 50 ohm) is much lower

Yellow Trace S11 measure at the diplexer input but not relevant for this discussion

Green and Blue traces are stored traces from the VNWA3 Auto Auto mode in previous picture

The two red traces are the measurements for the Highpass and Lowpass filters.

We see a much smoother trace with no/little “jumping’s” – quite obvious, as this mode has very few switching points.

But can we believe these measurements are the attenuation for the highpassfilter correct ?? Comparing the light gray trace in the background being the manufacturers data it is a “maybe” for the highpass filter but not for the highpass filter.

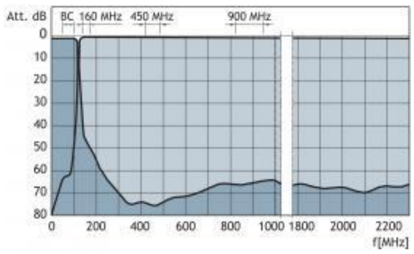
The reason is again the frequency components from the RF DDS, delivered by the TX port is harmonics/aliases and the fundamental frequency with full power is passing through the low pass section when measuring in the range for attenuation measurements. The RX port signal is mixing with the LO signal creating the IF but it is a “noisy business”.

Some comments at this point:

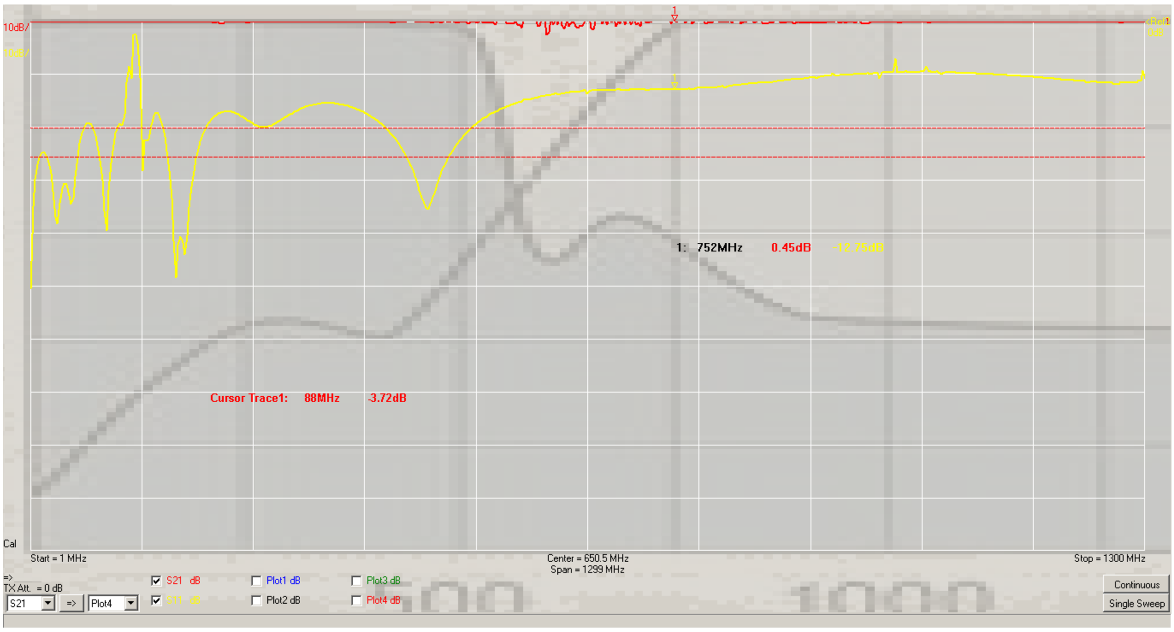
If we had purchased a professional VNA from R&S or HP costing a “Zillion Euro” than we would not see this side effect. Such product is first of all using clean signals to overcome such side effect. What about doing some filtering for the frequency range of interest ?? If we are testing some repeater duplex filter or a number of cavities in series the use of a bandpass filter covering the very small frequency range in question compared to the 1KHz to 1300MHz range the VNWA covers.

To perform such a demonstration I use anther diplexer from Procom which Lowpass range DC to 108MHz and High pass range from 136 to 1300MHz. I insert the Lowpass filter in the TX port path and calibrate the VNWA2 or VNWA3 with this filter include and afterwards repeat the measurement of the High pass filter 800 to 1300MHz. The VNWA is in not useable above 108MHz (degrading quickly above 108MHz) but as will be shown a first class VNWA for frequencies below 108MHz. Thus for HF and lower part of VHF one tend to let such a lowpass filter being a fixed fitted device.

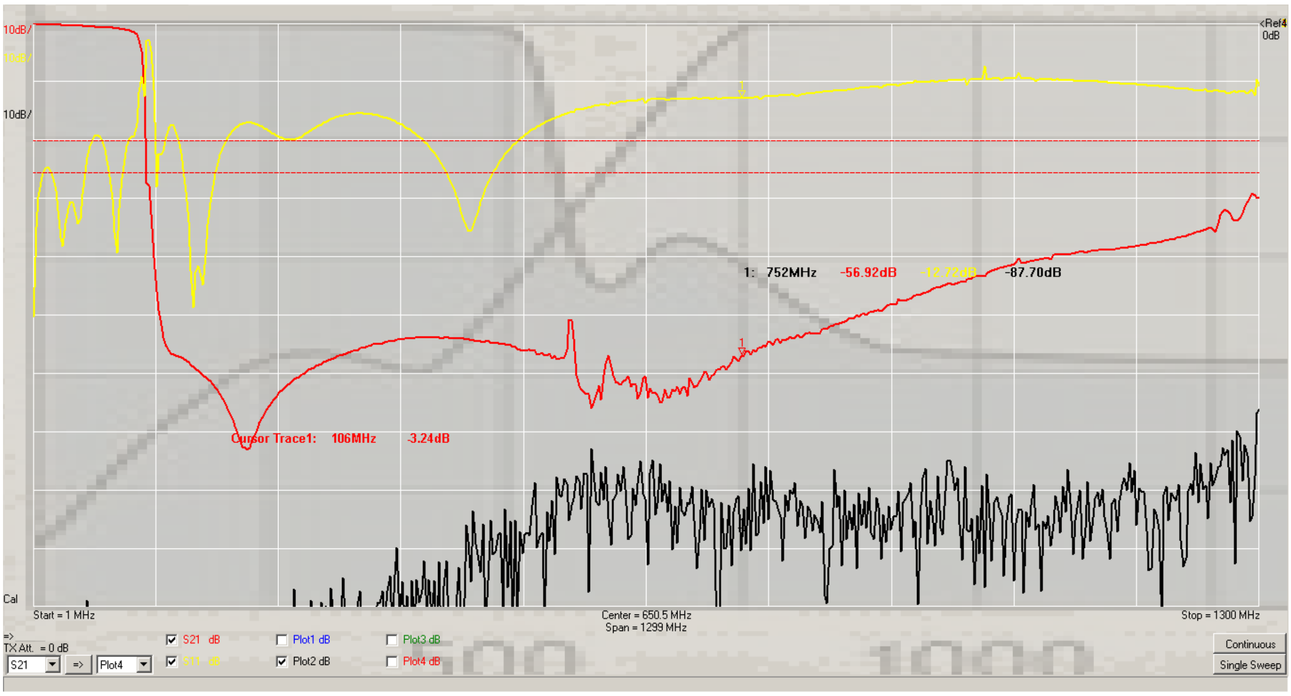
The specifications for the Procom LH 108/136-2G-3FME



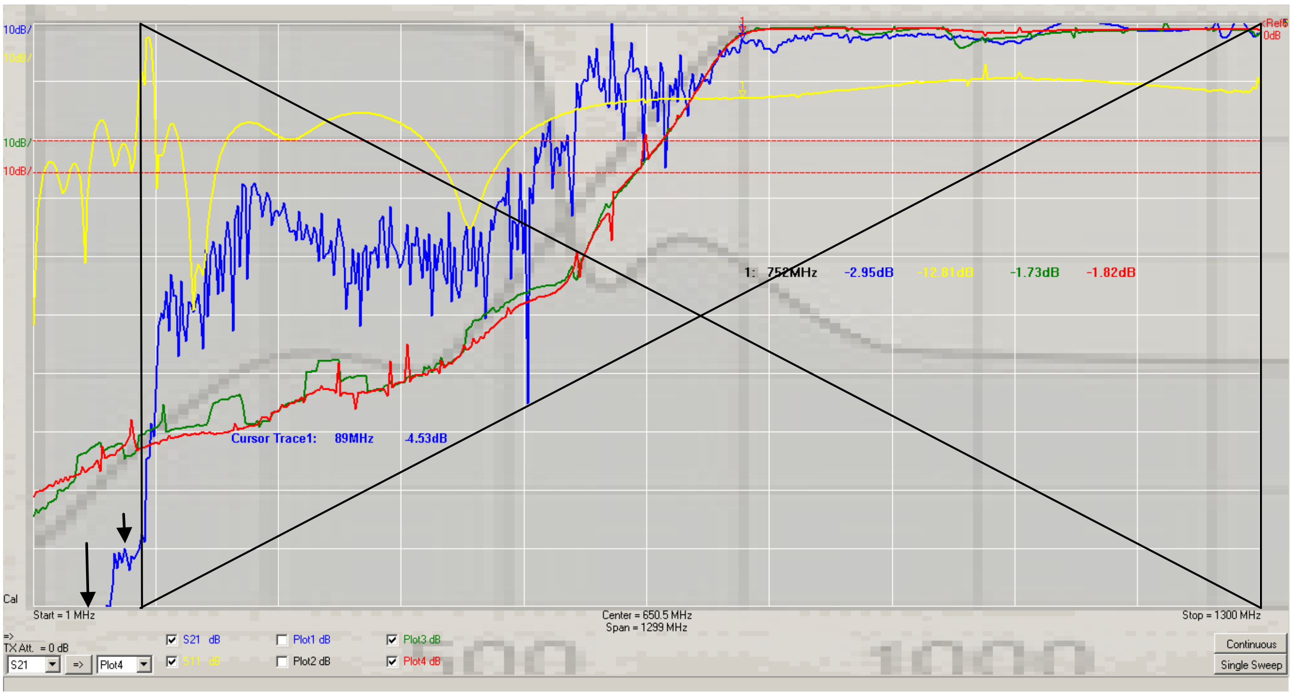
S21 Calibration of the VNWA with the 108MHz Lowpass filter fitted to the TX port



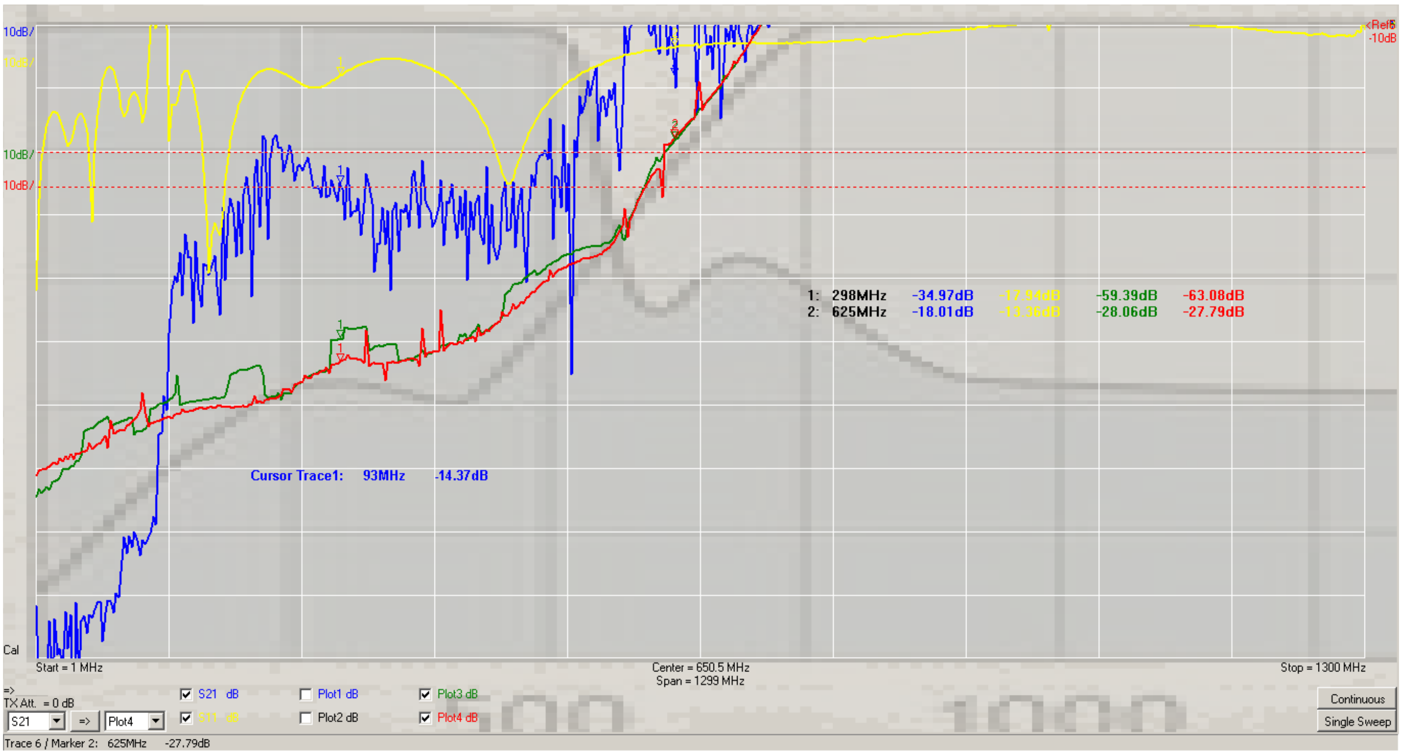
There seems to signal enough even at 1300MHZ to calibrate despite the attenuation in the 108MHz lowpass filter.



Repeated measurement of the 800 MHz Highpass filter of the DIPX500/800

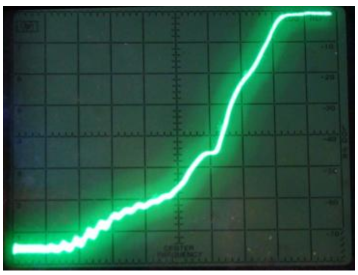


Now we see the blue trace for the DIPX500/800 has a much higher attenuation below 108MHz (se the arrows) more than 90dB and far in excess of the manufacturer specification (the light gray background picture). Changing the scale for the Red, Green and Blue trace to have -10dB at 10 divisions we see below we can measure -110dB for the filter at 1MHz seen on the below picture.



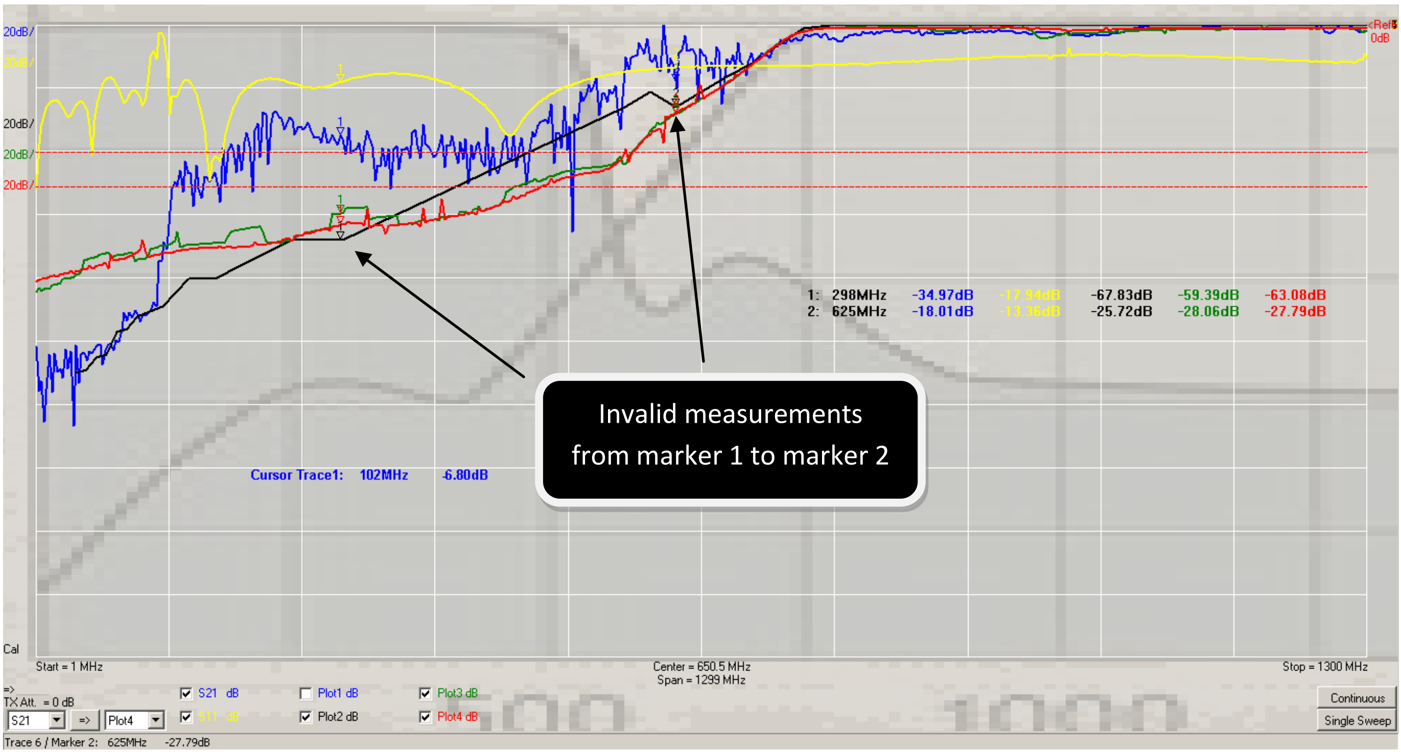
The improvement by implementing the 108MHz low pass filter is more than 20dB.

How about a sweep with my old HP141 Spectrum Analyzer with Tracking generator ??



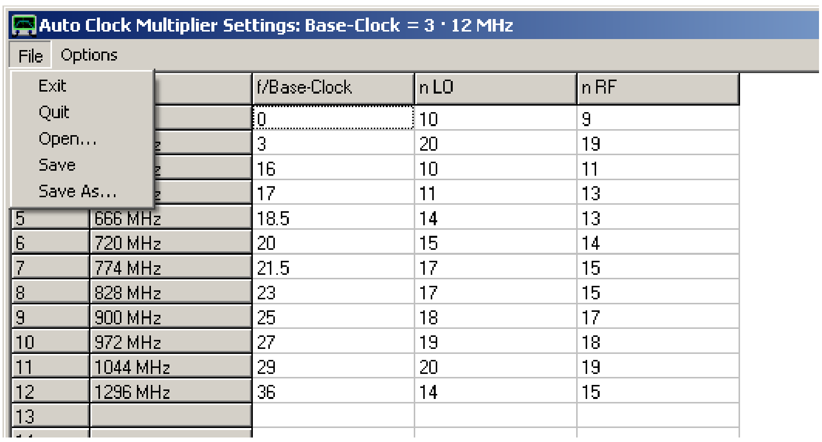
It is impossible to measure more then – 80dB if I shall finish to day ☺

Next step in the verification phase is to use my Marconi Signal generator as signal generator with +6dBm output and use my selective VHF Field strength Receiver HFV going from 25 to 300MHz. At 25MHz signal not detectable meaning more that -110dB. Above 300MHz I used my HP Power meter 437B but first at attenuation from -26dB results reliable as the harmonics (about -35 to -40dB down) is adding to the measured value (these harmonics is within the highpass range). The measured value typed in to a s1p touchstone file and loaded in to the trace plot2 (Black) and by change the plot scale to 20dB /division **you see that the VNWA does measure correct below 108MHz when a filtering of the TX output is performed.**



Conclusion:

It is important when you want to trust you measurement that you have a critical attitude and this document has hopefully given some inspiration to further study how the VNWA works and which limitation you may meet. A lot can be done fairly accurate but when you aim for measurement down to 50 dB and lower be very cautious what you measure and setting the VNWA in the good old VNWA2 mode is a good starting point. It is up to the user to find his own perfect switching scheme generation as few “disturbing signals” as possible, as the Editing the standard setup followed by Saving/Open as seen below, it there for design you own switching scheme. Do not panic ! In the Option box you retrieve the default settings.



		f/Base-Clock	n LO	n RF
		0	10	9
		3	20	19
		16	10	11
		17	11	13
5	666 MHz	18.5	14	13
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9	900 MHz	25	18	17
10	972 MHz	27	19	18
11	1044 MHz	29	20	19
12	1296 MHz	36	14	15
13				

Kind regards

Kurt de OZ7OU document created July 14 2012 Rev1