Audio Transcript for the Movie in English “HAMRADIO 2012 DG8SAQ VNWA UK”

Preface: This document is the English text or the presentation “HAMRADIO 2012 DG8SAQ VNWA published on YouTube (Google search for DG8SAQ and you will find it or go to my support homepage http://www.hamcom.dk/VNWA and find the links for both the various movies published.

Event 1:

Introduction to movie as a Lead in: ***Introduction***

Event 2:
SDR-Kits visit:

Title: Tom and Jan first time in person: ***tom and jan first time in person***

Transcript: I had the pleasure for the first time to meet Jan and Tom in person.

At the SDR-Kits boot: ***Busy Saturday morning***

Transcript: Let us enjoy how busy these two gentlemen was Saturday morning.

Welcome Greeting from Jan Verduyn: ***Jan Hamradio Wellcome final***

Transcript: Hello and Welcome to the HamRadio 2012 VNWA Presentation by Tom Baier

My name is Jan Verduyn of SDR-Kits and I trust you find this presentation by Tom on VNWA development, new Features and some novel Application interesting.

Before Tom's Presentation there is a brief Video impression of the SDR-Kits Stand at HamRadio 2012. Thanks to all of you who visited our stand at the Radio Fair and shared your experiences about the VNWA. It was great to meet you.

I like to thank Tom for making the presentation but also thank Kurt Poulsen OZ7OU for his time and efforts in producing an English version of the original VNWA presentation in German which he posted on You Tube.

Enjoy!

Event 3:
The Presentation part:

Translation note
Transcript: When during the translation the word “I” is used, then it is Tom which addresses himself.

Bigger meeting room
Transcript: First action was to find a bigger meeting room, as Tom had ordered a room for 50 people, but the one provided was not big enough so a new one had to be found, and I think we were actually more than 50 people during the presentation.

Slide 1 *: The topics of Hamradio 2012*
Transcript: HAMRADIO 2012, Evolution of the DG8SAQ Vector Network Analyzer, New possibilities of the VNWA3

Spoken introduction
Well let us get started, Let me first welcome all of you, to my presentation of VNWA3, and I am surprised that so many people have shown up, totally unexpected, but of course nice to see.

Some of you know me, others do not, my name is Tom Baier and I am employed at the University of Applied Sciences in ULM teaching mathematics and Physics. I am also a radio amateur since the age of 18. Previously I had professional employments, working in the field of High Frequency Technology, at Siemens later at Epcos.
So let us go ahead.

Slide 2: Let me introduce the agenda for the presentation, first what are S parameters and how are they used, next how does the VNWA work, and how was it created and finally what new features are available, with some examples shown.

Slide 3:
Regarding S parameters we are dealing with waves, here we see an electronic device with input and output which behavior can be compared to a lens, where on the left side a light beam enters, where a part of is being reflected, and another part absorbed in the lens, and a third part transmitted from the lens on the right hand side.
All waves going toward the lens are denoted **a,** and all waves going away from the lens are called **b**.
The left side is assigned number 1 (input) and the right side (output) is assigned number 2.

Similar behavior is seen for the electronic device (DUT), here seen inserted in a cable section.

Slide 4:
Here is a typical test object, in this case a crystal filter, symbolized by a square, where we have the incoming waves with a1 on the left side, and a2 on the right side, the outgoing waves with b1 on the left and b2 on the right side.
The S parameters are the ratios between b and a waves. Four different ratios can be formulated where
S11 is b1/a1,
S21 is b2/a1,
S22 is b2/a2
S12 is b1/a2
The test object is in this way fully defined by these four S parameters containing both amplitude and phase information.

Slide 5:

This picture shown the S11= b1/a1 of a test object, where we have the incoming wave a1 and the reflected wave b1. The absolute value of S11 is the return loss and here expressed in dB, which might look like the blue trace on the picture.
The S11 can also be expressed as VSWR (Voltage Standing Wave Ratio), based on the same data, but just rescaled according to shown formula.

Slide 6:

S21 is the transfer function b2/a1, and on the picture can be seen that the passband transfer loss/attenuation is small, and outside the pass band the attenuation is large. Our VNWA and for that matter any other VNA, can measure these S parameters.

Slide 7:

S11 is measured based on an outgoing wave a1 delivered from **TX out**, to the test object, and its reflection b1 measured. The portion of the outgoing wave not reflected but transmitted through the test object is measured by the receiver **RX in to yield S21**. This is not a complicated situation as such to be understood.

Slide 8:

How does the VNWA function? It consist of three basic building blocks. First of all we have the tunable wave generator, as the source, then secondly three receivers capable of magnitude and phase measurements which measure the incoming wave, the reflected wave and the transmitted wave. Thirdly a control and display system is required which takes control of all the VNWA hardware, computes measurement results and displays them

Slide 9:

I have implemented the tunable signal generator by using a DDS (Direct Digital Synthesizer). The three receivers consist of three Gilbert Cells. Note the mixer injection signal is also generated by a DDS signal generator. The IF section consists of the sound card in a PC. Control functions, data processing and display are also taken care of by the PC.

Slide 10:

A block schematic shows the Reflection Measuring Bridge, which measures the Forward wave, measured by M2 and the Reflected wave measured by M1. The transmitted signal delivered to **RX in** is measured by M3. On the top of the schematic is seen a switch, which is needed to multiplex two of the three signals to the PC sound card, as a standard sound card only has two channels (Stereo). Thus, with this concept we can measure either S11 or S21, but not both simultaneously.

Slide 11:

The first problem I had to solve was that the unfiltered DDS spectrum contained a large number of alias frequencies, which all mix to the same IF frequency, as the wanted signal at Fout, symbolized by the frequency distance between red and black vertical lines (IF= 1.2KHz), and as shown on the slide.

A common solution is to suppress all signals above the Nyquist limit with a lowpass filter, limiting the usable frequency range to less than half the clock frequency. An alternative way to solve this problem is to let the RF DDS and LO DDS run with different clock frequencies.

Slide 12:

By doing so, the different alias frequencies no longer mix to the same IF frequency but to different frequencies, symbolized on the picture by varying frequency distance between the red and black vertical lines, and thus the frequency range can be widely expanded beyond the Nyquist limit.The VNWA1 to be shown was the platform for these experiments.

Slide 13:

Such a VNWA1 design is practical for experiments and I demonstrated it to my friends and colleagues at the University.

Slide 14:

My friend Prof. Schumacher was of the opinion that such a device was ideal as a student project, but continuous coverage to the UHF frequency range was a must, and it should be reproducible, meaning possible to build more than one unit. On the next slide the design criteria are shown.

Slide 15:

Frequency range continuous to beyond 500 MHz
Reproducible production and on a printed circuit board
lowest possible cost

Slide 16:

Now some words about “the holes (Gaps) ” in the spectrum. A DDS is producing zero output power at the clock frequency and its harmonics, no matter which frequency it is programmed to. The solution to this problem is simply to use a variable clock frequency, by such an amount, that an output from both DDS’s is always obtained on the required measuring frequency. (two blue arrows don’t match anything!?)

Slide 17:

The result of these considerations, , was the VNWA2 as shown here . It was controlled via the parallel printer interface of a PC, via the DB9 connector seen at the top of the PCB, and Signal processing performed by an external soundcard. With continuous frequency coverage from 1 kHz to 1.3 GHz, the dynamic range of more than 90 dB to 500 MHz and 60 dB above 500 MHz. Both measurements of S11 and S21 can be made. This is the basic concept of the VNWA, and basically has remained unchanged up to now.

Slide 18:

In 2009 an important milestone was reached, as Jan G0BBL from SDR Kits was bringing the VNWA to the marketplace.

Slide 19:
We quickly realized that the parallel interface of PC’s was slowly being phased out, and the stereo line input, in particular on laptop PC’s, was changed to a mono input.

Slide 20:
We had to find a solution, and that led to the USB interface, which can be connected to the PC by just using a single USB cable .. That includes also the power supply of the VNWA. A USB sound chip is integrated onto the PCB, and use of the PC soundcard is no longer required.

Slide 21:
The next logical step was to integrate all of it on one PCB. The updated result is seen here, being the VNW3, with everything on one PCB. The USB connector is seen here. The **TX** and **RX** connector is seen lower left and right, then seen the two DDS chips, followed by the two operation control chips. A further improvement of the VNWA3 is the introduction of a 12MHz TCXO, to improve the frequency stability, and the introduction of a clock pre-multiplier. Top right is seen the TCXO, and in the center the 12MHz clock pre-multiplier, with multiplication factor ranging from 2 to 8, before the clock is transferred to the DDS chips. The clock pre-multiplier also gives the possibility to better suppress noise and spike signals.

Slide 22:
This slide shows a comparison where the VNW2 spikes seen on the blue trace and for the VNWA3 the noise spikes are considerable reduced, due to implementation of a more complex clock pre-multiplier switching scheme.

Slide 23:
Furthermore, there is the version VNWA3E available now, where E stands for expansion. It contains an optional printed circuit board with an additional USB audio codec, which allows simultaneous measurements of S11 and S21, thus reducing the measurement time by 50%. Top right is an RJ 12 connector for outside world connections, where you, as an example, can connect a transfer relay (or a home made test set) for automatic measurements of all 4 S parameters of a two port device, such that it is not needed to mechanically turn the device under test, for reverse measurements. It is also possible to connect an external reference signal, for improved accuracy. More on this later.

Slide 24:
Let’s look at application examples.. One of the major applications for the VNWA is measurements of impedances. The picture shows a typical plot for impedance measurements. The best possible way to measure of impedances will be addressed in the next slides.

Slide 25:

> The most common way is to connect the unknown impedance to the TX port, then measure S11 and calculate the impedance from it. The internal bridge is optimized for 50 ohm, when loaded with 50 ohm the bridge signal is zero, that means with impedances close to 50 ohm the bridge is very sensitive, but by measurements of 1 Kohm or 1 ohm, the accuracy is a lot poorer.

Slide 26:
A second method is to measure the current flowing through the unknown impedance, using the **RX port**. The **TX port** is used as a voltage source. When the unknown impedance is high, then the current is primarily depending on the unknown impedance, and the measurement is sensitive, whereas when the impedance is much lower than the output impedance of the **TX port** then the current is not changing very much. This method is very good for high impedance measurements, for an example measurements of small capacitances, but for low impedances the accuracy is poor. One benefit for this method is, it is only required to do a S21 Thru calibration. A drawback: The unknown impedance must not be grounded.

Slide 27:

A third method is to measure voltage drop across the unknown impedance, where the **RX port** is measuring voltage and the **TX port** is used as current source, although not ideal. This setup works perfect for low impedances, close to short circuit, but for higher impedances the voltage does not change very much.

Slide 28:
The fourth method is to combine the two previous methods by measuring RF-IV, meaning RF Current and RF Voltage independently, followed by calculation of the quotient. Measurements of all impedances can be performed, both high and low impedances. Automatic measurement can be done by using an RF-IV testhead obtained as a fair priced kit from Ivan Makarov in Canada, which can be controlled by the VNWA software such that I and V sweeps are made independently.

Slide 29:
To summarize I have taken three resistors 0.1ohm, 51ohm and 100Kohm, and increased their values by 10% to see the impact on the measurement results, depending on the various measuring methods. By S11 reflections at 50 ohm an enormous influences exist, otherwise hardly noticeable. For I measurements quite well at high impedances and for V measurements quite well at low impedances and for IV equal sensitive for all impedances. An important role for accurate impedance measurements is of course the calibration.

Slide 30:

On this slide I will show an influence not so widely known. Here, I have measured an SMD capacitor of 100 pF over a frequency span 10 to 60MHz with a resolution of 0.1pF. The upper blue and red trace shows the series resistance, which constitutes the loss of the capacitor, and the only trace difference is that the model for the load calibration standard, for the red trace, is defined to be ideal 50 ohm, while for the blue trace a series inductance of 2 nH is added. 2nH is a very small amount less than 1% of the load value. Despite this, the error is 50% on the series resistance, while for the capacitance value hardly any influence is seen. The slightest change in the Calibration Load model has a great impact on the series resistance and thus the measured capacitor Q. **As the imaginary part of the load standard in general is hard to determine, and often unknown, it is very essential to have a quality standard to compare with for its determination.**

Slide 31:

The rescue is a new calibration method, invented by Hewlett Packard long ago, but new to me. It is possible to repair this model error, by introduction of a new additional calibration standard, for an example a capacitor. The only condition is that the equivalent series resistance (ESR) of this capacitor standard must be known. If the ESR is zero then the method works best possible as no error can occur. So, the Q of the capacitor used must be very high. With the false model for the load calibration standard the blue and red trace still match demonstrating that this error has been repaired using this new calibration method, which has just been implemented in the new 36.8 test version of the VNWA, and will be included in the next General software release.

Slide 32:
Now something completely different: If you have one clock, then you always know what time it is.

Slide 33:
If you have two clocks, then you are never quite sure. I have two Rubidium standards and I was interested to see how well they were running in sync.

Slide 34:
The idea was the following. The VNWA3E has an external clock input, and one of the Rubidium standards is connected to this external clock input. Any signal test oscillator can be connected to the **RX port**, and then measure the phase change of the test signal relative to the reference signal and subsequently calculate the frequency difference to the nominal frequency.

Slide 35:
On this slide I have investigated how accurate frequencies can be measured, by measuring the phase during one second of the internal TCXO against itself. As the frequency difference shall be 0, it is the VNWA accuracy we measure, and by three repeated measurements I got a VNWA measurement accuracy of about +/- 10uHz. To measure a frequency during 1 second to within 10uHz, with conventional frequency counters, is a very difficult task.

Slide 36:
Here you see the measurement of the frequency difference between my two Rubidium standards. The red trace is the phase difference, as function of time. The slope of the line, being straight, is representing the frequency difference. The green trace is the calculated frequency difference. The noise is due to numerical calculation of the derivative and other noise contributions. It is possible to directly read the frequency difference, provided the frequency span is zero. We are thus measuring at the same frequency while the time increases from left to right, and, as the phase difference is not zero but drifting, the frequency difference is calculated to -2.5mHz, and the frequency variation is about 300uHz, as even a Rubidium oscillator is not fully stable.

Slide 37:
The experts display oscillator stability with such a Allan deviation curve, which I have found on the homepage of NIST the American National Institute of Standards and Technology, and as shown on the slide.

Slide 38:
Here you see a quite dramatic plot. I have measured the internal VNWA3 TCXO against a Rubidium standard. The green trace shows the frequency difference, and it looks quite dramatic, doesn’t it ?. Just pay attention to the frequency resolution being set to 0.25 Hz per division. In total the frequency offset is -3 Hz equivalent to - 0.3 ppm. The specification of the TCXO is 2 ppm so it is okay. We have now seen we can measure frequencies quite accurately. (Someone in the audience suggested to display start and stop time instead of start and stop frequency for zero span. I have implemented this now as this was a good idea.)

Slide 39:
A Further application for the VNWA is time domain measurements. On the slide we see a series connection of 3 coaxial cables, with characteristic impedances of 75 Ohm, 50 Ohm and 25 Ohm respectively, the latter being open. The blue trace shows the reflection characteristics in the frequency domain, which is not very informative. However, we can convert the frequency domain measurements into the time domain, as shown for the green trace, and we can now measure quite accurately the length of the cable, i.e. where the reflections take place at points 1, 2 and 3, and also we can measure the characteristic impedances as 72 Ohm for the first, 49 Ohm for the second and 26 Ohm for the third cable.

Slide 40:
My friend PA4TIM has made an interesting measurement of a defective Christmas Light Chain, to find the defective light bulb.

Slide 41:
The next example shows measurements on a biscuit can acting as a cavity, and the engineering students can quickly calculate the resonance frequency.

Slide 42:
By entering the data in the shown formula, for the lowest mode, the resonance frequency is 1209 MHz.

Slide 43:
When the resonance frequency measured with the VNWA, it is seen to be 1210 MHz. What happens if we fill the biscuit can with stuff?

Slide 44:
If we add material inside the biscuit can the epsilon value increases (no more being air only) and the frequency is lowered, quite nicely seen for the red trace. What can this be used for? Yes indeed … It can be used as level indicator of how much stuff is inside.

Slide 45:
There are people who are interested in such a level indication, and one organisation is NASA.
Imagine a rocket in free space, with no gravity present, the liquid fuel inside the tank is floating around so a traditional floating level meter cannot be used (a swimmer). The only way to determine the remaining level of fuel is by measuring the Cavity resonance frequency of the tank.

Slide 46:
And this is exactly what the gentleman at NASA have done. Here we see an original rocket tank spectrum measured, with the VNWA3. This is not a joke, the VNWA3 is intended to fly with a rocket for evaluation. (big applause from the audience)

Slide 47:
We are close to the end of the presentation, and to summarize it can be said the VNWA3 and VNWA3E are versatile test instruments, which have a professional potential and are thus also being used in industry and education. For example, we have many costumers who use the VNWA for tuning pick-ups of NMR Tomographs. Meanwhile VNWA3 is in use on all 5 Continents.

Slide 49,50,51,52:
I want to address special thanks to all those being supportive, some might be missing.

Final slide:
A final warning… VNWA makes you addicted. Thank you very much for you attention. (Applause from the audience)

29/08/2012 Kurt Poulsen de OZ7OU