MEASUREMENTS WITH THE NANOVNA

by Arie Kleingeld PA3A

Part 5: Measuring Low Impedances

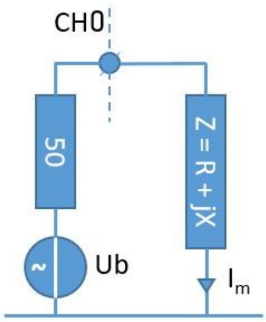
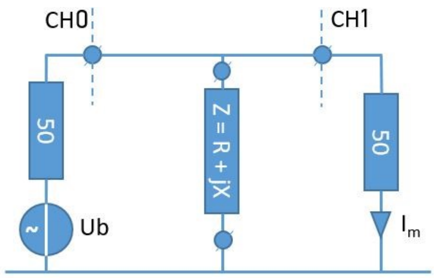
Preface

The nanoVNA's are made to measure impedances associated with the 50 ohms that are so important to radio amateurs. Experts say that as long as the measured values are between 5 and 500 ohms, the nanoVNA still does very well. In part 2 of this series of articles I discussed measuring high values (470 Ω, 4700 Ω and 10 kΩ), and how best to tackle this with the nanoVNA. In this part 5 we look at the accuracy of measured values of 1 Ω and even a little lower.

Measuring low impedance values requires some accuracy. If you measure a resistance of 1Ω with your regular multimeter, then that is already quite a task if you want to do it accurately. And an additional few tenths of an ohm can appear if you don't handle your measuring leads well. For example, in the case of the nanoVNA, this means careful calibration (especially the 0 ohms) and cables in the measuring setup cleaned and tightened as well as possible. It also does not hurt to redo the low-level measurements a few times a day later to ensure accurate reproducible measurement.

Measurement

We're going to use two methods to measure low impedance values.

Method 1: S11 R+jX	Method 2: S21 damping measurement with Z parallel
	

Method 1, the S11 measurement, is straightforward and is used by most radio amateurs to measure the SWR, among other things. You can immediately read the value of Z, R and X easily via nanoSAVER, one of the Windows programs that works together with the nano. You can export the S11 measurement in an S1P file. The formulas for converting the S1P file values to R + jX are in Box 1.

Method 2, the S21 measurement, initially looks a bit strange. Here the insertion loss is measured where the impedance to be measured is parallel. To give an insight into this method of measuring, a small explanation. For the current Im measured in CH1, the larger the Z, the greater Im, and thus a lower loss is measured. At Z = 0 (short circuit) current I_m will be equal to zero and the CH1 input will not measure anything that amounts to a very high loss. The measured S21 = Dr + jDi can be exported in an S2P file. You will find formulas in Box 2 to convert to Z = R + jX.

Why measure with that S21?

The reason is that professionals claim that for low impedances the S11 measurement loses accuracy. The characteristic S21 measurement provides higher accuracy for low impedances.

And that sounds plausible to me as an amateur. After all, if the range of the S11 R+jX measurement goes from 0 ohms to many kilos of ohms, then e.g. 0.33 ohms is close to the 0 ohm limit. If you then measure the S21 (loss) with that 0.33 ohm parallel (method 2) then approximately 37.5 dB of loss results. This appears to be in the middle of the range of my nanoVNA H3.2, which can measure between 0 and 80dB attenuation in the HF frequency range. We will see below whether that also provides a more accurate measurement value for R+jX.

Measurement of 1 ohm and 0.33 ohms and 0.20 ohms with S11 (R+jX) and with S21

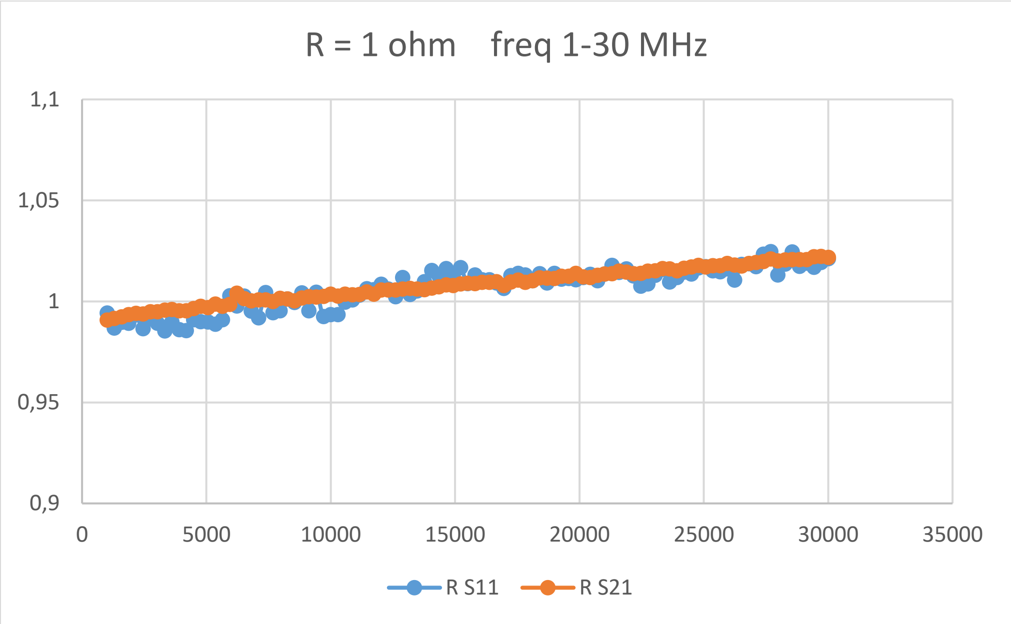
In this article we will therefore test whether the S11 R+jX measurement meets the low resistance values and whether the S21 measurement gives a better measurement result than the S11 measurement. The different resistance values are made with standard solderable 1 ohm resistors that are set in parallel for lower resistance values.

The photo *[left]* shows the simple measurement setup for the S21 measurement of the 0.2 ohm value as an example. Five 1 ohm resistors are soldered in parallel.

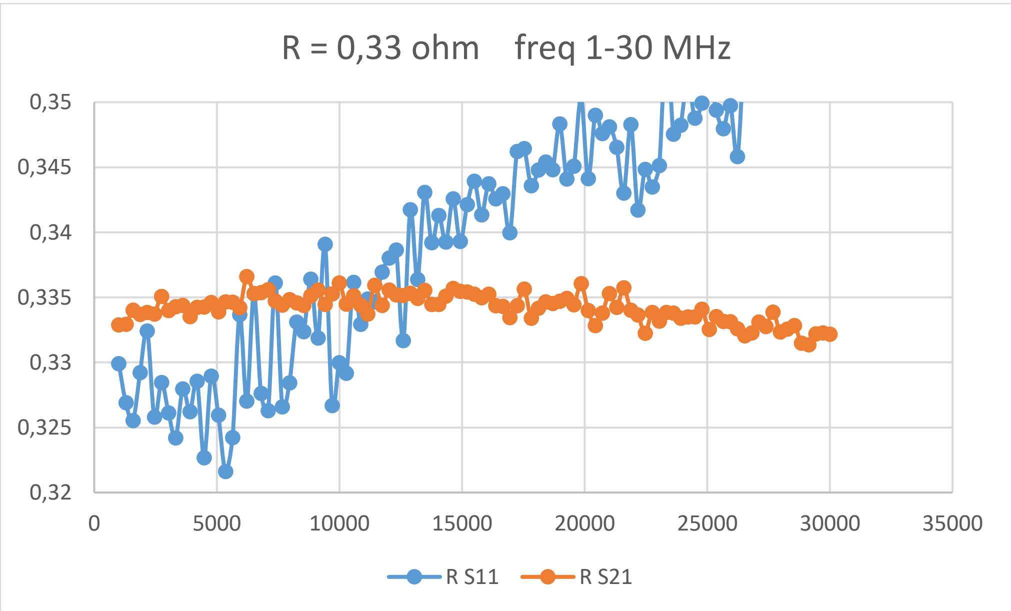
The graphs of the resistance values (R S11 and R S21) resulting from the two measurements (with S11 and S21) are grouped into one graph per value . The charts were created with Excel, based on the S1P and S2P files. The reactance (X) is omitted from the graphs for comparison of the R values.

Results

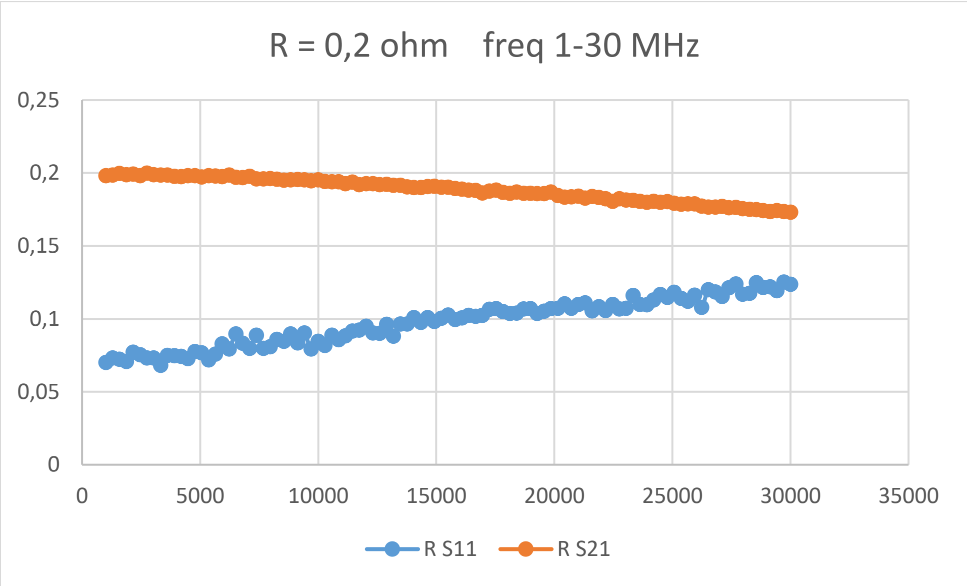
The results in the graphs speak for themselves. For a value of 1 ohm [First graph], both methods work well. A class gadget that nanoVNA! Within a few percent, the measured values are around 1 ohm over the entire HF range.



The deviations between the two methods only occur at the lowest resistance values. The S21 method really turns out better. The 0.33 ohm with the S21 measurement [below] clearly works out better in the graph than the S11 measurement.



At 0.2 ohms, the differences are even clearer although the 0.2 ohm also shows some deviation with the S21 measurement [below] if you look at the entire HF range.



With an SMD setup, the graphs might have been a bit nicer, but still... I have no aspirations to start a measurements lab. If you evaluate it even further, you should also remember that this is loosely measured, on the shack table, with an older type of nanoVNA (H3.2). In this, the internal 50 ohm reference value is not yet very similar to the actual 50 ohms. The newer type VNAs are a bit better.

Finally

The following topics have been discussed so far in this series:

1. A method to determine the characteristic impedance of a transmission line/coax
2. Accurate measurement of high impedance values > 5 kohm
3. Experiences measuring common mode chokes (application of topic 2)
4. Determining the type of core material of a toroidal core
5. Measuring low impedance values < 1 ohm

There are many other applications in which you can use the nano. However, the intention was to look up a few angles in the use of the nano in this series and apply them. We looked at the possibility of measuring values in so-called export S1P and S2p files from the nanoVNA and then processing them in Excel. The necessary formulae were included.

In Parts 6 and 7 I will address how you can safely measure the input impedance of a delicate receiver (is it really 50 ohm?) and how we can measure the Q of a coil.

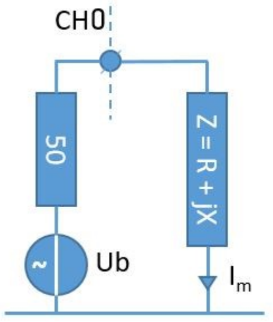
73, Arie Kleingeld, PA3A

Box 1.

S11 = Sr + j Si .

Dr and Di values are exported directly from nanoSAVER by means of an **S1P** file. R+jX can be calculated using sub-existing formulas. The principle of this is explained in part 2 of this series.

$R = 50\dfrac{1-(Si^2+Sr^2)}{(1-Sr)^2+Si^2}$	$X = \dfrac{100Si}{(1-Sr)^2+Si^2}$



Box 2.

S21 = Dr + j Di .

Dr and Di values are exported directly from nanoSAVER by means of an **S2P** file. R+jX can be calculated using the formulas below.

$R = 25 * \dfrac{Dr(1-Dr)-Di^2}{(1-Dr)^2+Di^2}$	$X = 25 * \dfrac{Di}{(1-Dr)^2+Di^2}$