MEASUREMENTS WITH THE NANOVNA

by Arie Kleingeld PA3A

Part 6: Measuring the input impedance of a receiver

The 'sacred' 50 ohm value

Our coaxial cables are 50 ohms, our SWR meters work at 50 ohms, the nanoVNA works at 50 ohm, the antenna tuners convert everything to 50 ohms and so my receiver also has a input impedance of 50 ohms. But is that really so? Measuring it is a nice job for the nanoVNA. The measurement charts presented in this article were created with nanoSAVER.

Measurement challenges

Measuring an impedance with S11 R+jX is easy, and displaying the S11 SWR gives us a familiar insight about the adjustment to 50 ohms. My nanoVNA version H3.2 is signalling of -5dBm (S9 +68dB) in the HF range, but other VNAs can reach 0dBm (s9 +73dB or 1 milliwatt). The latter means a voltage with a peak value of more than 0.3V is possible. The problem may then be that something unintentionally conducts or does not conduct (e.g. switching diodes). There is a chance that you will then measure just a different value than when you measure it with somewhat weaker values signals would say lower than the S9 +60dB maximum value of your S-meter.

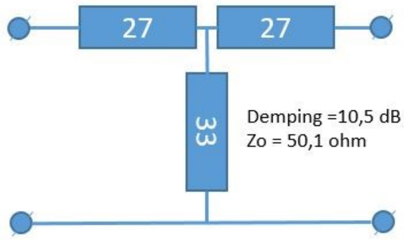
For example, you could attenuate the VNA signal by 10 or 20 dB. But can you, with a attenuator between the nano and the receiver, still correctly measure the input impedance? That's the question we answer first before connecting the nanoVNA to the input of the receiver.

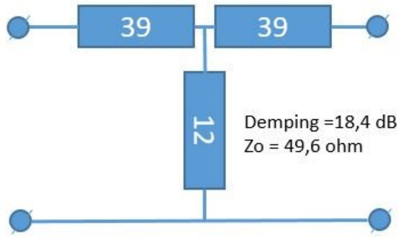
Making an attenuator

I make the attenuators from the junk box. If you search for '50 ohm attenuator' there is a lot of info to be found. From the many websites with attenuator documentation I choose the site of John M0UKD. He has collected several calculators on his site where resistance values are calculated for a desired attenuation. Nice to be able to use that.
(https://m0ukd.com/calculators/)

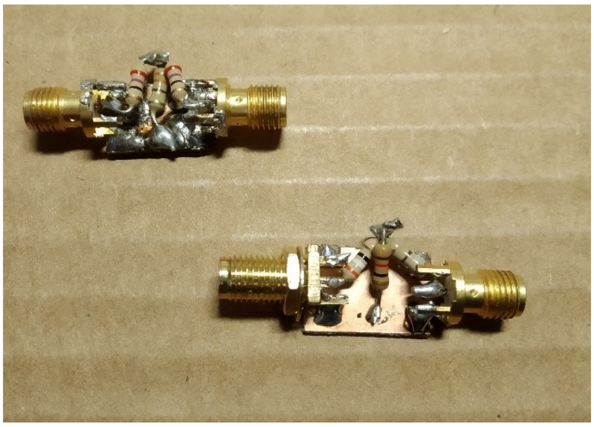
Which attenuator I make depends on the following four criteria:
1. Must be able to be made with only 3 standard resistors (from E-12 series)
2. Characteristic impedance (Zo) of the attenuator should be close to 50 ohms
3. Near 10 dB and/or near 20 dB attenuation
4. T-shape or PI-shape is not important

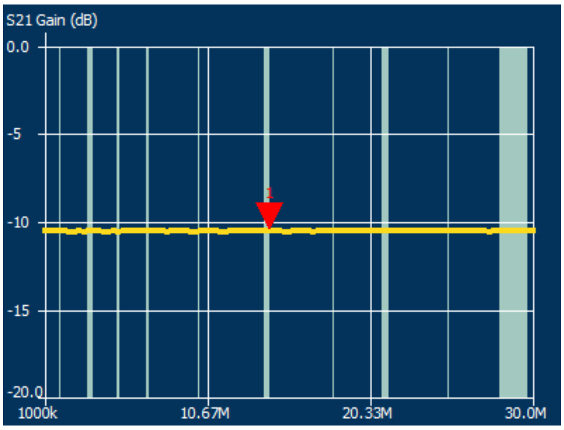
The following T-attenuators come pretty close, after some attempts at the attenuator calculator:





In practice, the attenuators look simple [see photo below]. Making attenuators for HF is easy and not critical. When measuring, the damping of both attenuators turned out to be correct, as an example see the S21 Gain of the 10.5 dB attenuator. The 18.4 dB attenuator was also spot-on.

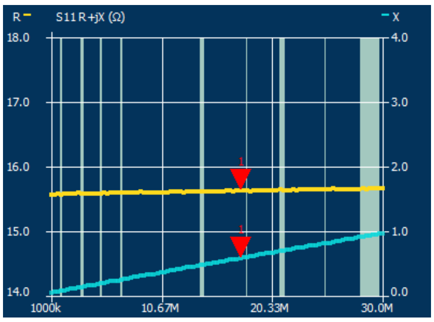


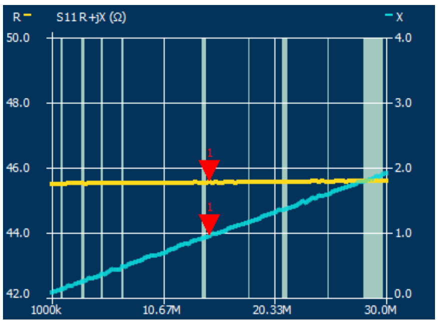


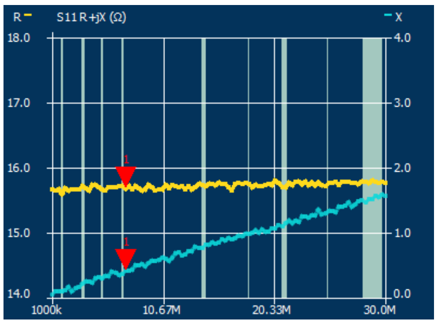
Measuring with the nanoVNA via the attenuators, the test

First we measure the S11 R+jX of an approximately 16 ohm resistor with the standard nanoVNA. The value turns out to be more than 15.5 ohms *[see the graph below, left]*. Without further fuss we then switch the 10dB attenuator in between and measure the 16 ohms again, and we get the middle graph. We see an incorrect value here (approx. 46 ohm). *[graph below, middle]*

Then we calibrate the nano in the usual way with the attenuator included in the chain. If we then measure the same 16 ohms again we get the graph on the lower right. We clearly see the 16 ohms returns. This is pretty much a copy of the left graph with no attenuator. *[graph below, right]*

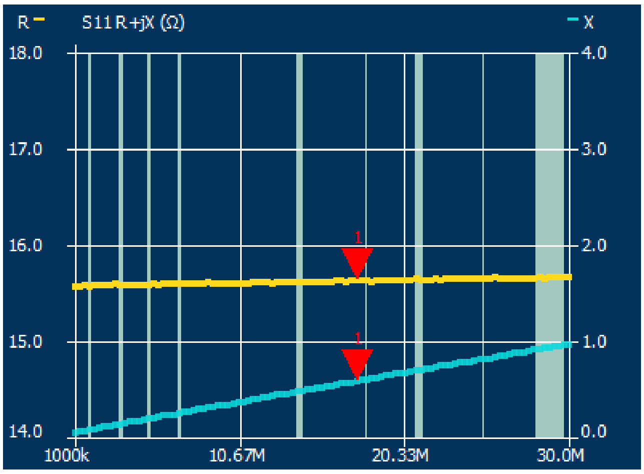


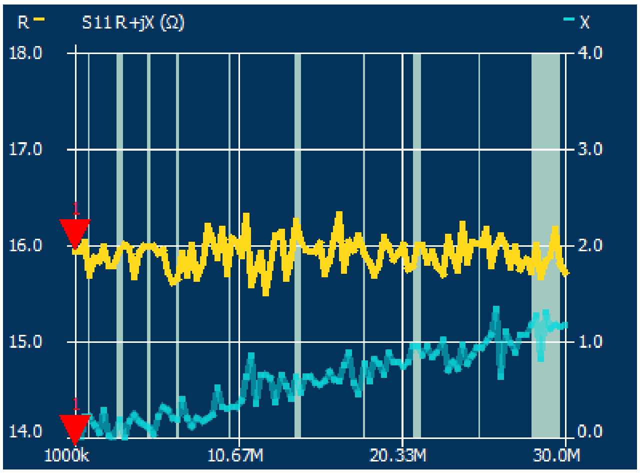




This is the power of the nano's calibration capability! Provided the attenuation is not too great, and you have recalibrated for the task, you can still make a proper measurement. With a different load (e.g. 75 ohms), I could achieve the same result.

I also measured the 16 ohms through the 18dB attenuator. The two measurements: first without the attenuator, and second with an 18dB attenuator and new calibration. We can see that the calibration for the 18dB attenuation is also neatly processed, but some noise has entered the measurement. But this is not really a problem.



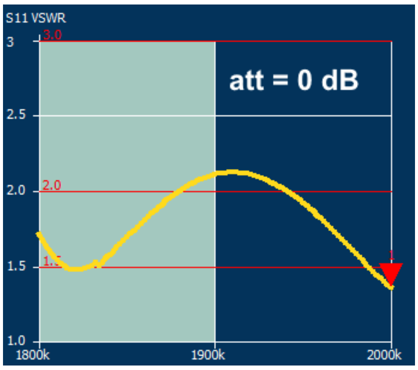


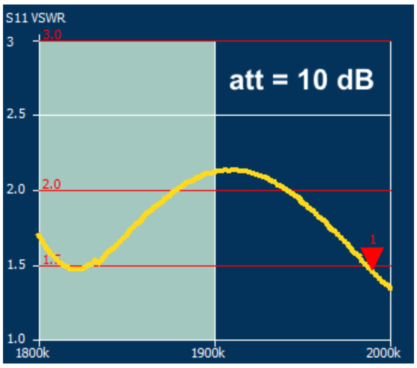
With this we have established that we can safely measure through the attenuators, provided the attenuation used is not too high.

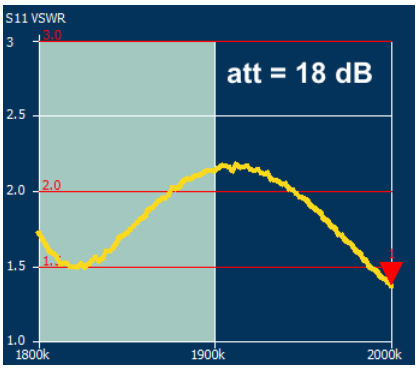
Measuring the input impedance of a receiver

The receiver in use is an Elecraft K3. In this case I chose the SUB RX (2nd receiver) and tuned it to the 160m band. Measuring other bands is similar, with or without different impedance and SWR values. We measure S11 successively without the attenuator (att = 0 dB), with the 10dB attenuator (att = 10 dB) and with the 18dB attenuator (att = 18 dB). In all 3 cases, the nano was first calibrated.

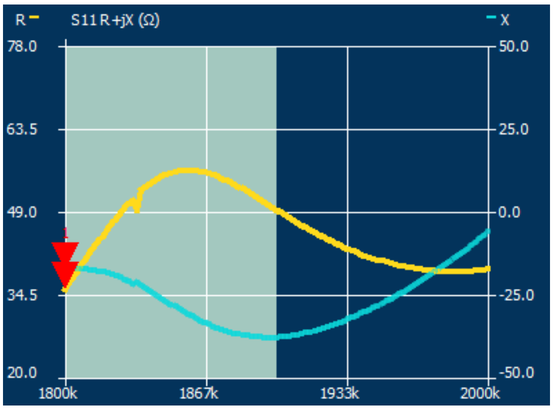
First of all, the S11 SWR curves *[shown below]*, are best known to us radio amateurs. The receiver's SWR input at 160m turns out to be between 1.5 and 2. There is hardly any difference between the three measurements. Therefore, if we use an attenuator, we can properly measure in a practical application.

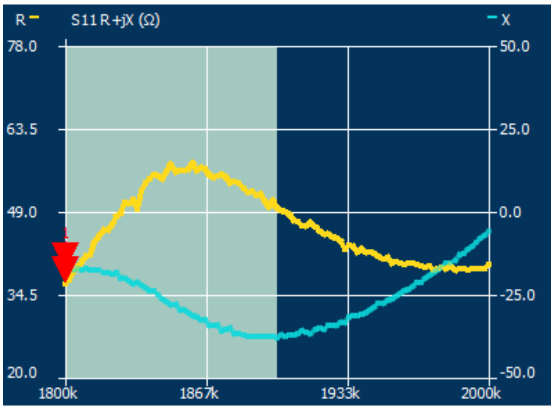






Next, we look at the S11 R+jX values to give a more in-depth picture. The measurements are done with 0 dB attenuation *[below left]* and with 18 dB attenuation *[below right]*.



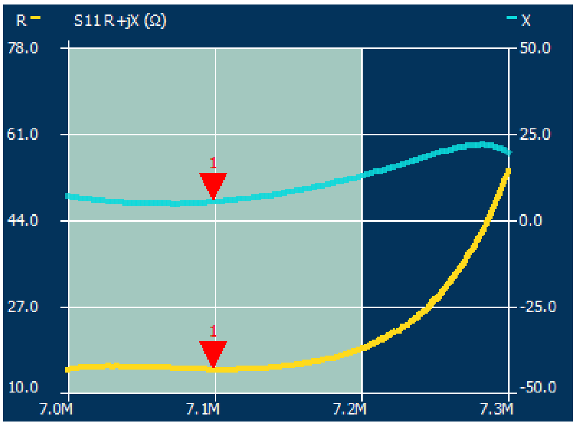


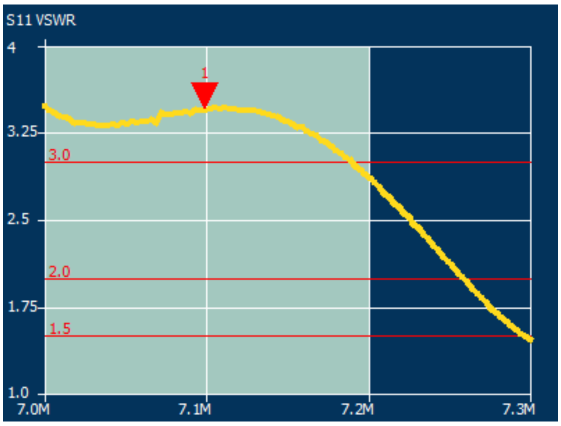
Here too we see that the measurements are equivalent, although in the case of the 18dB attenuator it is clear again that noise is seen on the measured values.

Conclusions

1. We see that we can confidently measure the K3 at the full capability of the nanoVNA. With or without attenuator produces the same results. With 10dB attenuation you can barely see the difference. We do see some noise in the measurements with the 18dB attenuation, but that is acceptable. So if you want to protect the input of the receiver, you can use an 18dB attenuator. The measured values will simply work if you have calibrated first. Using a higher attenuation will make the readings inaccurate. In my case, 25dB was too much for a good measurement.
2. At 160 meters, the K3's SUB RX is pretty close to 50 ohms, SWR between 1.5 and 2.
3. Calibration before measurement is *really* important. If the attenuator is not completely symmetrical, the measured values will vary if you connect the attenuator the wrong way around. Keep that in mind because it can make a lot of difference. Don't ask me how I know this ;-)
4. On other amateur bands, a receiver input may behave differently.

To demonstrate point 4, I measured the S11 at 40m in the example K3. The difference compared to 160m is clear. On the left the measurement S11 R+jX, on the right the S11 SWR. *[graphs below]*





In short, a receiver input of exactly 50 ohms is not an issue in my case. This can vary by band. If I went the royal road to connect my 75 ohm receiver antennas to the input of the SUBRX, then I should actually make an adjustment per band. That is something for the competitive contesters and purists.

The receiving antennas that I use here and there myself and that enter the shack with 75 ohm TV coax come without modification to the connected receiver. It turns out to be no problem in my specific situation.
You can also repeat these measurements yourself with your own receiver while, for example, you turn on the pre-amp or conversely turn on the attenuator. Maybe it will make a difference in input impedance for your transceiver.

Have fun measuring. Questions or remarks? Let me know. Contact details can be found on the PA3A website: https://pa3a.nl/contact-pa3a/.

73,

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