MEASUREMENTS WITH THE NANOVNA

Part 1: Measuring the characteristic impedance of a transmission line

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Preface

The nanoVNA (VNA stands for Vector Network Analyzer) has conquered the amateur world in a short time and will no longer need an introduction to many readers. The device is relatively cheap and accurate enough for the radio amateur. It's a small thing, hence the prefix "nano". Various versions of such a VNA have now been designed and produced, with increasingly better specs.

The VNA I use is the so-called nanoVNA version H3.2. The H stands for Hugen, the nickname of the designer / producer. The 3.2 stands for the printed circuit board version, which in my case means that it is approximately from the period of October 2019 and has a 2.8 inch screen. For an HF enthusiast like me, the small screen version H3.2 is fine. On the one hand because I never do anything with VHF, let alone on higher frequencies, and that my nanoVNA is always connected to a PC in my shack. For measuring antennas on location (mainly SWR), I still use the 'good-old' MFJ-259B that I paid for in Dutch guilders instead of Euro's at the time, and it has bounced around my shack for that purpose, but still gives good measurement results.

This article covers: determining the characteristic impedance of a cable, i.e. finding that known 50 ohms of the RG-213 cable or the 75 ohms of RG-59 cable, or just the characteristic impedance of a piece of power cord if you would like to use it as a transmission line. We do this with the nanoVNA, linked to the nanoSAVER program under Windows 10. This makes controlling the nanoVNA and reading the measured values much easier. The graph pictures of the measurement are also taken from this. In addition, I will also use the MFJ-259B analyzer for such a measurement. That too is actually a VNA, albeit more limited than the nanoVNA, but it also works very well.

A brief explanation of the theory regarding this measurement

When taking this measurement, it is nice to keep a few things in mind.

1. Impedance (we will measure that later)

Impedance is a combination of resistance and reactance and is expressed in ohms. We usually write this as Z = R + jX. By way of illustration: Z = 25 + j35, means that we are dealing with a resistance of

25 ohms, in series with a coil with a reactance of 35 ohms (that 'j' indicates the 90 degree phase shift. If there is –j35 we are dealing with a capacitor.

2. Behaviour of transmission lines that are open or shorted

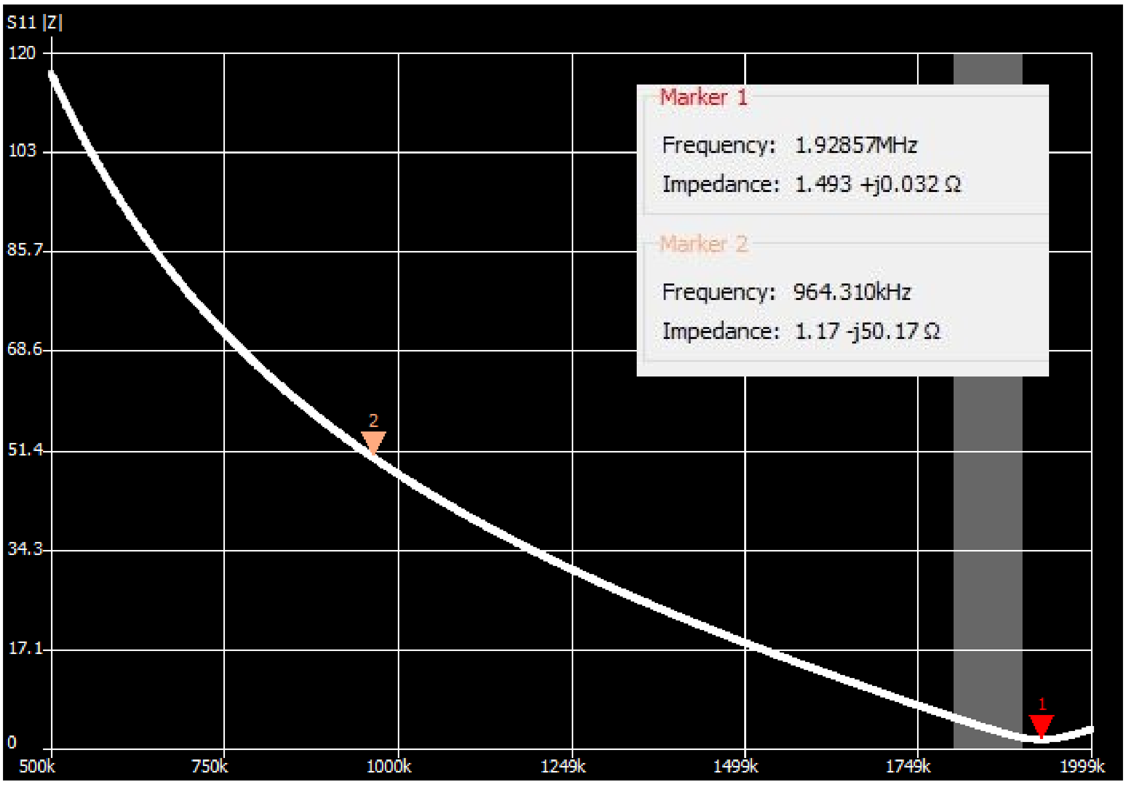
A topic that often shows up in the radio amateur exams… open and shorted transmission lines. With certain cable lengths you can then measure impedances at the beginning from almost 0 to almost infinity and everything in between. Known lengths with known properties are, for example, ½ or ¼ wavelength. The nuances can be found in all kinds of books or course material.

There is also a less known special length. That's the 1/8 wavelength. What it shows is the following: do you short a coax, or do you keep it open at the end, or do you connect a pure resistor of whatever value, and measure the Z = R + jX at the beginning of the cable. Then the approximate value of the characteristic impedance of the coax cable is equal to | Z | = square root ($R^2 + X^2$). We will use that in the measurements below.

Who said transmission line theory wasn't fun?

The measurement with The NanoVNA.

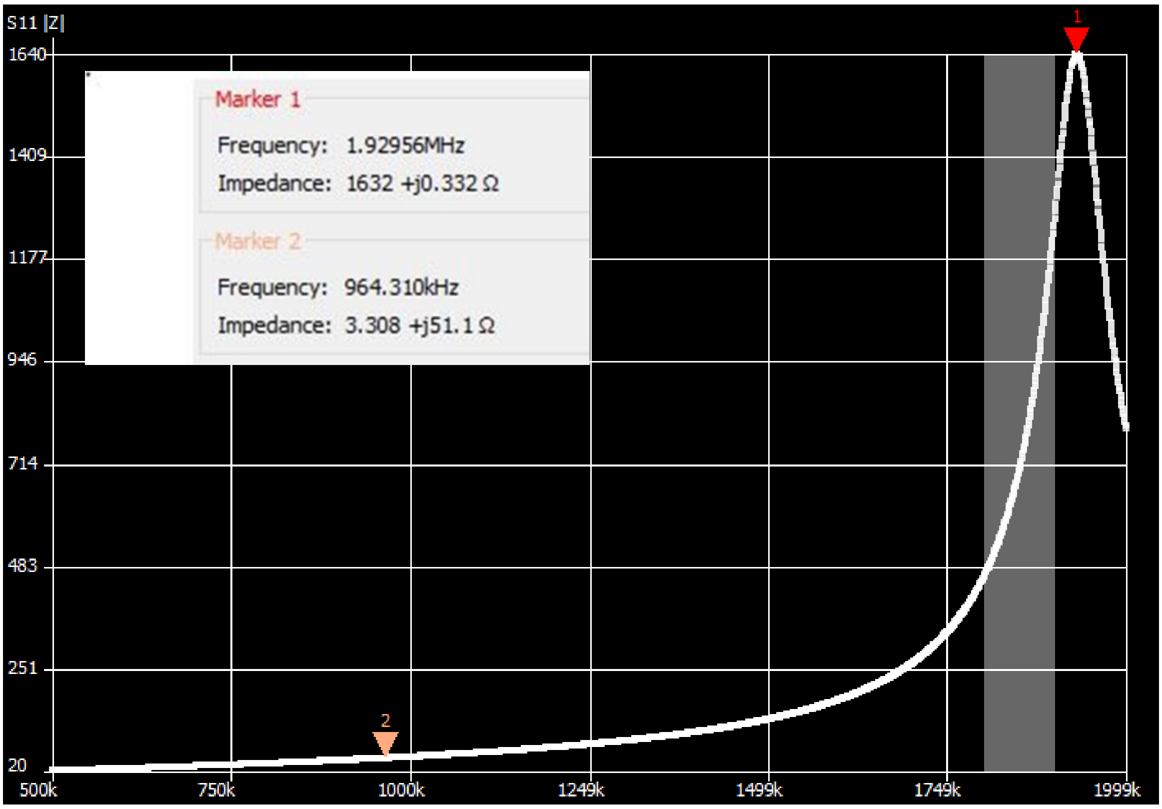
The nanoVNA is connected to about 25 meters of coax labeled "Belden MRG-213 Eca MIL-C-17". This has to be a very good cable. RG213 has a velocity factor of approximately 0.66 and is known to radio amateurs as 50 ohm cable. The coax is open at the far end (high ohmic) so if we select a frequency where it behaves like a quarter wave, about 25m, then you will see a low ohmic value there. This is shown in the following picture from nanoSAVER.



The red marker with no. 1 is at the frequency where the impedance is low/almost zero and practically ohmic (so not inductive or capacitive): 1928 kHz. At this frequency the electrical length of the cable is therefore 1/4 wavelength. So we don't need to know the exact length of the coax, nor the exact velocity factor, it is just ¼ wavelength long for that frequency. If you cut the frequency in

half, then for that frequency the electrical length of the cable would be 1/8 wavelength. That's where the second orange marker is, 964 kHz. We see the | Z | in the graph and read in nanoSAVER for marker 2 close to 50 ohms. | Z | = square root ($R^2 + X^2$).
Since the R is very small compared to the X, you can almost say that the X in value is equal to the characteristic impedance of the cable.

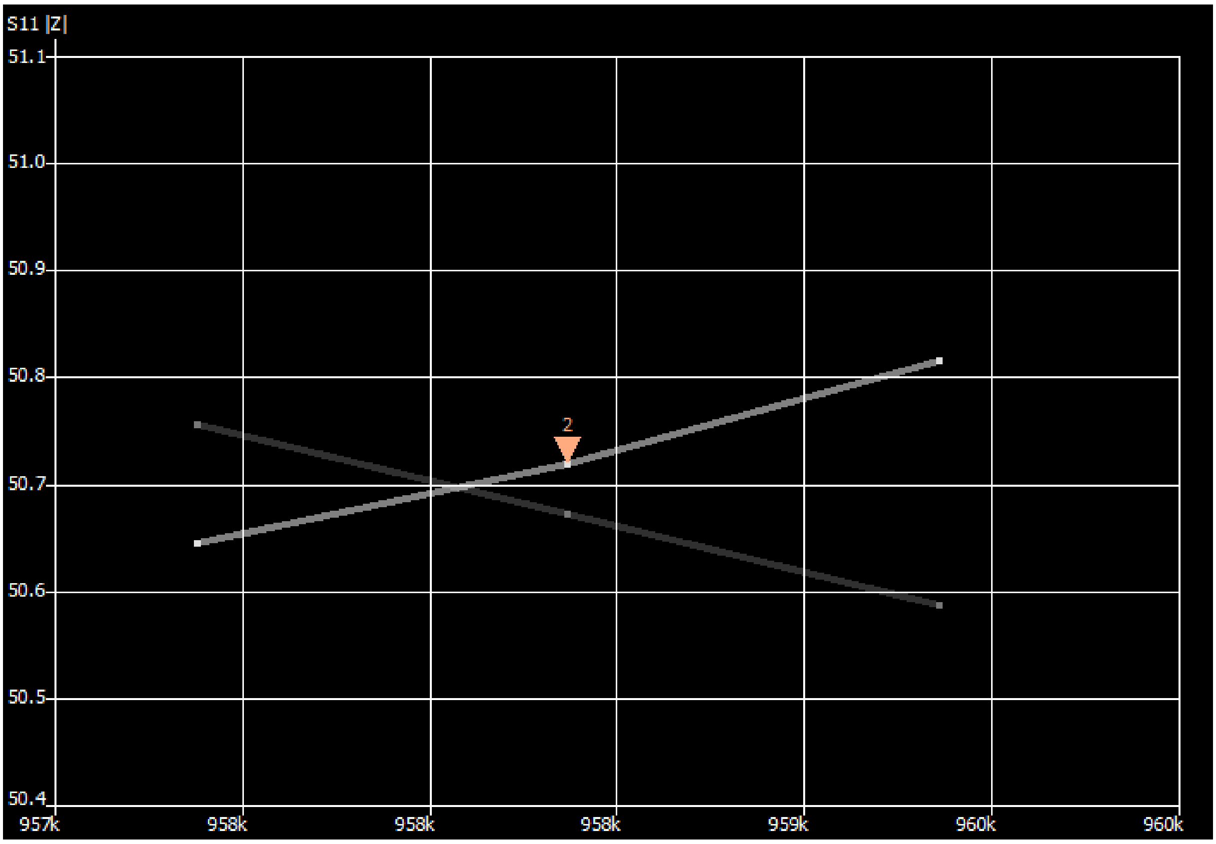
You get a similar picture if you short the same piece of coax at the end.



With the exception of one kHz, the high-impedance value is in the same place as the low-impedance value (marker 1). At the frequency for 1/8 wavelength we read at marker 2 that the characteristic impedance of the cable is approximately 51 ohms.
For a device selling for less than 50 euros (or US$60), it is not a bad result if you consider that we compared two completely different situations: a short-circuited cable and one that is open.

Incidentally, Belden RG-213 is known to have a true characteristic impedance of: 50.6 - j1.6 ohm, so about the value of the common reference to 50 ohm.

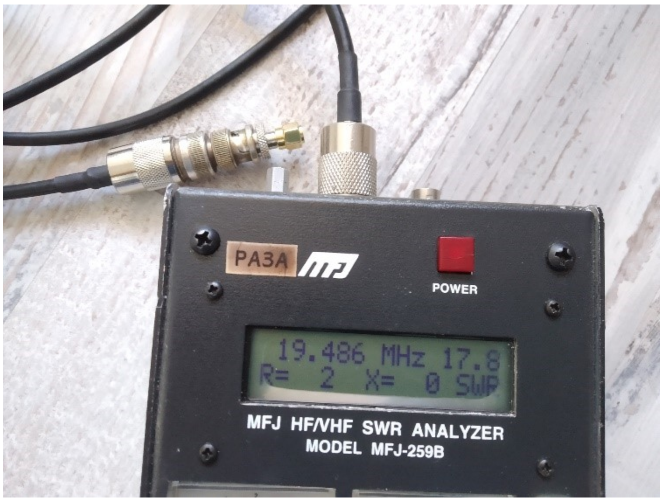
Experts sometimes take both measurements (open and closed line) and take a kind of average of the two measured values. They then superimpose the two graphs and see where the two graphs intersect to read what the value of | Z | is then. Let's do that too.



We now arrive at 50.7 ohms *[above].* Even rounded, with inaccuracies and neglect, this is almost too good to be true. I would have been happy with a value between 48 and 52 ohms… for my amateur purposes anyway.

Measurement with the MFJ-259B (who doesn't know it)

For the measurement with the MFJ, I find a piece of RG-58/U of unknown origin. The length is about 5 meters, and it is shorted. With half a wavelength between we should measure something of low-impedance again (reactance is also zero) and that turns out to be the case at 19,486 kHz. That's about right. Our roughly 5 meters of real length of cable => electrical length is 5 divided by 0.66 = 7.6 meters. A whole wavelength is then 2 x 7.6 = 15.2 meters with a frequency of more than 19.7 MHz. Now the length of the coax was not really measured exactly, but it looks pretty much like it was accurately estimated.



For measuring at 1/8 wavelength, the frequency must be 4x lower than that for ½ wavelength, so approx. 4.875 kHz. The reading on the MFJ is now: Z = 5 + j53. The characteristic impedance of the cable is then | Z | = square root (25 + 2809) = 53.2 ohms. According to the specs, a Belden RG-58/U would have a characteristic impedance of 53.9 - j2 ohms. Right on target. *The MFJ-259B did it again!*

In the next article (Part 2 of the series) I want to determine the damping of a sheath current choke (also known as common mode shoke) on a coax cable, and since it is also said on various forums that the impedance of such a choke must be at least 5000 ohms, we will measure whether that is confirmed with our little instrument. So, to be continued…

Source coax data: taken from ac6la.com: TLDetails.
TLDetails is an educational and useful program that works with precise formulas to show the behaviour of different transmission lines. Heartily recommended.

73,

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