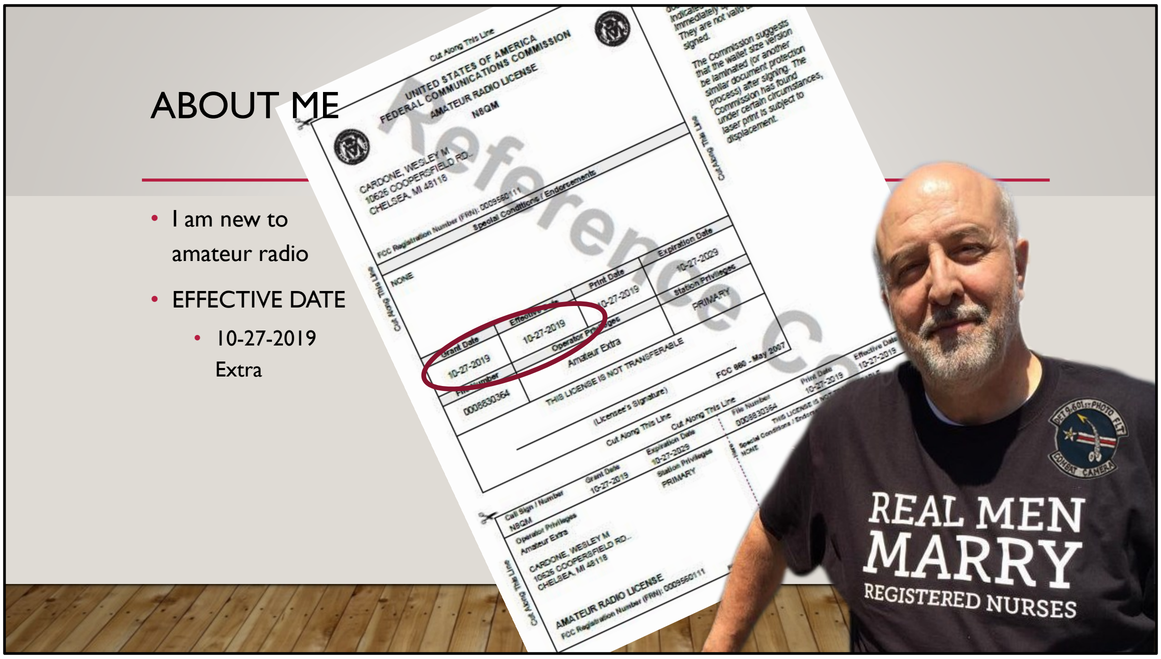
Thank you for taking the time to see me to speak on the widely known but little understood nanoVNA. The nanoVNA is truly an amazing device with many very great and amazing capabilities. Let me say first of all that most of the YouTube videos and tutorials give you a bucket full of fish. My purpose tonight is to teach you how to catch fish for yourself. We will spend a minute or two simply naming some of that capability but we will concentrate our efforts tonight on just a vector impedance measurement function and the principles behind it. In doing so we briefly review some of the materteral of earlier presentations. I will put up the notes and slides for tonight's presentation on the web site for anyone to download. But also understand that I was putting finishing touches on this presentation right up to the opening of this meeting so there may be rough spots. This presentation should take about 50 minutes plus time for questions.

But I bet you a buck that some of you are wondering why the title for tonight's presentation. In choosing such a title I didn't mean to imply that the nanoVNA compares with the blood of Christ in its efficacy to satisfy divine justice and forgive sin. But there are things that we often think of as everyday gifts from God such as man's best friend, the dog, loyal and true to the end. Likewise, the nanoVNA may be the amateur radio operator's best friend opening doors in amateur radio for well under a hundred bucks that would otherwise require spending between 500 and 800 dollars.

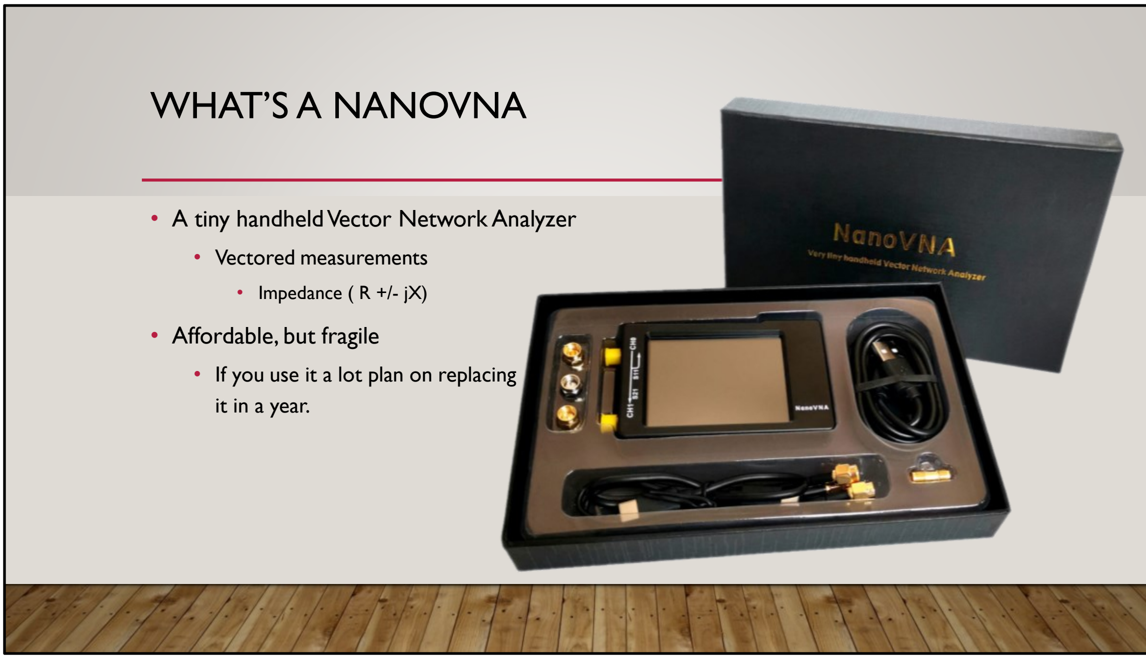


But before we go any further, I would like to make a disclaimer. I am new to amateur radio and will celebrate my 1 year anniversary in amateur radio this October. It was on September 14th when I took my Technician's license exam in Ann Arbor at the American Red Cross building. In tonight's presentation I may appear as a know-it-all but rest assured, I don't know noth'n about no amateur radio, now how. I can tell you a little bit about electro-magnetic and transmission line theory but when it comes to amateur radio, I don't know zip, really. That's why I come to these meetings to associate with the likes of all of you so that I can learn about amateur radio and its wonderful benefits. Having made that disclaimer, let us move on.

WHAT DISCUSSED & NOT TONIGHT

- DISCUSSED
  - We will be concentrating on what the thing is doing and some practices to optimize and obtain reliable readings.
- NOT DISCUSSED IN DETAIL BUT EXAMINED
  - Operation of
    - Buttons
    - Menu
    - Etc.

There are several YouTube videos on the basic operation of the nanoVNA where gut-level tutorials are given. In tonight's presentation we will also go through somewhat of a gut-level tutorial, but I will be stopping along the way to expand on some of the important aspects of the nanoVNA that I think amateurs will benefit from knowing something about. I want you folks to leave here tonight with a better understanding of what the nanoVNA is doing so that you can put it to real work in solving your various amateur radio projects.



So, what is a nanoVNA, anyhow? Virtually all of them come with the parts shown here. The one capability that the nanoVNA has which all amateur operators, the ones who don't mind cutting coax and attaching PL-259s, to will be interested in is the nanoVNAs ability to make vectored impedance measurements. That is simultaneous, real resistance and imaginary reactance which together make a vector quantity. But the nanoVNA is fragile. Don't drop it or pretty much breath too hard on it or else you will be spending another $40. But compare that to a RigExpert. If you drop it and kick it around it will probably kick you back.

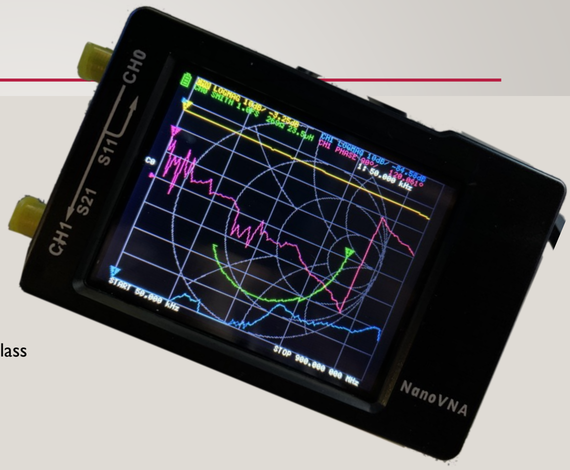
WHAT'S A NANOVNA DO, ANYHOW?

- Measure
  - coax (transmission line)
    - Length
    - Attenuation
    - Characteristic impedance
    - Identify distance to a fault
  - Antenna vector impedance (this is our focus tonight)
  - Filter response
  - SWR
- Time domain: simulates time domain by Laplace transform of frequency
- Sweeps frequencies from 50 kHz to 900 MHz

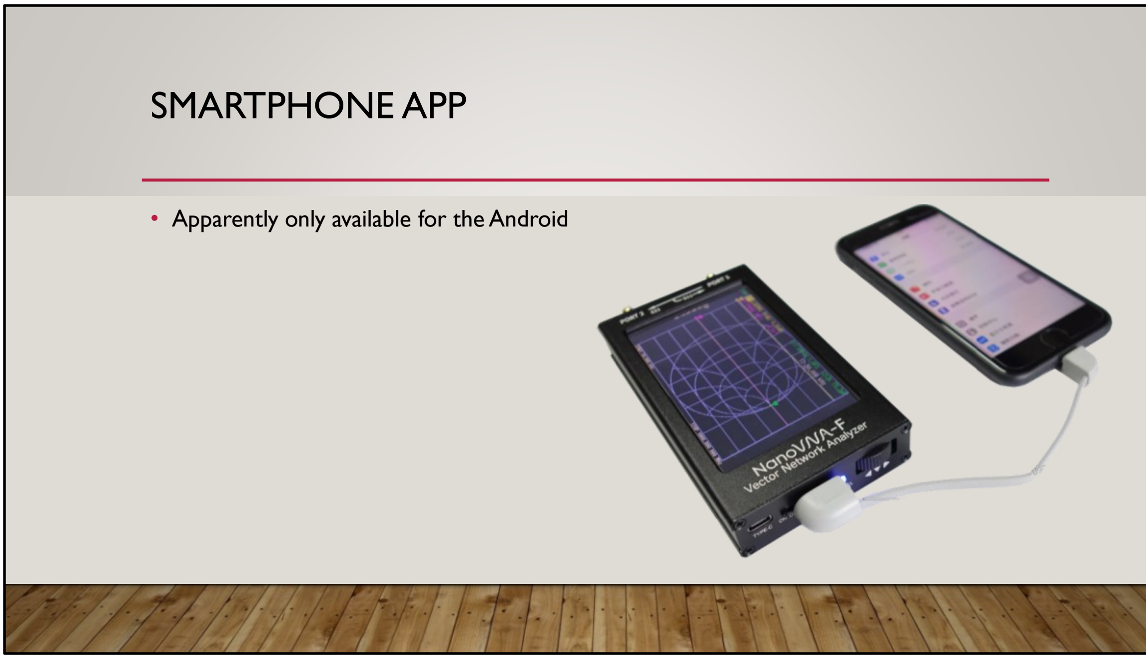
There is an easy way to answer the question of what does a nanoVNA to. That question can be answered by asking another question: What are most of the things that amateur radio operators do concerning the interface between their transmitters and antennas? But tonight, as noted earlier, all we will be looking at is a vector impedance measurement.

DISPLAY

- 4 traces can run simultaneously
  - Often this is distracting
  - Turn off those not being used
  - All are on by default at power on
- Size
  - 2.3 inch standard size
    - VERY hard to read, get a magnifying glass
    - Otherwise works great
  - 4.3 inch much better (much costlier)



The nanoVNA has four traces: yellow; green; blue; and purple, which can be arbitrarily assigned to any of the functions that the device is capable of. Any or all of them can be turned off. There is some manner of elusiveness to them which we will explore later that will help you greatly if you understand it. Most nanoVNAs come with a 2 inch screen. For me, personally…this is too small. I literally use a magnifying glass to read most anything other than menu labels. Really. For about an additional $75 you can get a model with a 4 inch screen. But now we are talking $150 for a nanoVNA so a point comes when we lost the cost effectiveness of the nanoVNA relative to a $500 antenna analyzer. The cheap one will work as well as the expensive one, you will just be squinting at it a lot more. But I will talk about where to buy these things at the end of the presentation. Don’t make my mistake and buy from Amazon.



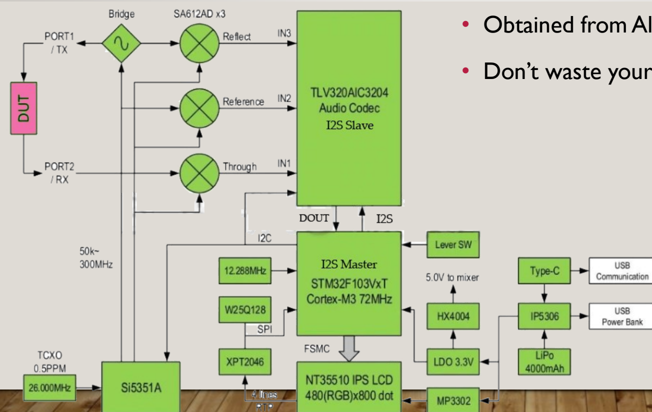
I can’t say much about smartphone apps for the nanoVNA since I use an iPhone. Most nanoVNAs come with a USB-C to USB-C cable.

RECOMMENDED MUST SMA HAVES

- Measurement Standards
  - 50 Ohm Load
  - Short
  - Open
  - Purchased standalone these cost from $20 to $40 but almost always are included with a new nanoVNA.
- Female to Female Adapter
- Male to Male cable (2x)

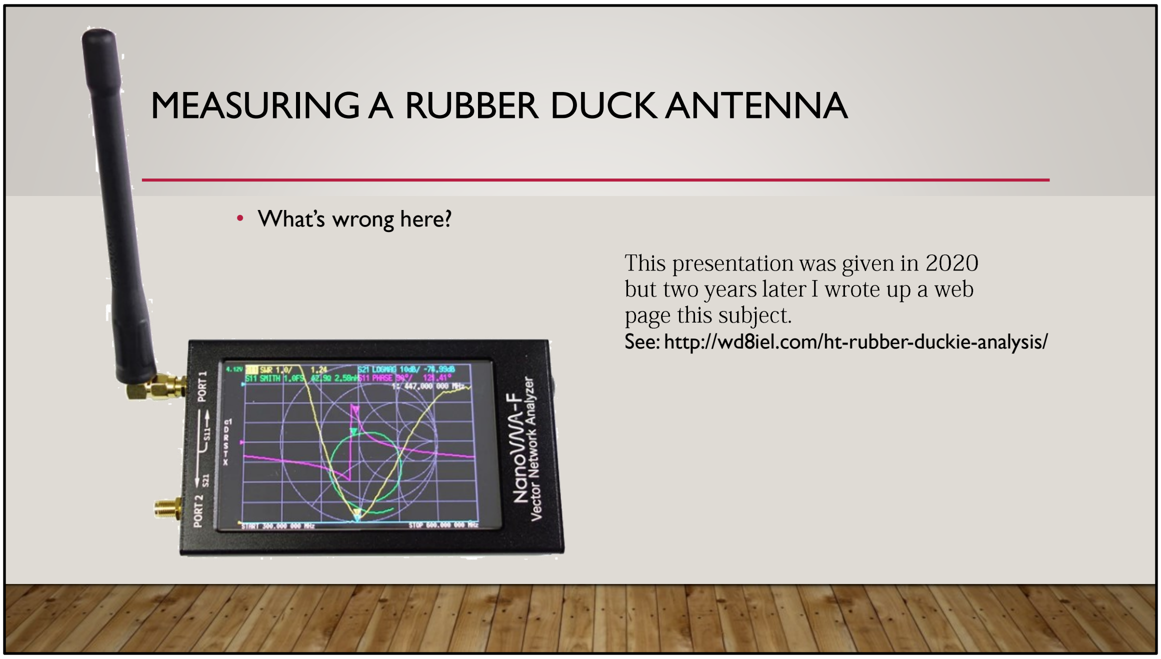
There are some things that you must have with a nanoVNA. Foremost among these are measurement standards. This is so because, as we will see in tonight's presentation, most every time you breath you are calibrating the nanoVNA. As we will see later, every time you change the frequency sweep you will need to re-calibrate. Fortunately, virtually all nanoVNA packages include these standards. But they are small and easily lost so take special care not to lose them. You can make your own if you need to replace them but they are readily available as standalone items to buy for $20 to $40.

BUT WHAT DOES IT DO INSIDE?

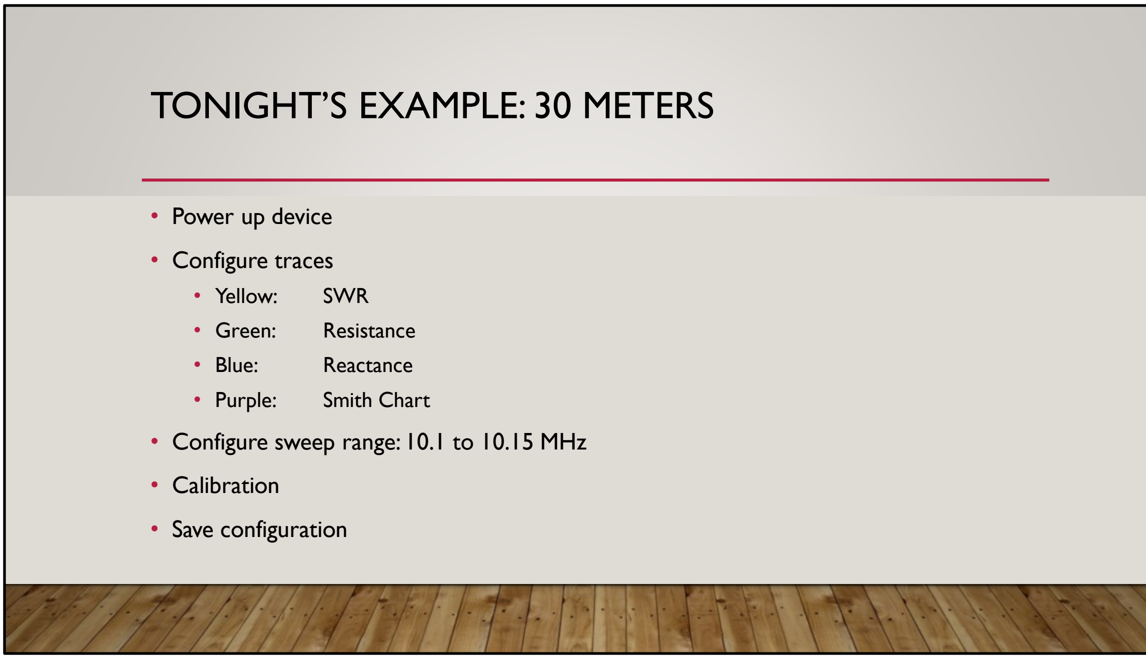


- Obtained from AliExpress.com
- Don’t waste your time looking at this.

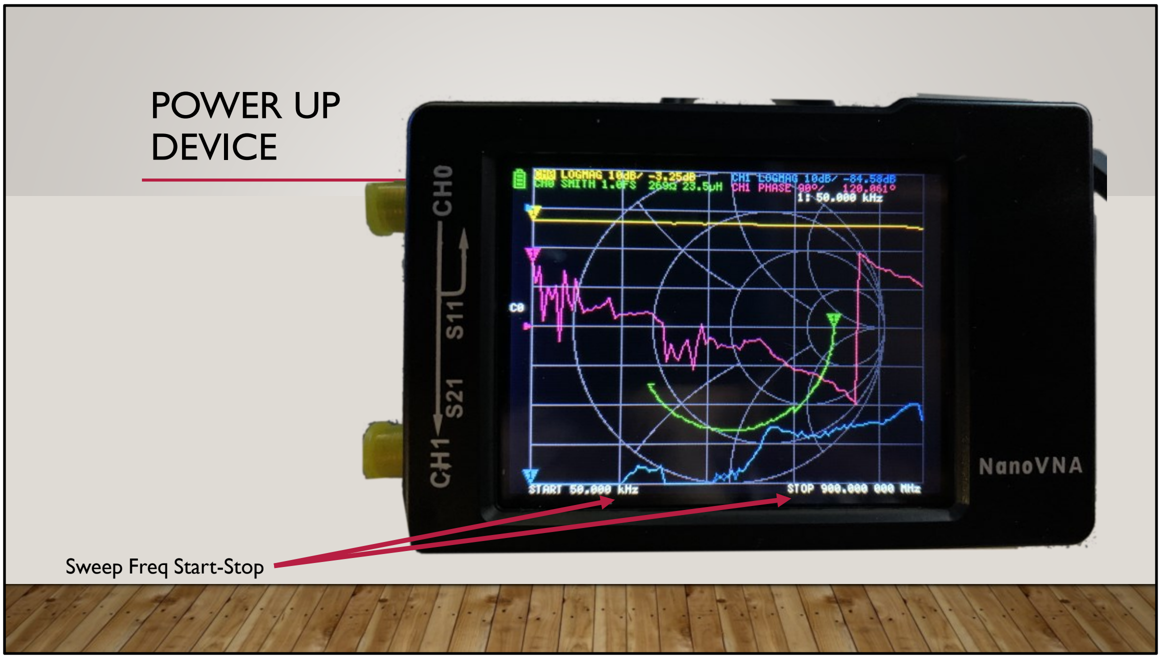
I found a discussion of the internal workings of the nanoVNA but let’s just leave it at that. There will be no benefit to understanding that level of operation. The one workings under the hood that it is imperative to understand, however, is that the nanoVNA always samples 100 data points in any frequency sweep. More will be said about this later.



We will talk about this later but I want to start the wheels of thinking moving here. I see this in YouTube videos a lot. People think that they can measure a rubber duck's vector impedance by simply attaching it to the nanoVNA. Folks, you can't do it and still get a valid measurement. Some of you could answer it right now with the information we covered in the May meeting, The Mighty Dipole Part 2 and its follow up presentation last month in the July meeting on "The ABCs of Smith Charts." For now I want you to think about it. If you understand the flaw in this concept you have got your antenna theory under control.



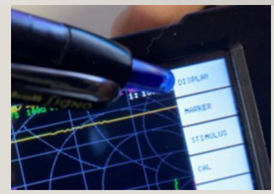
For tonight's example we are going to solve for a tuning stub for my own real life 160 meter off-center fed dipole. The thing doesn't work for 30 meters and doesn't even come close but has a vector impedance that might surprise many. To summarize the next few slides we are going to first power up the nanoVNA, then configure the four traces to suit our purposes and preferences, then set the sweep range (otherwise called "stimulus"), and ONLY then having set the stimulus, perform the calibration, and then finally save the configuration to one of the nanoVNA memory channels. The CRITICAL path in this procedure is to set the stimulus and only THEN do the calibration.

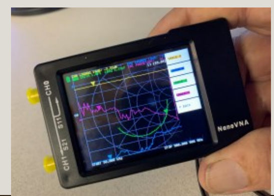


When we power up the nanoVNA its sweep frequency set points or stimulus are at the device maximums. This is important to remember because you must set these points to what is applicable for your application BEFORE you do the calibration. This is easy to forget.

CONFIGURE TRACES

- Find DISPLAY in the menu
- A sub-menu appears listing the four traces available.
- All are on by default
- Clicking on any one of them is a 2-step process.
  - 1st click selects (shown next slide)
  - 2nd click hides the trace





Configuring and hiding or unhiding the displays is tricky as we will see in the next slide. You cannot use your fingers. The rounded end of a ballpoint pen works nicely. It takes a little practice to touch the display with the blunt instrument so as to call up the display but once you learn it, it's pretty easy after that. But at this point we arrive at a really tricky part of the trace selection menu. Trace selection is a 2-step process. One click selects, a second click hides the trace. Please pay attention in the slide after the next where we will see how to tell if any given trace is selected or not. This will save you much grief if you understand how the nanoVNA is trying to communicate with you.

IMPROVED 4” DISPLAY MODEL

- The menu may be accessed much more conveniently via these MENU buttons.
- May still access MENU via the touch screen.
- This is a massive convenience.
- Also, this model has a metal chassis, much more durable than the $40 model.

But first, I went ahead and did buy the 4 inch model just because it was getting old having to use a magnifying glass EVERY TIME I wanted to read some text. I bought it from Amazon before I knew better and paid $150. We’ll talk about where to buy these things in a later slide so you don’t make my same mistakes. This improved model not only has a much larger screen but it has a metal chassis for durability and buttons to access the menu. The button menu access is a vast improvement over the touch screen method on the smaller display unit.

TRACE SELECTION AND HIDING

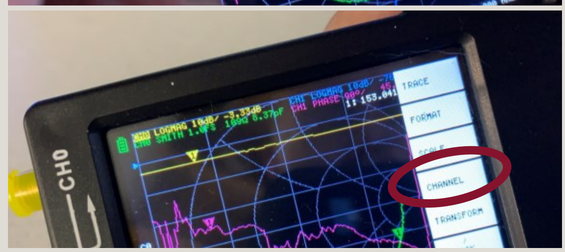
- Carefully note in the upper picture at right that the yellow text CH0 prefix is NOT inverse highlighted.
- Note in the lower photo the CH0 prefix for the yellow trace IS inverse highlighted.
- Selection is part of the 2-step process.

Each trace legend is prefixed by the name of the channel it is serving—channel 0 (CH0) or channel 1 (CH1) in this case. Most nanoVNAs have two ports such as this one. Names differ a little but will say CH something. You may assign a trace to either of the two ports.

And now this is what I want you to pay careful attention to… I want you to carefully note the difference between these two photos which illustrate how to tell if a trace is selected or not. In the upper photo, the yellow trace is not selected. In the lower photo you can just barely see that the channel prefix is inverse highlighted indicating that the trace IS selected.

YELLOW TRACE SELECTION

- Having selected the Yellow trace…
- Click BACK as illustrated at right/upper.
- The parent menu appears as shown at right/lower.
- Look for CHANNEL.
    - Push into CHANNEL if the port is set for CH1 to switch to CH0.
    - For this exercise we are not using CH1.



So now having selected the trace we click BACK in the menu. At this point please pay special attention to this next step. This nanoVNA has two ports, CH0 and CH1 although names can differ slightly between different models. We are not using CH1 for this exercise but the trace could be set to read from CH1 which would give us no end of grief if not corrected. In fact, during the development of this tutorial I was working with a brand new nanoVNA which was defaulting traces 1 and 2 to CH0 and traces 3 and 4 to CH1. This oversight caused me much grief. I kid you not. I knew that the antenna vector impedance was something very ugly at 10 MHz but the nanoVNA was telling me it was nearly perfectly at 50 Ohms resistive, zero Ohms reactive—the Holy Grail! But I knew it was not so and lost maybe an hour figuring it out.

FORMAT THE YELLOW TRACE

- Click FORMAT
- On the sub-menu that appears click SWR.
- The menu will entirely disappear.
- Tap on the menu area to bring the menu back.
- At the very bottom of the menu click BACK.

Click FORMAT and then SWR. This assigns the SWR function to the yellow trace. From that point the yellow trace represents the SWR of whatever is connected to the CH0 port. At this point CH0 is open so the yellow trace is meaningless except that it is registering an open.

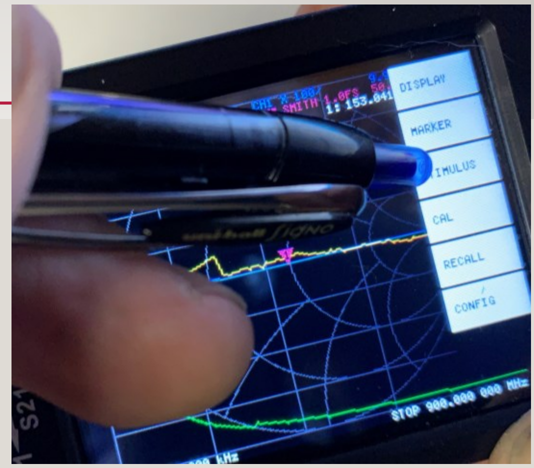
REPEAT THE PROCESS FOR THE OTHER TRACES

- Yellow Trace
  - SWR
- Blue Trace
  - Reactance (found under MORE)
- Green Trace
  - Resistance (found under MORE)
- Purple Trace
  - SMITH

I will repeat the process for the other three traces but assign them according to that shown in the enumeration. For the sake of simplicity the slide presentation will not illustrate each trace configuration. All of them are done like the first was done. Further, I had originally planned to go through a live configuration demonstration with the nanoVNA but was running in excess of my time limitation.

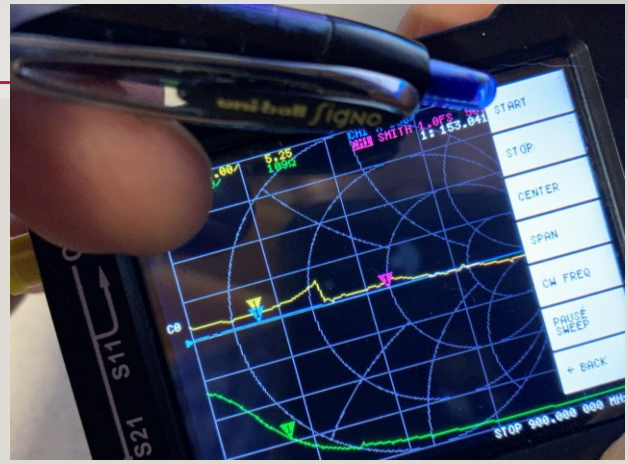
SET THE FREQUENCY SWEEP OR STIMULUS

- For the example used here we are sweeping for the 30 meters band.
- In the menu find STIMULUS and click on it.



We may now set the stimulus though we could have done it before configuring the traces. The only requirement regarding the soon to come calibration is that calibration MUST happen after the stimulus is set. So, you say, “Why is that?” I heard somebody say it. Hold on to your hats. We will get there.

SWEEP SETTING



- Frequency sweep parameters are set using
  - START
  - STOP
- There are other ways to set the sweep parameters but this is probably the most common.
- Click START

Now let's set the frequency sweep or stimulus. There are a couple of ways to do this but probably the easiest is to tell the nanoVNA a start and a stop frequency. Let's do the start frequency first. Find START in the menu and click it. Which will bring up a keypad.

SETTING THE SWEEP FREQUENCY

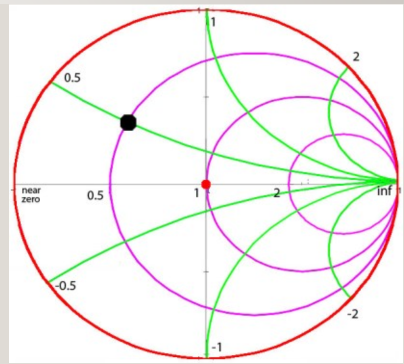
- Click in the frequency entering the numerals and then multiplier, x1, k, M, G
- Enter 10.0 MHz
  - 10.0
  - M
- When you click the multiplier the entire menu disappears.
- Call up the menu again for STIMULUS and enter the END frequency
  - 10.15
  - M

A numerical touch pad appears so press 1 and then press zero and then the multiplier M for mega. The menu will disappear. Touch the blunt end of you pen anywhere on the touch screen and the menu will reappear. Press STOP and the 1 and the 0 and the dot and the 1 and the 5 and then the multiplier M for mega. The menu will again disappear but look at the bottom of the display where you will see the new stimulus displayed. Sadly, I don't have that shown here.

CALIBRATION AND THE SMITH CHART

- It is now time to do calibration.
- Relating calibration to the Smith Chart enables a visualization of what is happening.
- Therefore we will in the next slide briefly review the Smith Chart with an 8-minute animation.

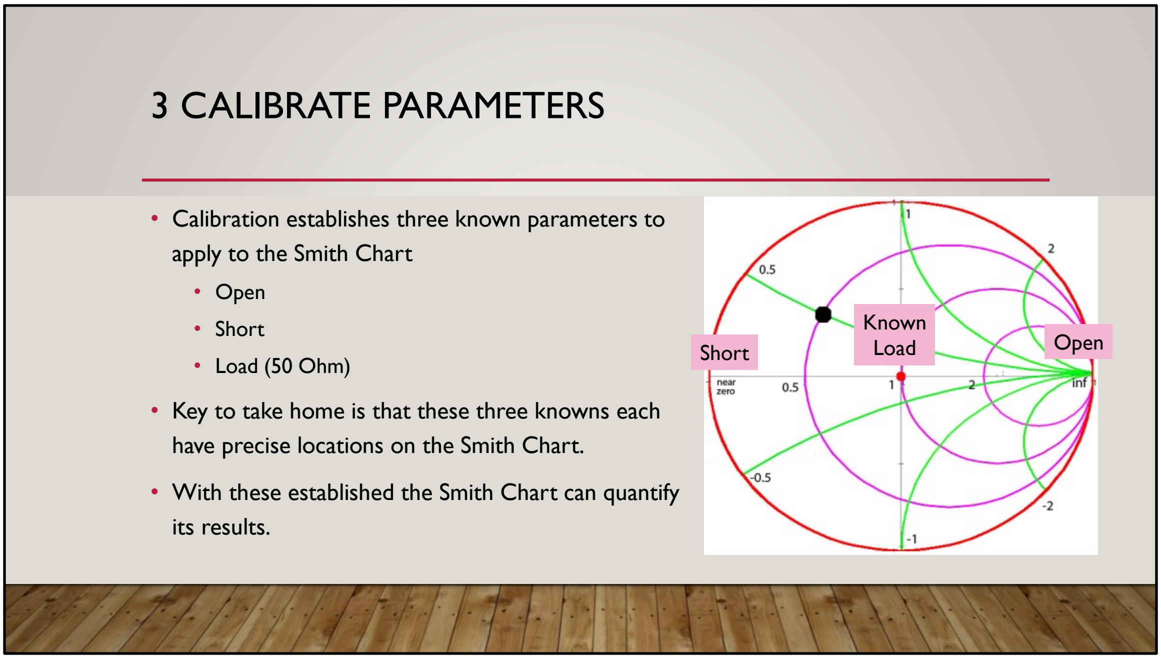
Next slide please…



Now, finally we come to calibration. But I would like to do the calibration with a reference of how it fits in within the Smith Chart. Therefore I have an 8 minute video animation to illustrate what the Smith Chart is all about. Last week we viewed the first 5 minutes of this video. Now we will view the entire 8 minutes.

This video is online at

https://vimeo.com/wcardone/basicssmithchart



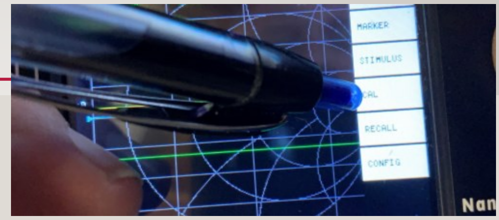
Our next step is calibration but let's talk about calibration first and what it represents. This is an important slide so I want to spend some time here. Our calibration is going to be for three conditions: an open, a short, and a 50 Ohm load. Doing this calibration allows the nanoVNA to establish where those standards lie on the Smith Chart. A short is nearly zero Ohms and belongs on the far left. An open is nearly infinite Ohms and belongs on the far right. A 50 Ohm load, or whatever characteristic impedance we are working with, belongs directly in the center of the Smith Chart at home plate, the red dot.

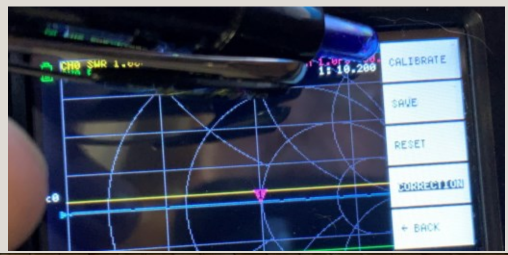
The nanoVNA has 100 sample points it will take and will distribute them evenly between the stimulus end points—the short and the open. Put another way, the nanoVNA will divide the frequency spread by 100 and put sample points at each of those incremental points. For example, let us say that we did our calibration at power up. This device defaults to a frequency sweep at power up of 0.05 MHz to 900 MHz. What is 900 minus 0.05? I don't have my handy dandy calculator available. Somebody, please tell me what is 900 minus 0.05? Oh, wait a minute… I think I figured it out. 900 minus 0.05 is 900. Okay next, what is 900 divided by 100? I need some help here, folks. Somebody please tell me… That's right. 900 divided by 100 is 9. So, with this knowledge, where do you suppose the sample points will be placed if we did our calibration at power up? They will be placed at the starting point of 0.05 MHz, then 9.05 MHz, 18.05 MHz, 27.05 MHz and continuing on to 882.05 MHz, 991.05 MHz and finally 900 MHz.

Now, let us suppose that having thus calibrated, we set our frequency stimulus to tonight’s example of 10.0 MHz to 10.15 MHz, the frequencies representing the FCC allocation for 30 meters? What sort of reading accuracy do you suppose we can expect to get? Not too good, that’s for sure. What’s worse, we might end up spending the greater part of a Saturday afternoon using that number building something that doesn’t work and throw our hands up in disgust at the end of the day. But let us suppose that we set the stimulus FIRST and THEN calibrated. Our sample points would be placed at 10.000, 10.0015, 10.0030 and on the other end 10.1485 and finally 10.15 MHz. That will be acceptable.

CALIBRATION

- Find CAL in the menu.
- Clicking this produces a sub-menu containing CALIBRATE at the top. Don't click on it just yet.
- Click on RESET.
- Click CALIBRATE





NOW finally we are ready to do a calibration. Tap the touchscreen to call up the menu and navigate to CAL. Click on CAL which calls up a sub-menu containing CALIBRATE at the top. Click on CALIBRATE.

LOCATE STANDARDS

- Locate the three standards and make them readily available.
  - OPEN
  - SHORT
  - 50 Ohm Load
  - F-F patch cable
  - F-F adapter

Locate the three measurement standards and place them where they will be readily available but yet out of the way to prevent them falling on the floor or otherwise being lost. If you lose or lose track of these you need to buy replacements. About now you are probably wondering why use a patch cable. The answer is for strain relief as we shall see in a later slide when we attach the antenna.

CABLES

- Attach the patch cable to CH0
- Attach F-F adapter to cable end

First step, attach the patch cable and female to female adapter.

THE OPEN

- Attach the OPEN standard.

Find the open standard and attach it to the cable end.

CALIBRATION STEPS

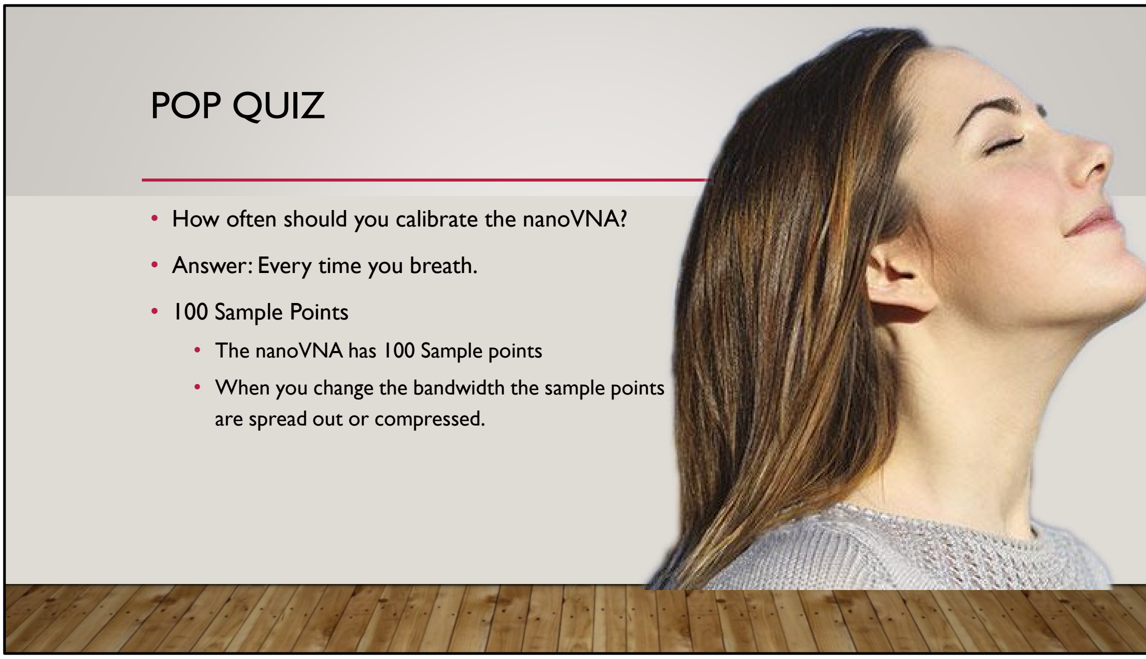
- The open standard has been installed on CH0
- Locate OPEN in the menu structure.
- Click OPEN.
- The nanoVNA chimes and highlights SHORT.
- Connect the short standard and click SHORT.
- Connect the 50 Ohm standard and click LOAD.
- Click on DONE.

Click OPEN. The nanoVNA chimes and highliths SHORT which is the next step. Connect the short anc click SHORT. Then the 50 Hom standard and lastly click DONE.

SAVE TO MEMORY

- It is common to shut off power to the nanoVNA during its use and when done, depending on the particular nanoVNA, some attributes you have set will be lost when the device powers up again.
- Saving a configuration to memory helps a great deal when cycling the power.

Typically when we use the nanoVNA we are in and out with it. We use it a little, then shut it off. An hour later we may want to continue or maybe something may have happened to interrupt us and it would be nice to restore a configuration from memory rather than having to go through calibration again. Some units are different than others in this regard as far as what portion of a configuration is saved but all of them lose their calibration when power is cycled.



The nanoVNA just simply has 100 sample points no matter what bandwidth you choose. The benefit is that all sweeps will happen blazingly fast. The downsides are legion. But the price is right as long as you always remember to calibrate whenever you change the bandwidth sweep.

PUT THE MEASUREMENT STANDARDS AWAY

- Put the measurement standards perhaps back in the nanoVNA box.
- If you lose these you will be buying replacements.

Keep thing tidy regarding the measurement standards. They are incredibly easy to lose.

Before we go any further… just a reminder that I have a question coming up in a later slide. Keep you thinking caps on.

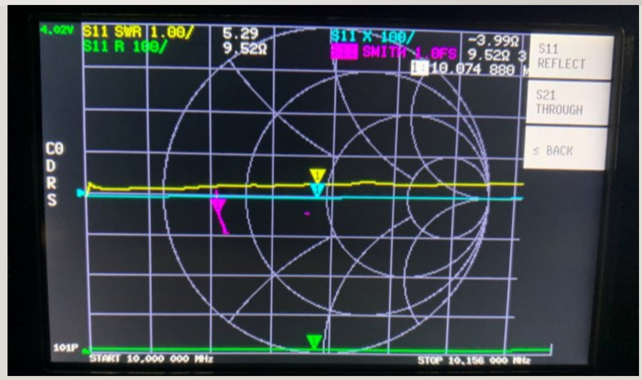
IMPEDANCE MEASUREMENT

- Attach antenna
- Patch cable provides strain relief.
- Capture impedance at 10.01 MHz

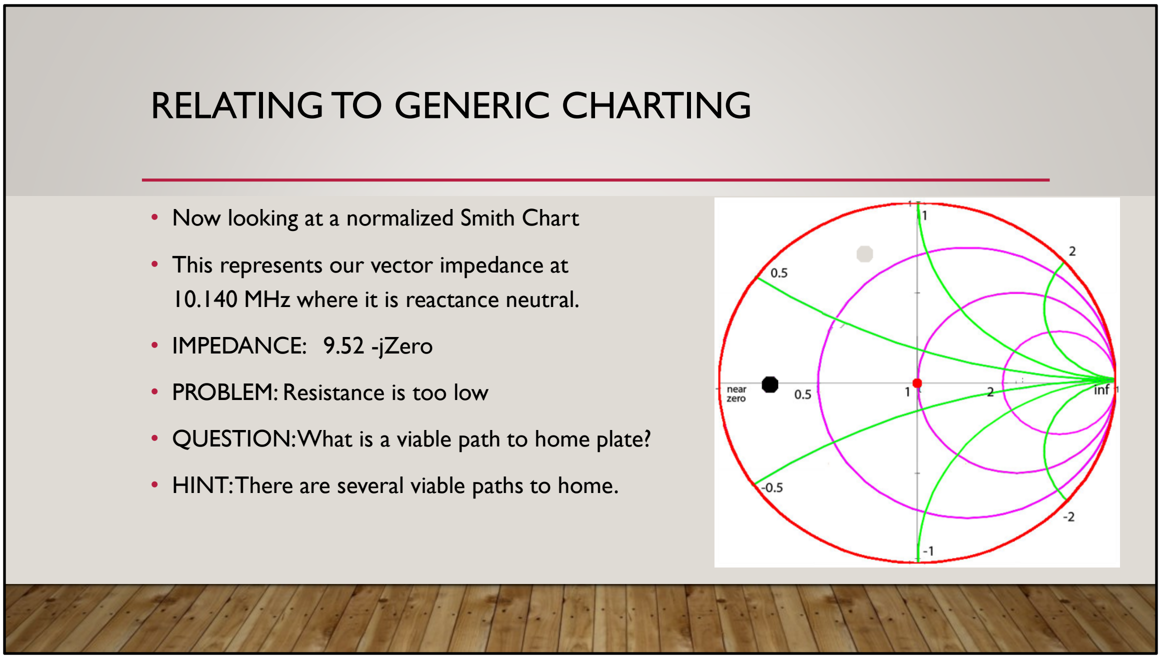
We are now ready to attach our antenna coax to the patch cable. You can see now why the patch cable is necessary. Connecting the rugged coax RG-213 cable directly to the CH0 port would eventually break the port free from its cheap plastic chassis. But even if the quality were much stronger, connecting RG-213 would be an unnecessary strain on CH0. In the next slide we will start the capture of the antenna vectored impedance for the 30 meters band.

CAPTURED VECTOR IMPEDANCE AT 10.074 MHZ

- Yellow trace
  - SWR = 5.29:1
- Blue trace
  - Reactance = -j3.99 Ohms
- Green trace
  - Resistance = 9.52 Ohms
- Purple trace
  - Smith Chart: Through 30 meter band reactance is mainly capacitive and a little inductive.



What do we see!!!!! The vector impedance at 10.074 MHz is 9.52 –j3.99. That is 9.52 Ohms of real resistance and 4 Ohms of capacitive reactance. The Smith Chart representation shows the frequency sweep impedance being nearly 9.5 Ohms through all of 30 meters and nearly reactance neutral at 10.140 MHz where it reads 300pH. But wait a minute… Doesn't this violate our rules of the road for dipoles? We have an antenna that is reactance neutral but an SWR of 5:1.

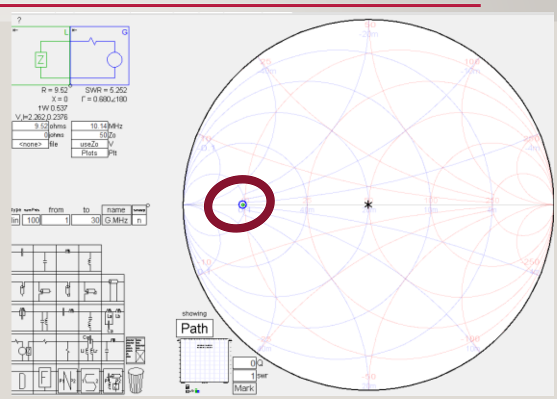


We have a vector impedance and have placed it on a normalized Smith Chart. Don't let the number conversions between actual and normalized confuse you. We are only interested in the position for now. We will let the computer crunch the actual numbers later but for now look at where the vector impedance lies. It is perfectly reactive neutral but has too low of a resistance. So, talk to me, folks. Think about what we have learned in how to manipulate and move impedances. This is impedance neutral so you would think that there is no solution by adding or subtracting reactances…or is there? We can add transmission line length and that will rotate the mark clockwise around home plate. Adding a half wavelength of coax (at 10 MHz that would be roughly 15 meters) would put dot in the same place except add a little signal attenuation.

Let's talk about what happens when we do things. First of all we want to realize a net resistance increase because we are to the left of home plate. What happens if we add a series capacitor feeding the antenna? Remember that the frequency is not changing. Reactance increases to the antenna at least moving us in the correct direction to the right. Here's the thing folks: Adding either capacitance or inductance in series with the antenna will move the dot diagonally up or down helping with the impedance but, and here's the key, somewhere along the line it will intercept either a conductance or resistance line which leads to home plate. Let’s try it out in SimSmith.

SIMSMITH TO THE RESCUE

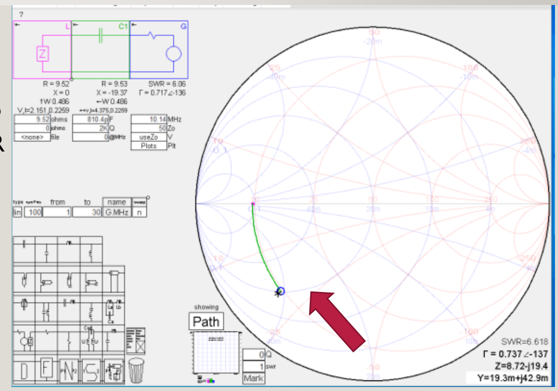
- Vector impedance added to SimSmith
- QUESTION: What effect does adding a series capacitance have?
- Next slide please…



I have plotted our vector impedance in SimSmith. Do you remember now that I told you not to worry about conversions to normalization? Let the computer take care of that stuff. Our question to SimSmith now is what effect does adding a series capacitance have?

ADDING A SERIES CAPACITOR

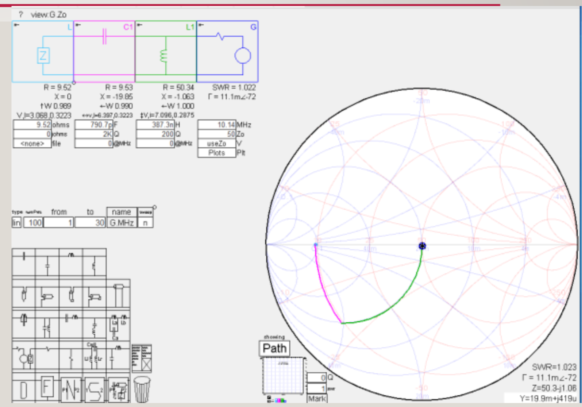
- We have added a 810pF capacitor in series with the transmission line.
- It has, of course added capacitance but also moved us in a favorable direction to LATER increase the resistance.
- Do you see what we have done?
- We have intercepted the 0.02 conductance line!
- What should a next step be?



We have added an 810pF capacitor in series with the antenna putting it at the end of the coax where one capacitor lead connects to the coax conductor and the other connects to the antenna feed point. Look what happened! We have intercepted a conductance line that leads directly, does not stop at jail, to home plate. What should a next step be? Any ideas? … Having added the capacitor our new vector impedance is capacitive so we need to add some inductance but in what format: series or parallel? If we add an inductor in series it will simply cancel our new capacitor and retrace the line in the wrong direction from which we came. If we add a parallel inductance however… Let’s see what SimSmith says. Next slide, please.

COMPLETING THE LOOP: AN INDUCTOR

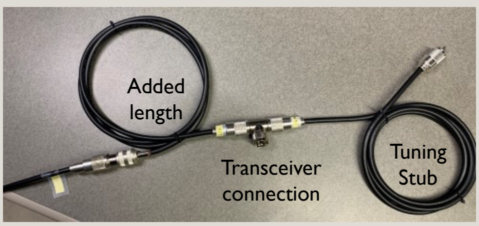
- We have added a 387nH inductor in parallel with the antenna feed point, feed point to shield.
- This takes on a path directly to home plate, the Holy Grail, 50 Ohms resistive, zero Ohms reactive.
- But where do you find capacitors and inductors in these non-nominal sizes?
- ANSWER: You don't.
- SOLUTION: Cut transmission line to fit.

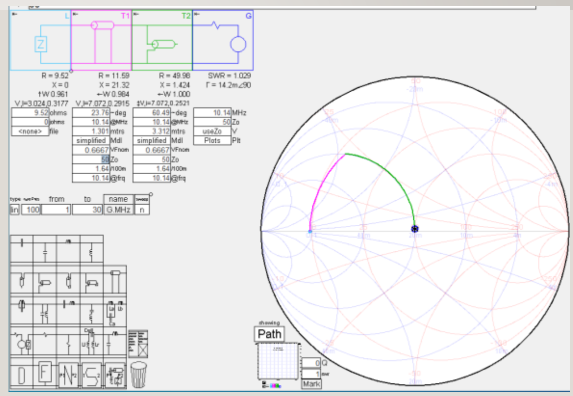


So now look at what happened. We added a parallel 387nH inductor and it took us straight home. That was easy. But will it be easy to build? No, it will be very hard to build because capacitors and inductors are not manufactured in those nominal sizes. The solution is to cut coax which we learned how do measure and do in last month's presentation.

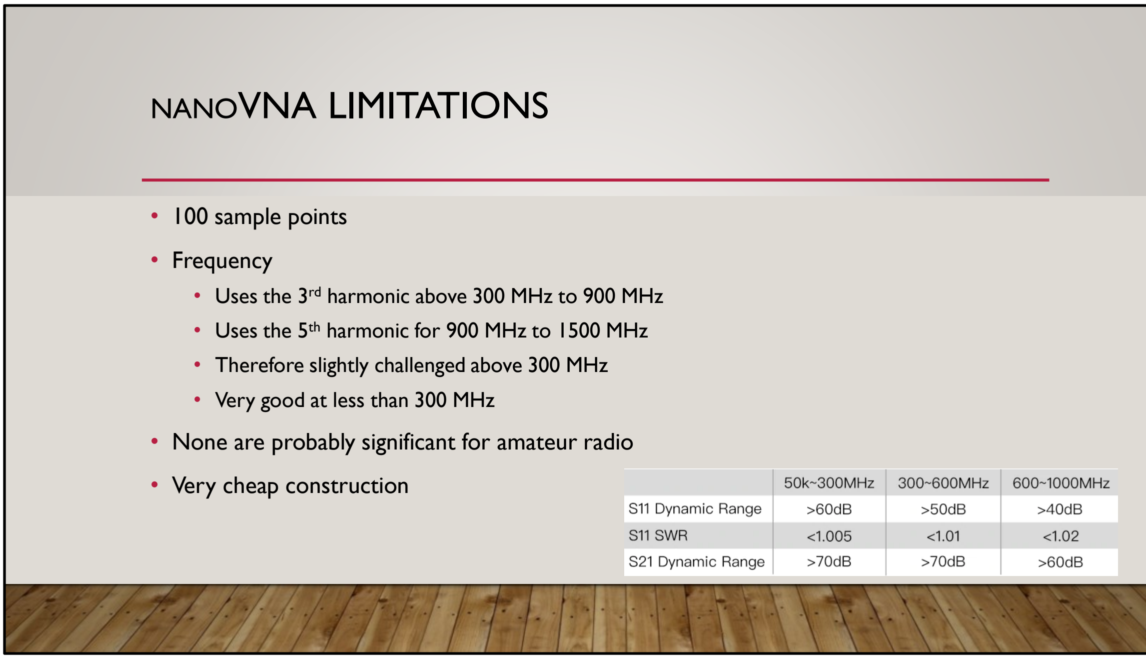
CUT COAX TO FIT

- Added 1.30 meters length to the existing antenna transmission line.
- Added 3.312 meters of RG-213 coax shunting the antenna input.





As noted earlier, there are always more than one way to skin a cat. We learned in last month's meeting that there are a variety of ways to cut up coax to achieve many varied results. Here we added 1.3 meters of length to the existing coax which lifted the vector impedance point inductive but in the correct direction so as to intercept a conduction line which leads to home. We were then able to add an open stub which acts as an inductor being able to cut it to a required length so as to achieve the called for inductance. That was pretty easy, I think.



So I think we have already seen some limitations of the nanoVNA. The most important one by far is its limitation of having only 100 sample points. This is an inconvenience type of limitation but need not be an accomplishment limitation. This is critical to understand because it affects optimal ways to use the device. Prime most among these optimal practices is calibration. Pretty much every time you turn around you need to calibrate the device. But more specifically, you need to calibrate it any time you change the frequency spread that it is operating with.

Another limitation that is little talked about is its use of harmonics to achieve measurements at high frequencies. A RigExpert antenna analyzer doing 900 MHz might cost upwards of $800 but be advised that above 300 MHz the nanoVNA starts seeing some accuracy limitations.

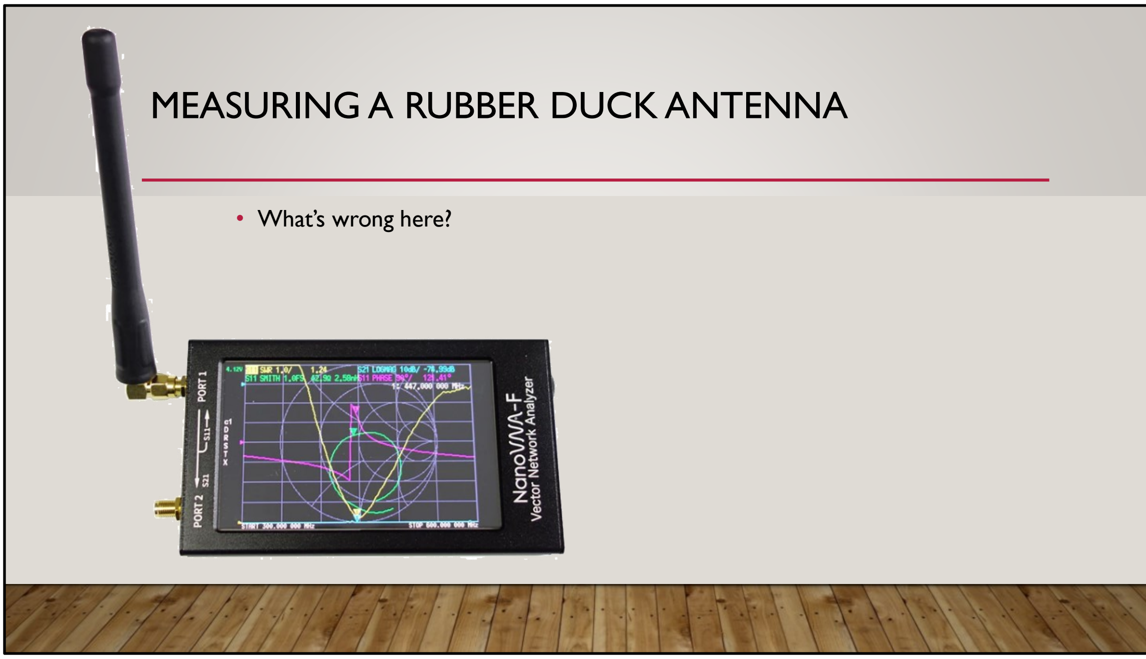
COMPUTER INTERFACE

- nanoVNASaver
  - Developed by Rune B. Broberg
  - Multiplatform tool
  - Save Touchstone files from the nanoVNA
  - Sweep frequency spans with more than 101 sample points
  - Display results on computer display

I have not used it but nanoSaver seems to be popular and effective to interface the nanoVNA with a computer.

WHERE TO BUY

- Caution
  - Many knockoffs available
  - There are fakes
  - By nature cheaply made but some are far lower quality than most
- Avoid large scale generic operations such as Amazon
- Patronize
  - GigaParts GigaParts.com
  - R & L Electronics RandL.com
  - AliExpress (AliExpress.com)



Talk to me folks.

This will not work because there is no counterpoise. HT manufacturers rely on the HT itself to provide a counterpoise for the rubber duck. Plugging in a rubber duck to the nanoVNA neglects the counterpoise and will always by definition give an erroneous reading.

QUESTIONS

- DISCLAIMER: I don't know noth'n about no amateur radio, no how.
- Wesley Cardone
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