

Instant Tuning for a Manual Tuner

Constance Stillinger, W6EFI and Robert Melville, WB3EFT

October 2024

Starting point

- Compact kit
- Keep in car for nice days
- Random wire (41'), throw into trees
- Requires a tuner



Manual Tuner (Matchbox)



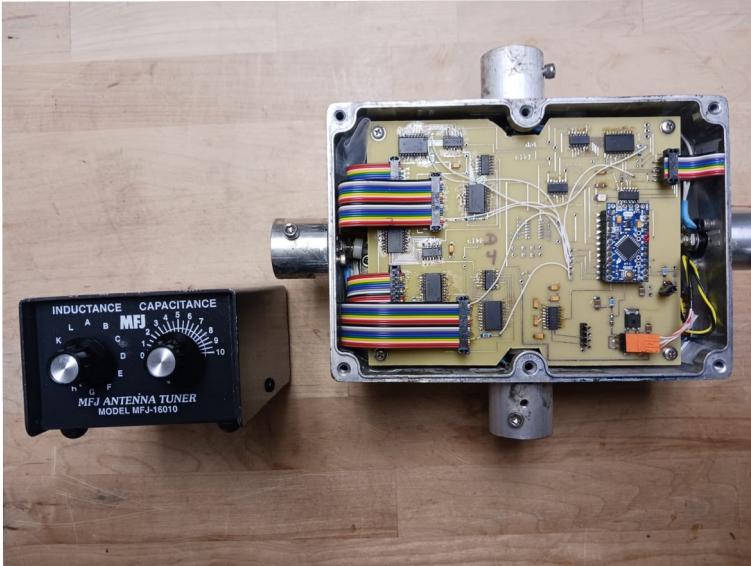
- L network
- Matchbox



Problem & Inspiration: Silent Tuning

- Auto Tuners
 - Transmit
 - Measure SWR
 - Iterate
 - Need power, noisy, heavy-ish, need license
- Manual tuners
 - Set, transmit, measure SWR, adjusting, re-measuring SWR ...
 - iterate until $\text{SWR} < 3$ or bored.
 - Or do it by ear and live with an approximate result

Another Way: Silent Tuning



(Melville & Hamilton)

Measurements of tuner

+ Scattering parameters of antenna

+ Math

= Lookup table of settings for each frequency

Relays and servos

Random wire + matchbox

- Adapt for a manual tuner?
- Useful or practical?
 - non-licensed listeners
 - Considerate use, even on frequency
 - Fewer iterations in the field
 - Shack verification of antenna health
- Curiosity -- “I want to bounce my signals off the aurora borealis” “will my downspouts antenna”

Procedure

- 1 Characterize the matchbox once, on the bench
- 2 Sweep the antenna – once in the field
- 3 Run program with inputs
 - Matchbox file
 - Antenna sweep file (touchstone)
 - Frequency of interest
- 4 Output is settings (inductor, capacitor, connection)
- 5 Set and operate

1. Characterize Tuner



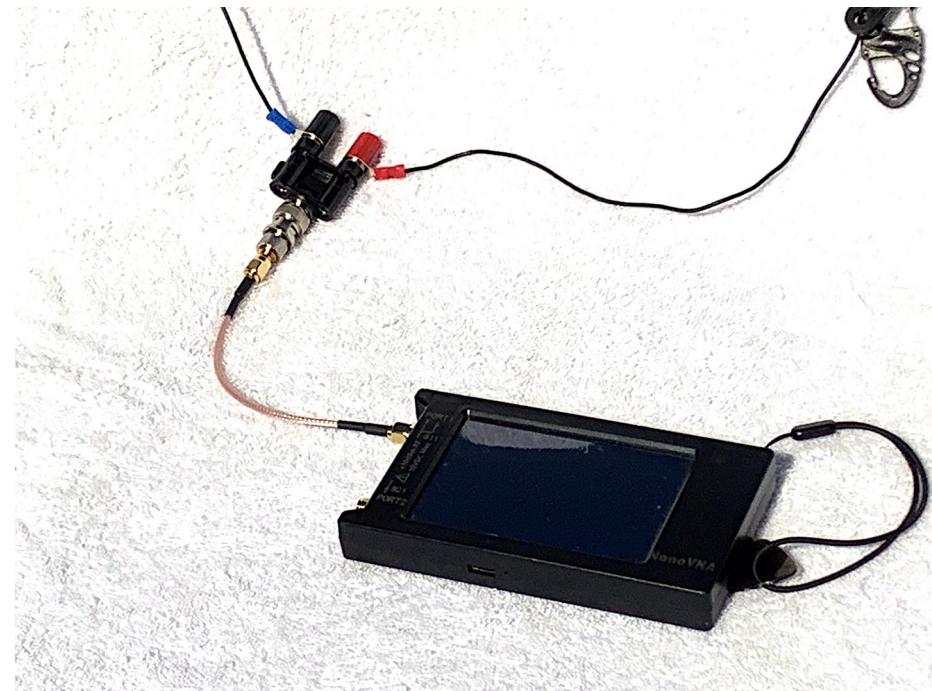
Characterizing MatchBox with benchtop VNA.

For each combination of knob settings, S11 & S12 are written to a file on the laptop.

Tedious, but only needs to be done once.

2. Measure the antenna

- Note -- **Not** measuring SWR
- Collecting scattering parameter S11 across operating range
 - Nanovna (cheap) or RigExpert (\$\$ but more portable) etc
 - Save S1P (touchstone file)
- Note – **use a longer jumper**

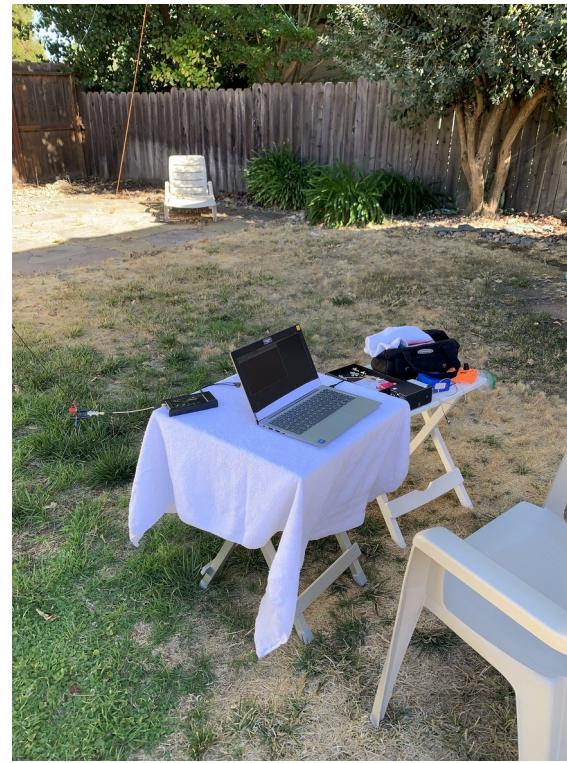


Wire Antenna

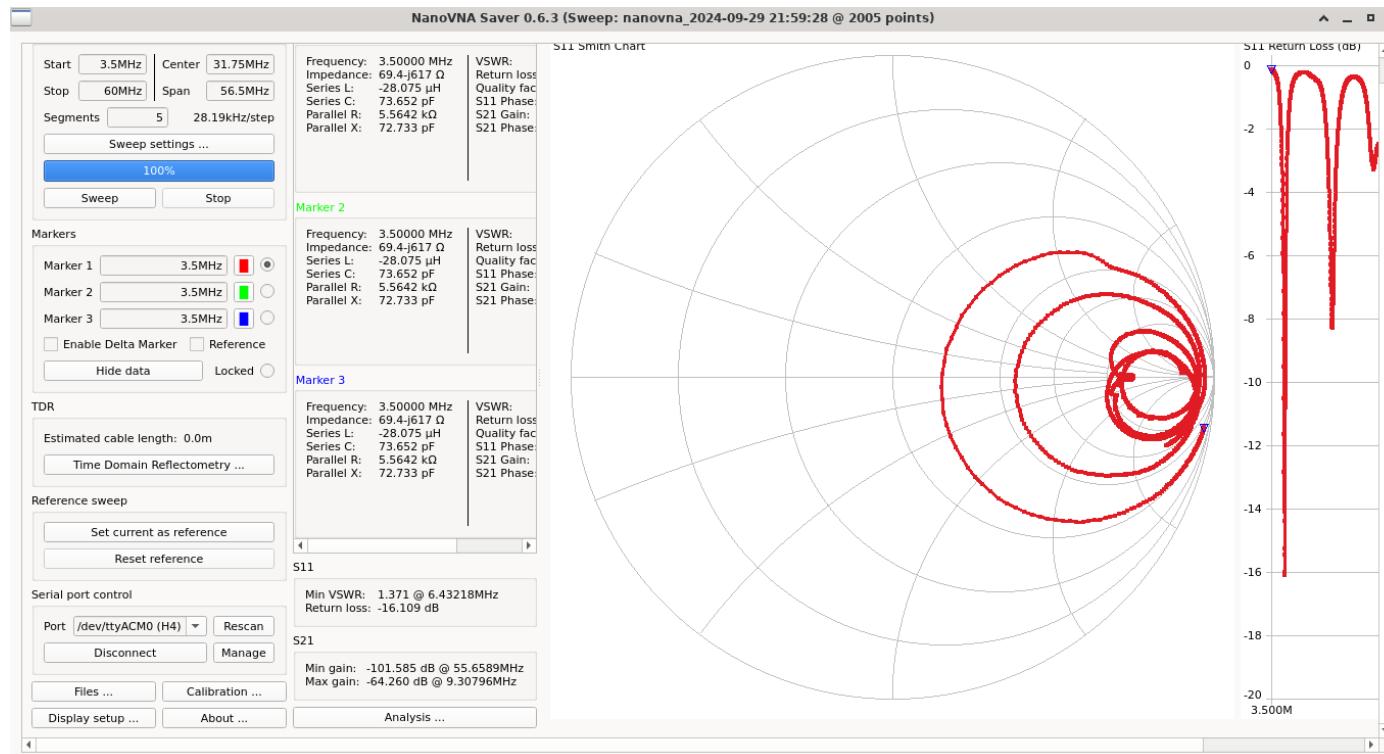


- 41 foot (12.5 m) “random” (nonresonant) wire with counterpoise
- BNC to binding post / banana plug adaptor
- Arborist’s bag and line for getting end up in a tree

Field Station



Sweeping the antenna



Files

- Tuner model file - ONCE
- Antenna sweep file

```
W6EFI QRZ? head matchbox_fullsweep
#00 0.00
-1.668930e-04 -1.217937e-02
-7.677078e-05 -1.293850e-02
-1.177788e-04 -1.350069e-02
-1.630783e-04 -1.414919e-02
-2.527237e-04 -1.474953e-02
-2.560616e-04 -1.530743e-02
-3.376007e-04 -1.588726e-02
-4.663467e-04 -1.651096e-02
-5.102158e-04 -1.709843e-02
W6EFI QRZ?
```

```
W6EFI QRZ? head antenna-sweep.s1p
# HZ S RI R 50
3500000 0.968524288 -0.16958
3528194 0.968009984 -0.171774128
3556388 0.967150592 -0.17366896
3584582 0.966259072 -0.175629824
3612776 0.965635776 -0.178835568
3640970 0.965098112 -0.1806528
3669164 0.96412768 -0.183494512
3697358 0.962757184 -0.185992
3725552 0.962109056 -0.188524432
W6EFI QRZ?
```

3. Run the program

```
#compile once
```

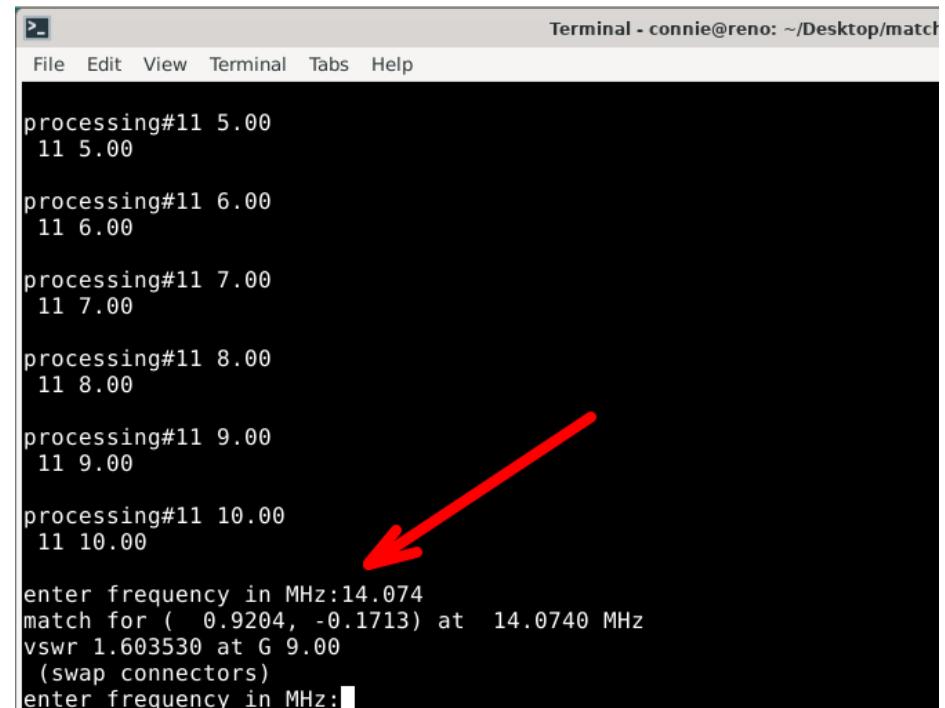
```
gcc -o qsy qsy.c -lm
```

```
#run in the field-- interactive
```

```
./qsy matchbox_fullsweep antenna.s1p
```

```
# Enter 14.074 MHz
```

→ **Set to G 9**



```
Terminal - connie@reno: ~/Desktop/match
File Edit View Terminal Tabs Help
processing#11 5.00
11 5.00

processing#11 6.00
11 6.00

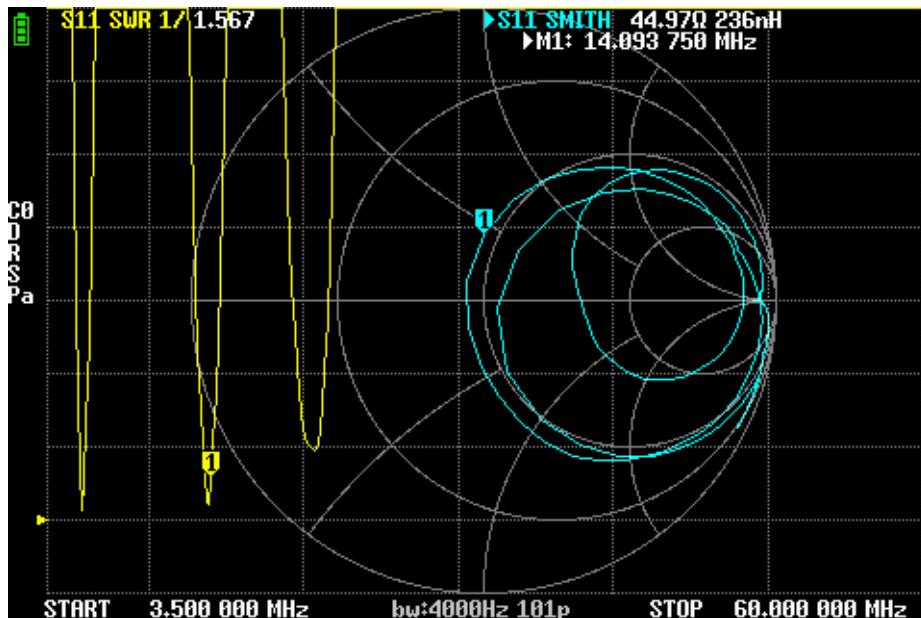
processing#11 7.00
11 7.00

processing#11 8.00
11 8.00

processing#11 9.00
11 9.00

processing#11 10.00
11 10.00
enter frequency in MHz:14.074
match for ( 0.9204, -0.1713) at 14.0740 MHz
vswr 1.603530 at G 9.00
(swap connectors)
enter frequency in MHz:
```

It works



#run in the field-- interactive
./qsy matchbox_fullsweep antenna.s1p

Enter 14.074 MHz

→ **Set to G 9**

SWR ≈ 1.5

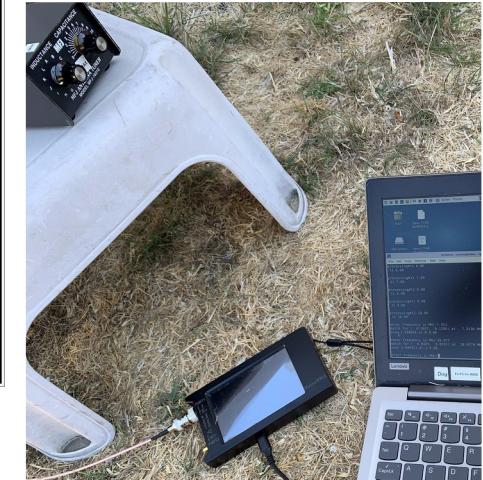
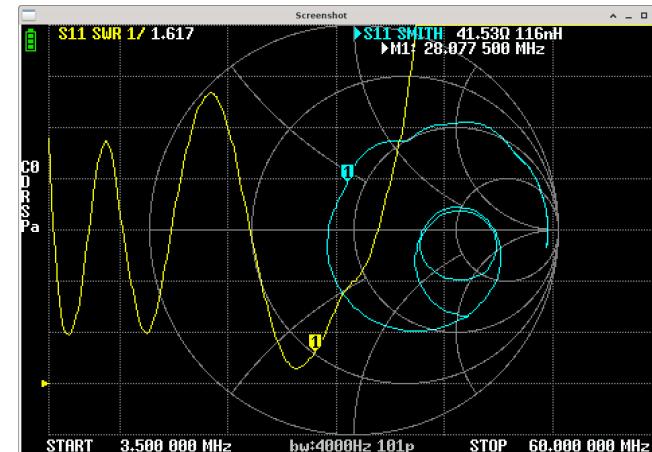
(Nanovna only 401 pts. 14.093 closest)

Great for a “random wire”

Another antenna – my downspout



```
enter frequency in MHz:28.077  
match for ( 0.8420, 0.0531) at 28.0770 MHz  
vswr 2.046411 at J 9.00
```



- 28.077 MHz
- Before: SWR = 10
- After: SWR = 1.6

Incidental lessons learned along the way

(move this to speaker notes)

- Learned that we wanted more capacitance
 - Added a capacitor with a switch.
 - Recharacterized, adjusted search
- Need good connections, reliable connectors and jumpers
- ***Jumper from NanoVNA to antenna feed point needs to be at least several feet long.*** Antenna measurements for ANY antenna are unreliable when you are standing right at the feed point
- Can be twitchy depending on how solid your mechanical connections are

Parting comments – why even?

- tuning by ear is time-honored tradition.
 - But, it depends on your ear
 - can get you stuck in local minima which we avoid.
 - Tuning by ear can be tedious.
- In the field, being able to start with settings that are close and then just do a minor tweak is a big win
- Not having to transmit is a win
- Less wear
- No need for ATU power or weight
- Because we're hams, we like to tinker

Things to do next

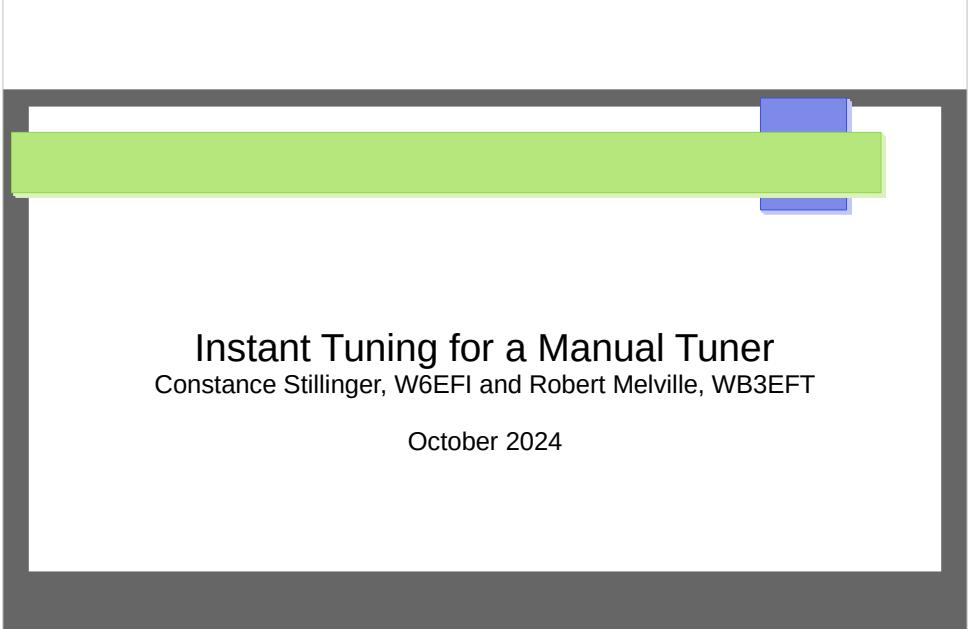
- Nomogram or booklet? Ie, no compute in the field?
- Ideal wire length for a given tuner – modelling, or measuring
- Put everything in a single box: autotuner that incorporates a VNA/measure S11 plus small compute. Or modular kit.
- Put all the compute on your phone – phone will run c or python.
 - Connect phone to VNA, VNA to antenna
 - Run program, set tuner, win contests!
-

Resources

- Matchbox sweep files
- Code

References

- R. Melville and S. Hamilton, "Silent Tuning: Matching a transmitter to an antenna without emitting a signal," MILCOM 2021 - 2021 IEEE Military Communications Conference (MILCOM), San Diego, CA, USA, 2021, pp. 808-812, doi: 10.1109/MILCOM52596.2021.9653009.
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- Have a compact kit, ATU a little big and heavy, needs power, cheap ones are wonky. Small manual preferred but tuning is a little tedious.
- Small autotuners exist
- Curiosity-- is there a different way to do it?

Manual Tuner (Matchbox)



- L network
- Matchbox



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 - Or do it by ear and live with an approximate result

- Auto Tuners typically work by transmitting, directly measuring SWR and searching.
 - Requires transmitting
 - Requires a powered tuner with relays etc
- Manual tuners work by setting, measuring SWR, adjusting, re-measuring SWR ... iterate until $\text{SWR} < 3$ or bored. Or do it by ear and live with an approximate result.
- Melville and Hamilton took a different approach
 - Characterize the tuner and antenna
 - Calculate result
 - Remotely adjust tuner head with servos and relays

Another Way: Silent Tuning



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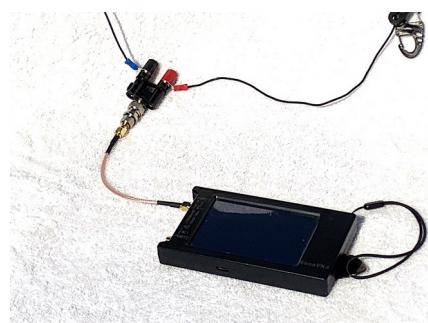
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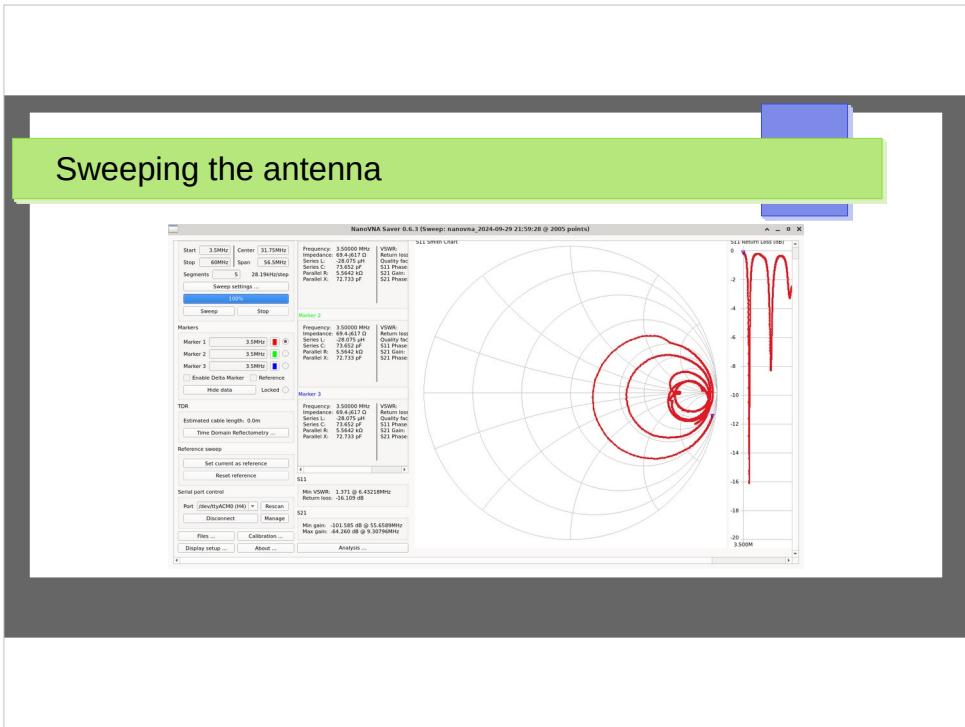
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Field Station





- NanoVNA Saver
- Click on “Files” and “save 1-port file” S1P file
- Touchstone file

Files

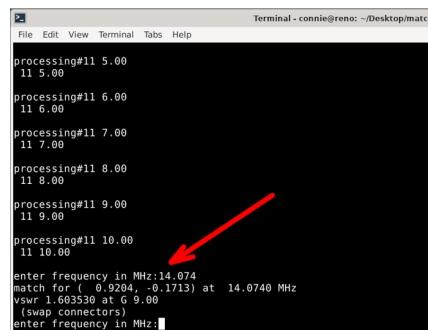
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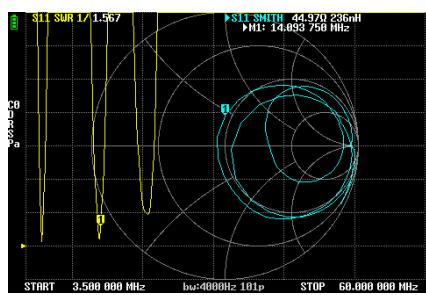


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Side note: my downspout and gutters are around 1.5:1 on the 20m band so not a good demo here. But it's a good problem to have! I have worked the middle of the country on phone on this downspout with 10 Watts on 20m and no tuner

Lessons learned:

MUST take antenna measurements with at least several feet of jumper. DO NOT be right next to the antenna when you measure it. This goes for ALL antennas. Standing near it with your VNA guarantees messed-up measurements

Re NanoVNA + freeware on computer: great little instrument, but you do get what you pay for. Setup occasionally locks up when alternating screenshots and measurements

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