

# Instant Tuning for a Manual Tuner

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# Starting point

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



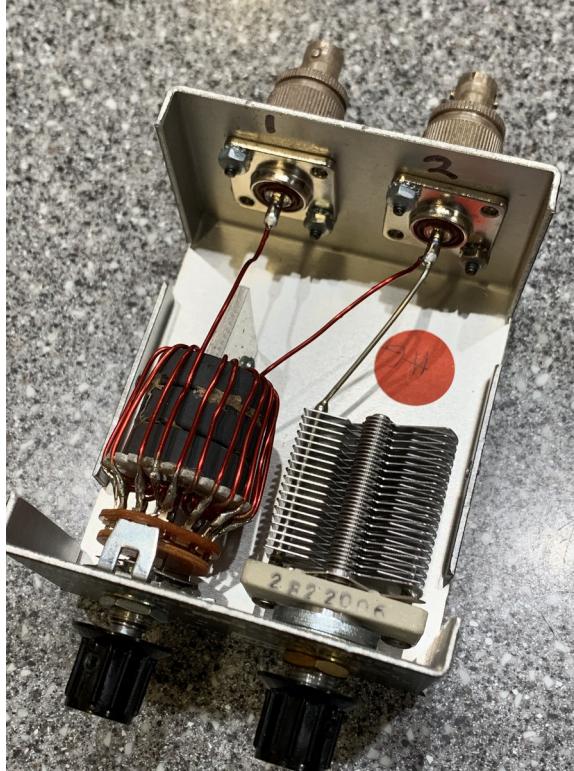
# Manual Tuner (Matchbox)



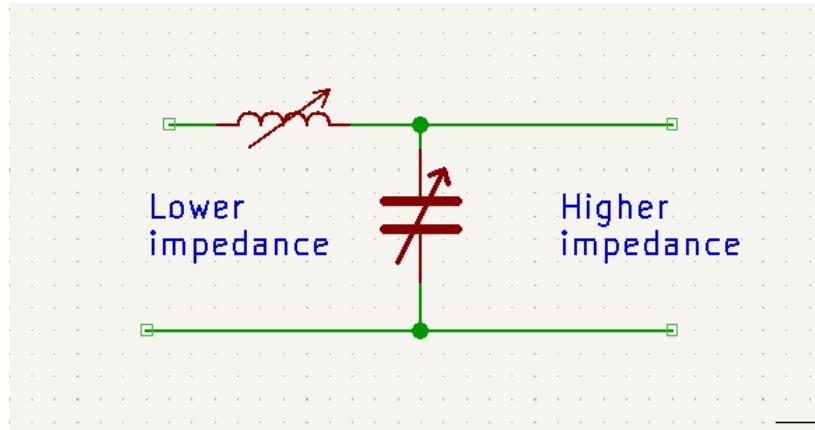
- L network
- Matchbox



# Matchbox guts and schematic



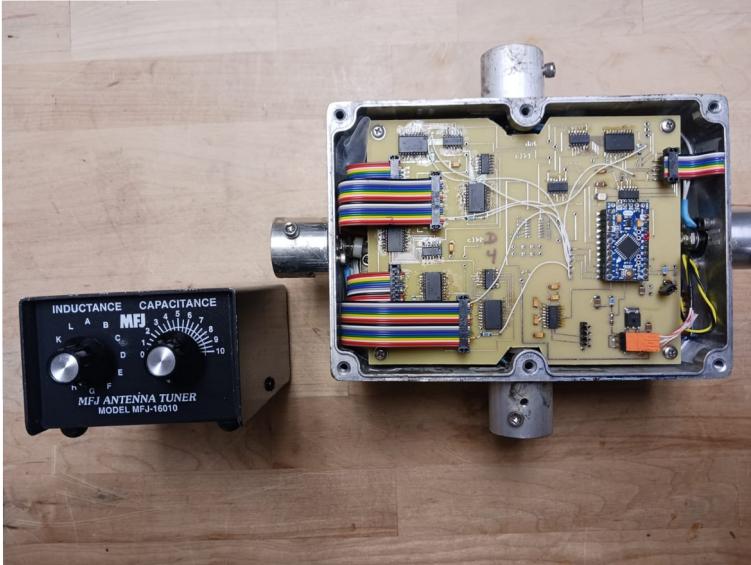
L Network



# The Usual Tuning Process

- 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
- Auto Tuners -- typically
  - Transmit, measure SWR, adjust, iterate
  - Need power, noisy, heavy-ish, need license
  - Hot-switching relays (wear)
- Is there another way?

# Another Way: Silent Tuning



(Melville & Hamilton)

- Parameters of tuner, on bench
- + sweep of deployed antenna
- + Math
- = Lookup table of settings  
for each frequency

*Relays and servos*

## Random wire + matchbox

- Adapt for a manual tuner?
- Useful or practical? lol
  - non-licensed listeners
  - Considerate use, even on frequency
  - Fewer iterations in the field
  - Simpler, lighter, no power to tuner needed
  - Shack verification of antenna health
- Curiosity. --  
“I want to bounce my signals off the aurora borealis”   “will my downspouts antenna?”

## Procedure – high level

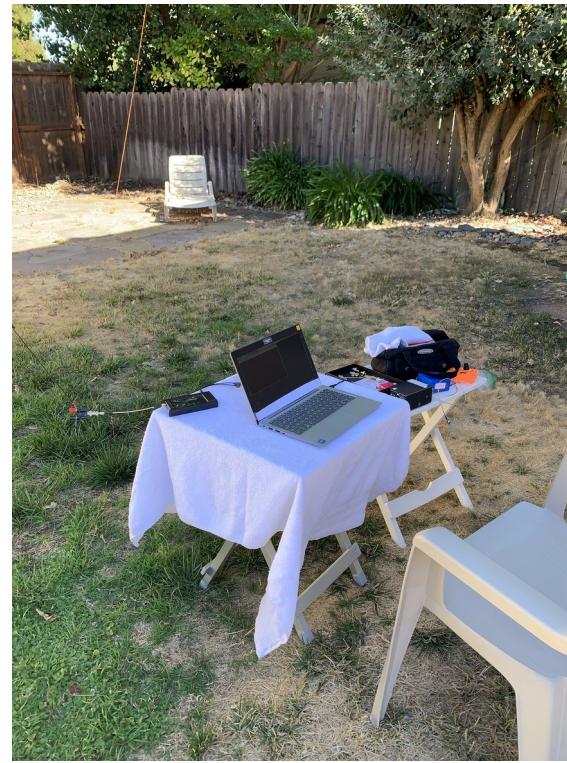
- 1 Freq sweep the matchbox for all settings combos. Do once
- 2 Sweep the antenna by itself – once in the field
- 3 Run program with inputs
  - Matchbox “personality” file
  - Antenna sweep file
  - Frequency of interest
- 4 Output is settings (inductor, capacitor, connection)
- 5 Set and operate

# Example: Random Wire Antenna (with counterpoise)



- 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



# 1. Characterize Tuner “Personality”



Characterizing MatchBox with  
benchtop VNA.

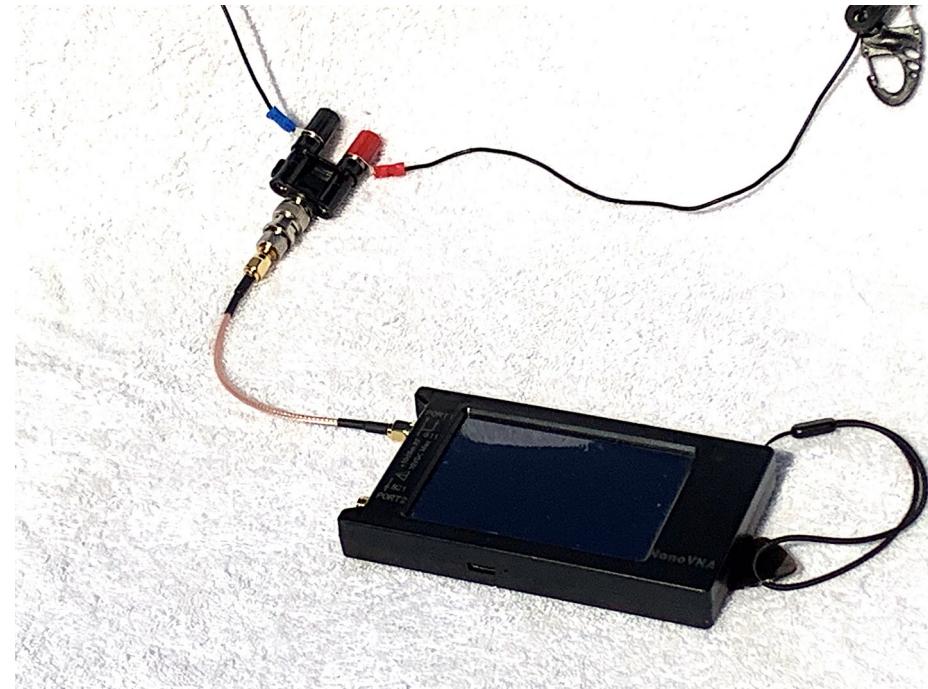
For each combination of knob settings, sweep from 8kHz to 32MHz.  $S_{11}$  (with  $50\Omega$  term),  $S_{22}$  (with  $50\Omega$  term), and  $S_{12}=S_{21}$ , are written to a file on the laptop.

Tedious, but only needs to be done once.

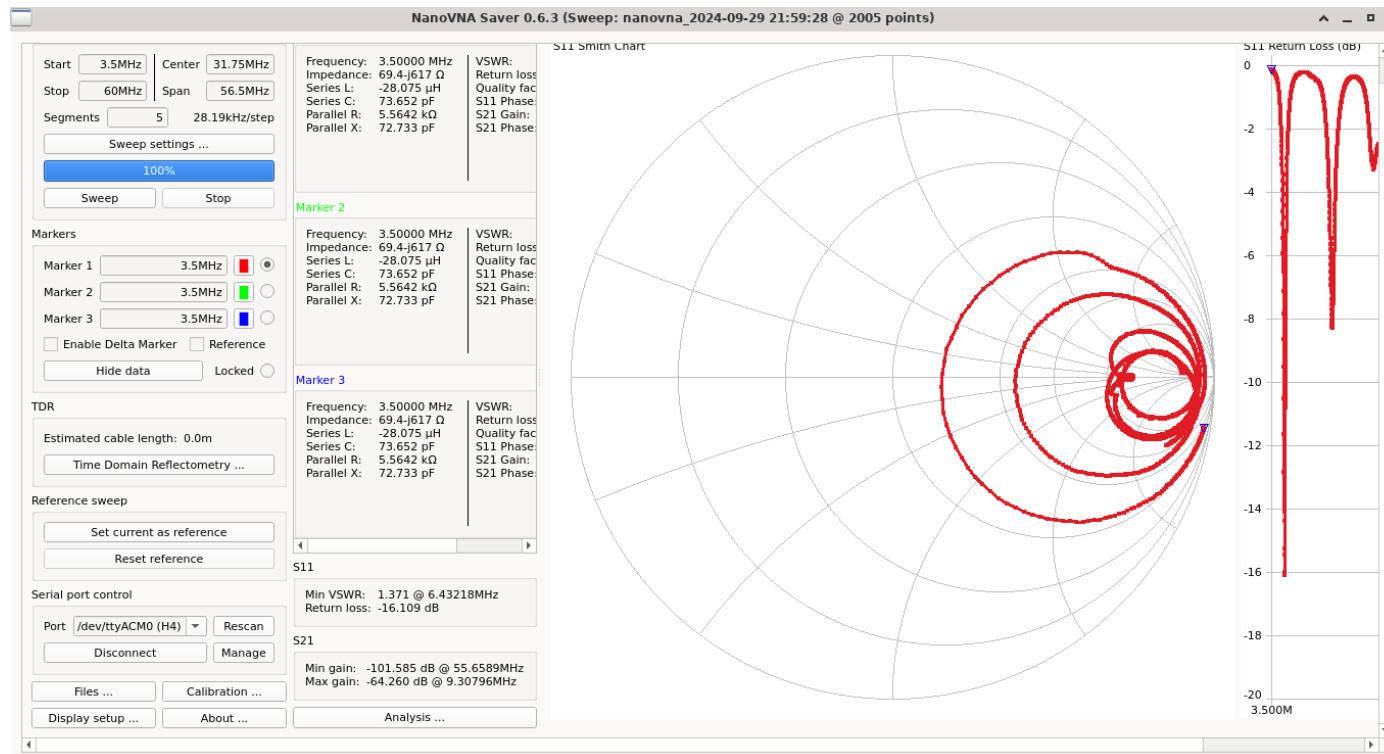
Thanks to Paul AA6PZ for reminding us that for an L-network,  $S_{12}=S_{21}$ , saving time!

## 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 file (touchstone file)
- Note – **use a longer jumper!**



# Sweeping the antenna



# Files

- Tuner personality 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 at the prompt

→ **Set to G 9**

(Program simply calculates all SWRs,  
then does a search)



```
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

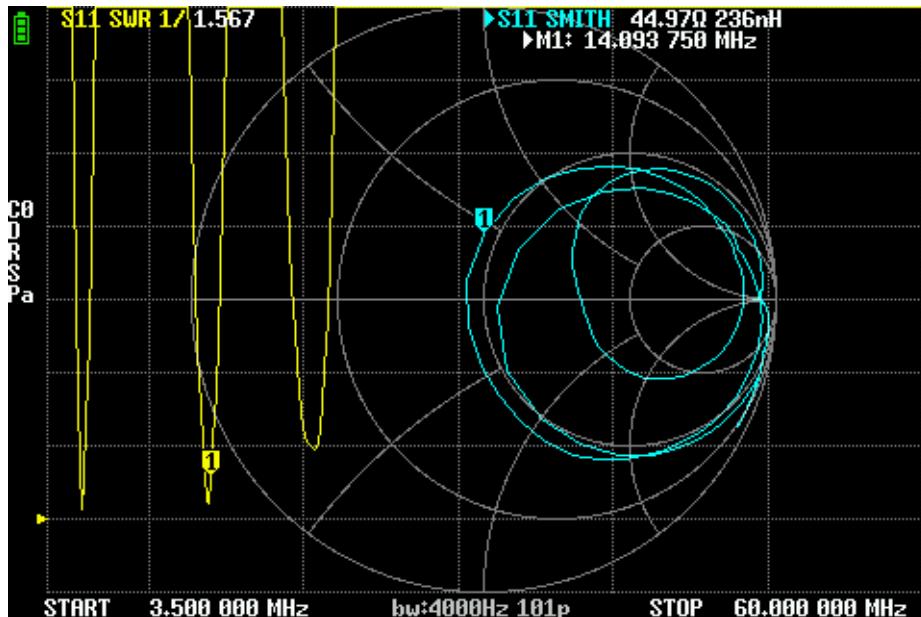
processing#11 8.00
11 8.00

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**

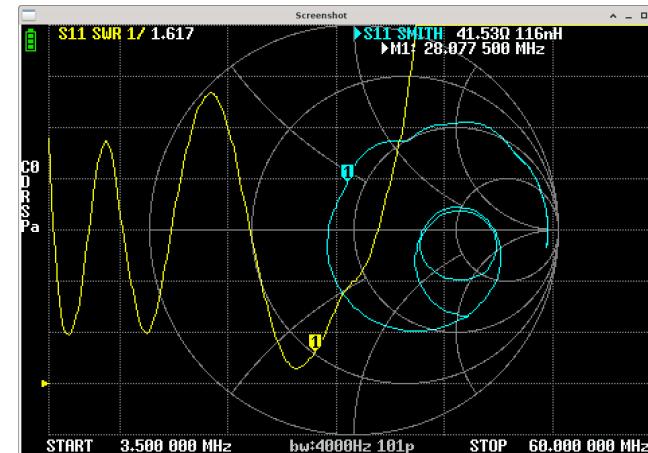
(Nanovna only 401 pts. 14.093 closest)

Great for a “random wire”

# Another antenna – my downspout on 10m band



```
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 (random settings)
- After: SWR = 1.6

## Incidental lessons learned along the way

- 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
- L tuners are simple, one-solution, but narrow bandwidth, adds twitchiness

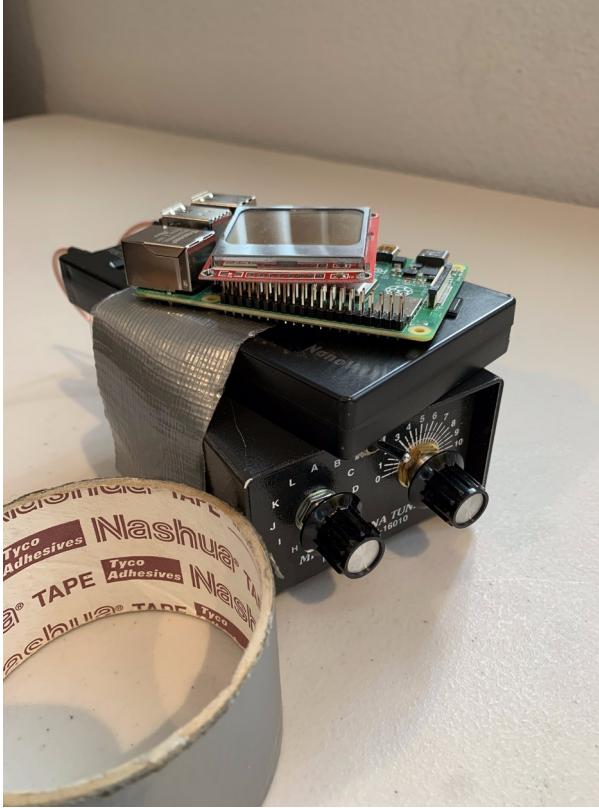
## Things to do next

- **Nomogram** or booklet? Ie, no compute in the field? (cf aviation)
- 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!
- Create tuner personality file from component values
- Other tuners – eg Z-match – Aaron **AK6IM** is trying this

# 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.
- Don't have to transmit.
- Less wear.
- No need for ATU power or weight.
- Don't have the problem of your body interfering with tuner or antenna while adjusting it
- *Make big \$\$ selling ham products!* lol jk (next slide...)

# Commercial product concept



Matchbox + nanovna + rpi  
+ little display  
+ **DUCT TAPE**  
  
= prototype

Why even...? ...Ultimately:

Because we're hams, and we like to tinker! -- that's one of the reasons the amateur bands even exist

Thanks and have fun!

GE es 73 de W6EFI

## Appendix 1: L-Match Tuner

- Capacitor and inductor, one in series and one in parallel with antenna
- Which way depends on whether the antenna R is high or low.
- That's why you sometimes reverse the connections.
- In theory should always be able to get a match (limited by cpt values)
- Orientation determines hi-pass or lo-pass

## Format of the matchbox “personality” file

- S11, S12, S21, S22 values over freq range of interest
- Each combination of settings is preceded by its own # format header
- Each line corresponds to a frequency -- 801 of them in Hz: 800kHz to 32MHz inclusive
- The first 801 lines are S11 for that set of frequencies
- The next 801 lines are S21 for the same set of frequencies
- The third set are S12 ... (Note: S12 = S21 so this is redundant)
- The fourth set are S22 ...

## Appendix 3: qsy.c algorithm summary

- Read matchbox “personality” file (S11, S12, S21, S22 for freq range)
- Read antenna sweep file (S11 for freq range)
- Read input frequency
- Do some interpolation for frequency
- Iterate over all combinations of L & C settings and antenna connected to each port
- Calculate resultant input reflection coefficient and SWR, save them all in a table
- Search table for lowest SWR
- Print those settings, may include direction to reverse the ports

# Appendix 4: Calculation notes

Reflection coefficient  $\Gamma$

$$\Gamma = \frac{V_r}{V_f}.$$

or

$$\Gamma = \frac{Z_L - Z_o}{Z_L + Z_o}$$

$$SWR = \frac{|V_{\max}|}{|V_{\min}|} = \frac{1 + |\Gamma|}{1 - |\Gamma|}$$

$$|\Gamma| = \frac{SWR - 1}{SWR + 1}$$

$Z_L$ : load impedance

$Z_0$ : characteristic impedance of feedline

$V_r$ : reflected voltage

$V_f$ : forward voltage



At the input port, the VSWR ( $s_{in}$ ) is given by

$$s_{in} = \frac{1 + |S_{11}|}{1 - |S_{11}|}$$

At the output port, the VSWR ( $s_{out}$ ) is given by

$$s_{out} = \frac{1 + |S_{22}|}{1 - |S_{22}|}$$

$S_{11}$  is the input port voltage reflection coefficient

$S_{12}$  is the reverse voltage gain

$S_{21}$  is the forward voltage gain

$S_{22}$  is the output port voltage reflection coefficient.

Now connect a load (antenna) having  $\Gamma_L$  ( $S_{11ant}$ ) to the output port.

Input reflection coefficient with the output termination arbitrary and  $Z_S = Z_0$ .

$$\begin{aligned}s'_{11} &= \frac{b_1}{a_1} = \frac{s_{11}(1 - s_{22}\Gamma_L) + s_{21}s_{12}\Gamma_L}{1 - s_{22}\Gamma_L} \\ &= s_{11} + \frac{s_{21}s_{12}\Gamma_L}{1 - s_{22}\Gamma_L}\end{aligned}$$

SWR looking into the tuner with the antenna attached

$$SWR_{tuner \text{ with ant}} = \frac{1 + |S'_{11}|}{1 - |S'_{11}|}$$

## Appendix 5: $S_{12} = S_{21}$ for L networks

-  $S_{11}$ :

$$S_{11} = \frac{Z_1 - Z_0}{Z_1 + Z_0}$$

-  $S_{22}$ :

$$S_{22} = \frac{Z_2 - Z_0}{Z_2 + Z_0}$$

-  $S_{21} = S_{12}$ :

$$S_{21} = S_{12} = \frac{2Z_0}{Z_1 + Z_2 + 2Z_0} = \frac{2Z_0}{j\omega L + \frac{1}{j\omega C} + 2Z_0}$$

These equations express the S-parameters in terms of the inductance  $L$ , capacitance  $C$ , and the reference impedance  $Z_0$ .

# References

## Silent tuning

- 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.

## Antennas and tuners

- ARRL, *The ARRL Antenna Book* (24<sup>th</sup> ed)
- Krischke, J., DJ0TR, *Rothammel's Antenna Book*

## Scattering parameters, reflection coefficients

- [https://en.wikipedia.org/wiki/Scattering\\_parameters](https://en.wikipedia.org/wiki/Scattering_parameters)
- [https://people.engr.tamu.edu/spalermo/ecen689/sparam\\_agilent\\_tutorial.pdf](https://people.engr.tamu.edu/spalermo/ecen689/sparam_agilent_tutorial.pdf)

# Resources

- Matchbox personality files (for MFJ 16010 manual tuner)
- Code (yet to be posted – contact presenter)
- Latest presentation
- 
- Will be posted to <https://github.com/conniest/InstantTuning>
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# Author Biographies

**Connie Stillinger, PhD., W6EFI** Connie was originally licensed in the 1970's as WN2EFI -- passed the 5 wpm code test -- but it lapsed before even making it into the callbook. About two years ago she rediscovered ham radio as a great way to make friends, hike around parks, and have fun tinkering together. She enjoys operating all modes on HF ranging from CW through Hellschreiber to SSTV.

**Robert Melville, PhD., WB3EFT** Bob worked at AT&T Bell Labs for 17 years in the areas of computer-aided design, numerical simulation of electronic circuits, and design and fabrication of RF integrated circuits. He has taught electrical engineering at Columbia University and served with the United States Antarctic Program at the Amundsen-Scott base at the South Pole doing engineering work in support of geophysics experiments. Bob is a Senior Member of the IEEE, who referees for IEEE-sponsored journals and conferences, and the Society for Industrial and Applied Mathematics. He co-organized a conference on numerical circuit simulation at Sandia National Labs and participated in the AT&T "Teachers and Technology" enrichment program for high-school math and science teachers.