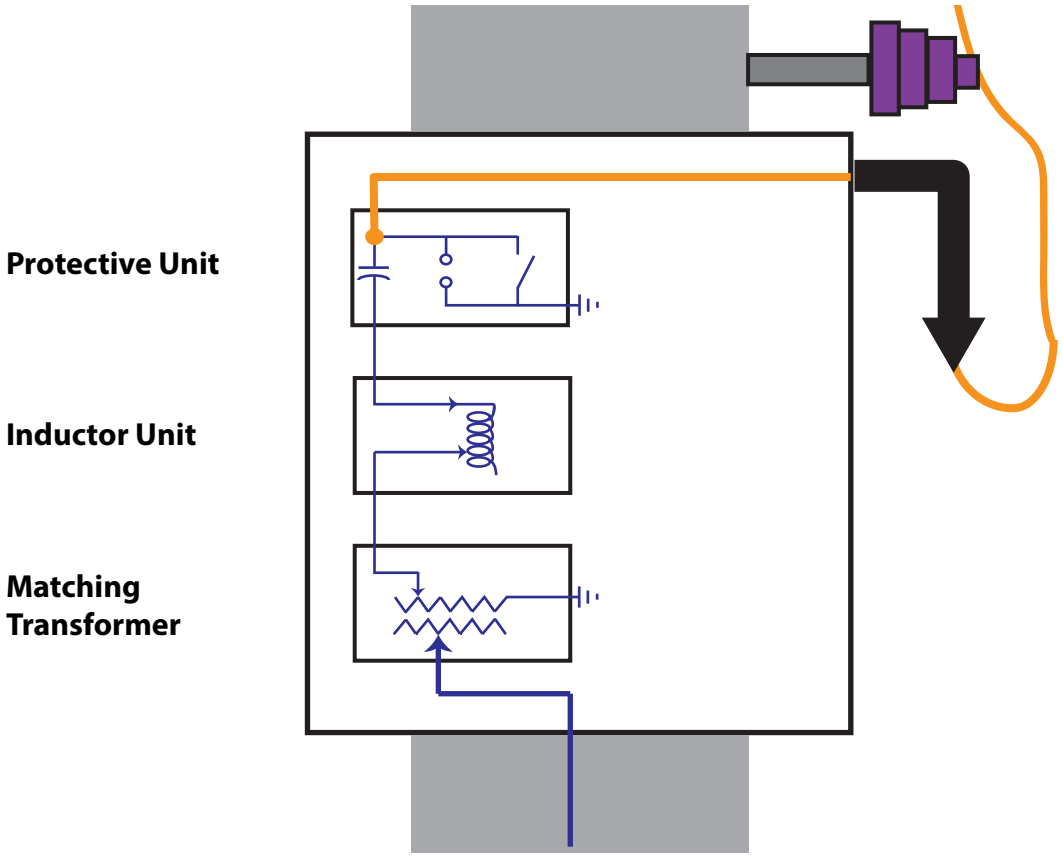
Line Tuner Unit: Single Frequency Tuner

HOW IT WORKS:

A Single Frequency Line Tuner is used to pass a single grouping of frequencies within a given range with a low percent of reflected power. The tuner is made up of three components: the Protective Unit, an Inductor, and a Matching Transformer. Each component comes in multiple flavors. The inductor in the tuner makes a series LC circuit with the CCVT. At resonance the two make a low impedance to our carrier frequency.



In this issue, we will discuss all the components of a single frequency tuner. We will cover the basics of tuning and how it is done. We will learn some of the limitations of the equipment and some design/ordering criteria to watch out for.

Let's reveiw Chapter 30 from the book to see what exactly we are doing when we do tuning.

Line Tuner Unit: Single Frequency Tuner

This is a portion of my book "Power Line Carriers - Simplified".

Chapter 30
Series LC Circuits

A series resonance LC circuit is a band pass filter. The **L** and the **C** are chosen to create a low series impedance at a given frequency, **f**.

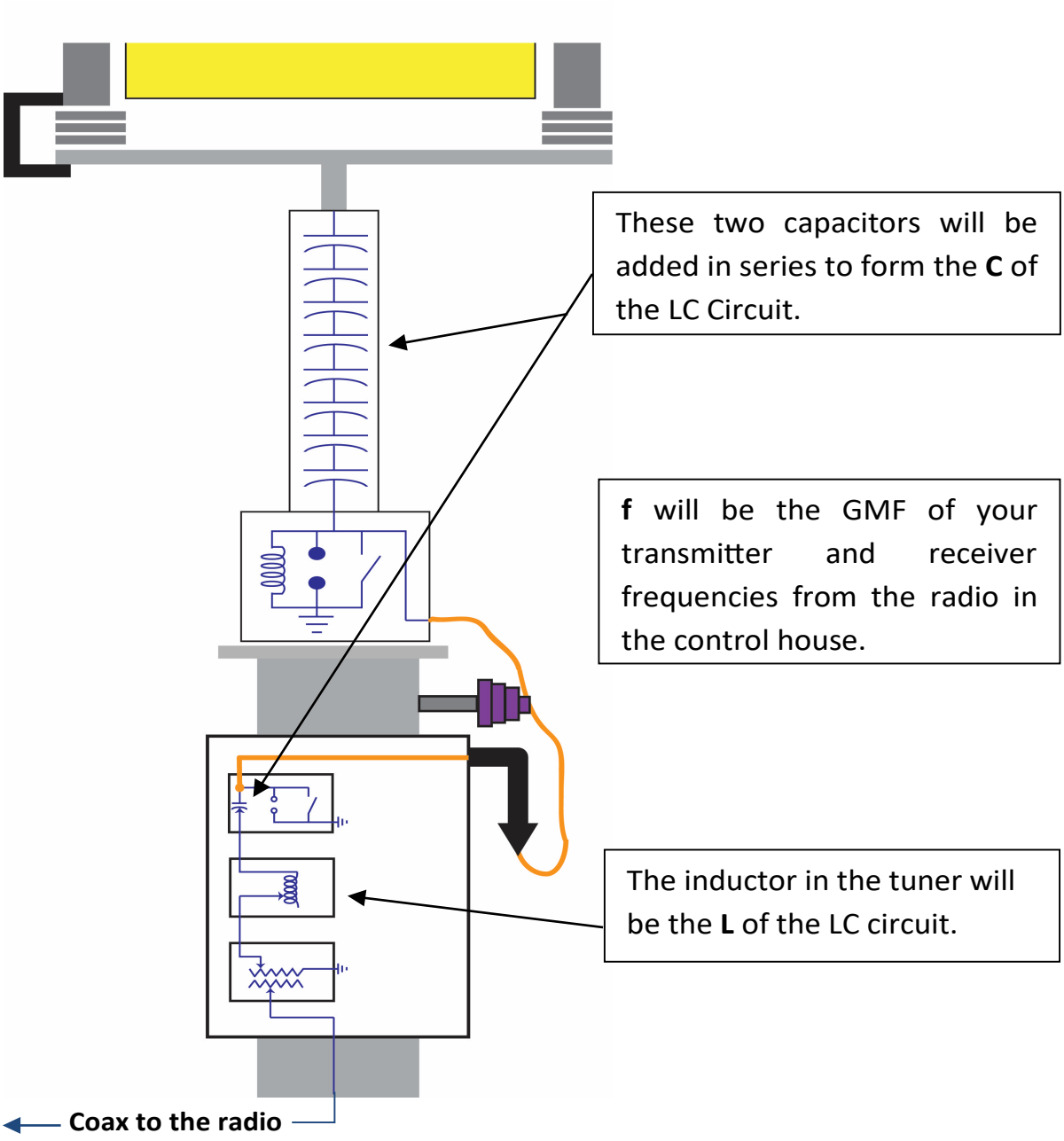
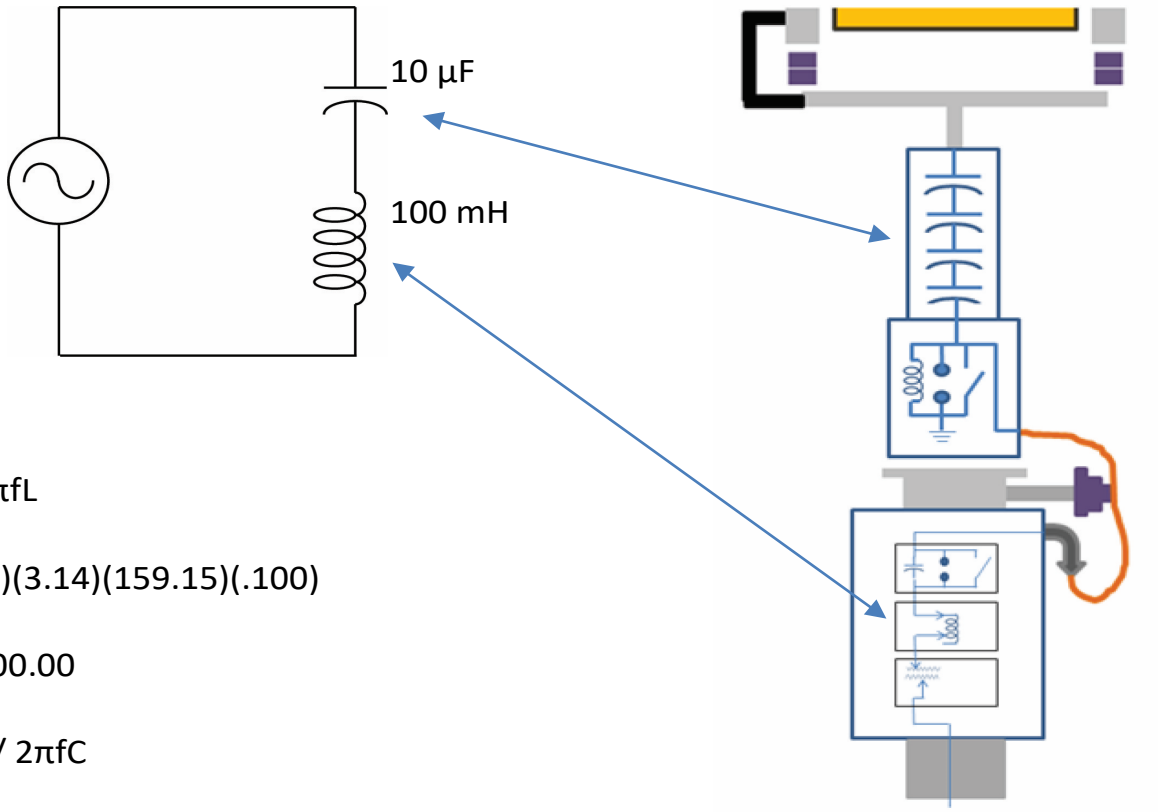


Figure 30.1 – CCVT/Tuner a Series LC Circuit

Line Tuner Unit: Single Frequency Tuner

Series LC: Simple Math Example



$X_L = 2\pi fL$

$X_L = (2)(3.14)(159.15)(.100)$

$X_L = 100.00$

$X_C = 1/ 2\pi fC$

$X_C = 1/ (2)(3.14)(159.15(.000010)$

$X_C = 100.00$

$Z_{series} = Z_L + Z_C$

$Z_L = (0 + jX_L)\ \Omega$ $Z_C = (0 - jX_C)\ \Omega$

$Z_{series} = (0 + j100)\ \Omega + (0 - j100)$

$Z_{series} = 0$

Figure 30.2 –Series LC Circuit Calculations

In real life, zero is not attainable. If the tuner has the correct components ordered to match the CCVT, it will be close. The tuning should get real close to 0%.

Line Tuner Unit: Single Frequency Tuner

Series LC: Real Example

Givens:

L = Tuner Variable Inductor Unit L = ??? H

f = Carrier Center Frequency f = 160 kHz

C = CCVT Value C = 0.006µF

Since C and f is predetermined, L will be the value we calculate.

$X_C = 1/2\pi fC$

$X_C = 1/ (2)(3.14)(160{,}000)(.000000006)$

$X_C = 165.87\ \Omega$

We know $X_L = 2\pi fL$. Solve for L.

$L = X_L/2\pi f$

At resonance $X_C = X_L$.

$X_C = 165.87 = X_L$. Plug 165.87 into X_L

So…

$L = (165.87)/(2)(3.14)(160000)$

$L = 0.165$ mH

In this example, real life values were used. Two givens are supplied.

F = 160 kHz → This is the Geometric Mean Frequency given to us by the application group.

C = .006 µF → This is the Cn of the CCVT obtained from the nameplate of the unit.

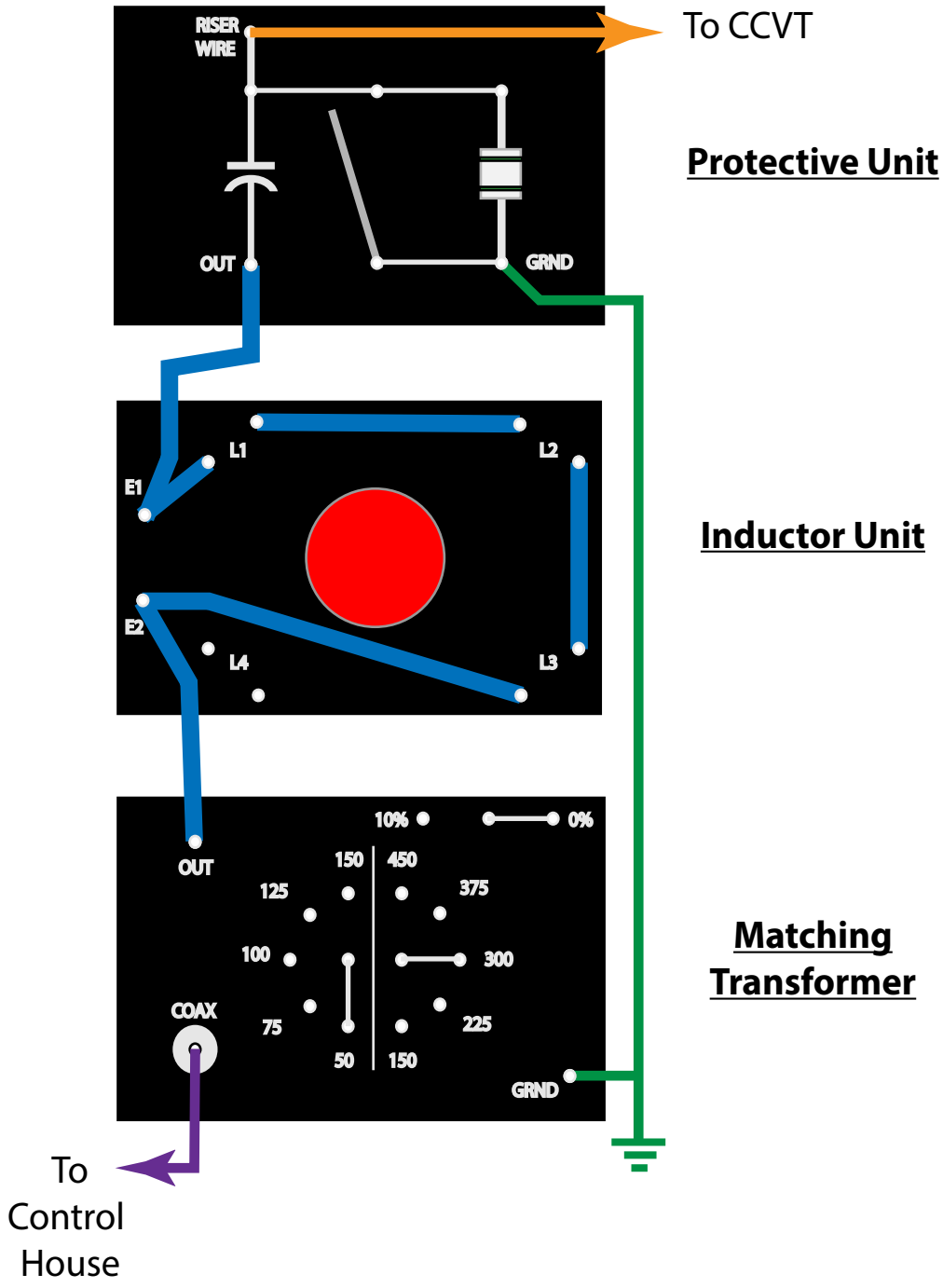
Typically, companies will use the same Cn value for a voltage of line. (0.006 for 230 kV)

With these givens, L is determined to be 0.164 mH.

Note: To keep it simple, I left out the blocking cap located in the protective unit of most tuners. Identify the tuner manual and verify if the blocking cap is present.

Line Tuner Unit: Single Frequency Tuner

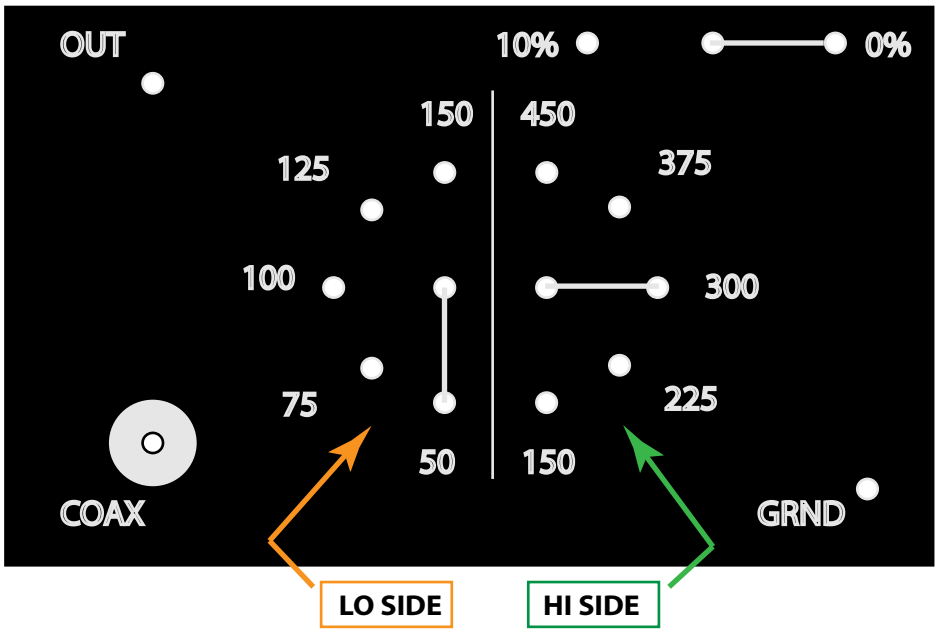
Single Frequency Tuner Overview



This is what any single frequency tuner will look like. The Matching Transformer is the first unit in the tuner and is the place the coax connects. It leaves this unit and goes thru the inductor unit and lastly to a protective unit. From here, it goes to the CCVT.

Line Tuner Unit: Single Frequency Tuner

Matching Transformer



Low Side

The Matching Transformer has a low and high side. The low side is typically on 50 Ohms. The low side ties to the coax that goes to the radio in the control house. The transmitter on the radio is a 50 Ohm transmitter. The receiver will be terminated in the house at 50 Ohms. Therefore, except in rare instances, the low side will always be on 50 Ohms.

High Side

The high side will be set by trial and error. In the end, it will represent the characteristic impedance of the transmission line. In theory, we use 300 Ohms as a typical model for a transmission line. In actuality, the line will be based on many factors.

0% or 10%

This jumper will be either in 0 or 10 position. It allows for some adjustment in the chosen impedance strappings.

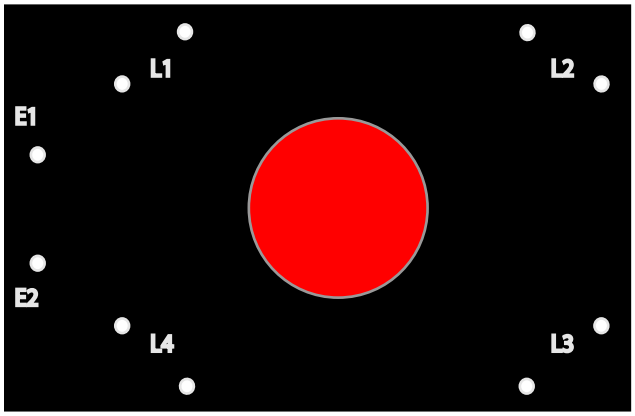
The transmitter carrier signal from the control house enters on the Coax connector. It travels thru the low side of the transformer and out the high side. The signal leaves the OUT terminal and goes to the Inductor unit.

Line Tuner Unit: Single Frequency Tuner

Inductor Unit:

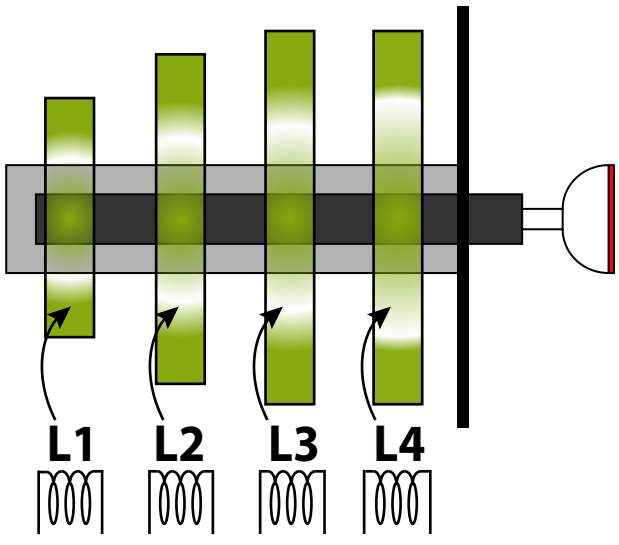
The L of Series LC circuit comes soley from the Inductor Unit. The inductor is made up of a set of series coils. These coils are strappable to give you different inductor values. A slug is then attached to a dial. Rotating the dial moves the slug in and out of the coil. The coil or series of coils are the overall range of the inductor. By inserting or removing the slug into the coil varies the inductor value of the overall range.

Inductor



Top View

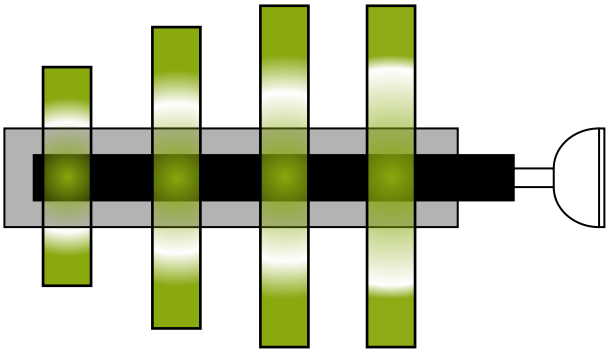
E1 and E2 are the jump off spot to the next components of the tuner. L1, L2, L3 and L4 are the 4 inductor coils. They can be placed in series with each other to create different ranges of inductance. The white dots are actually screw terminals. Each terminal goes to one side of the coil.



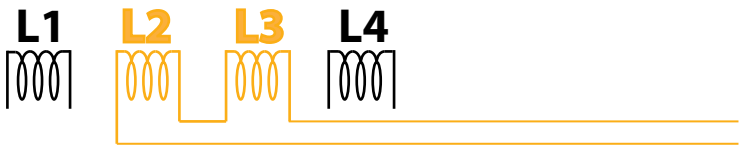
Side View

This is the side view, or more appropriately, what's behind the black board. Their are four individual coils (green). Each coil is brought out to screw terminals on the front of the unit for easy access to each coil.

Line Tuner Unit: Single Frequency Tuner

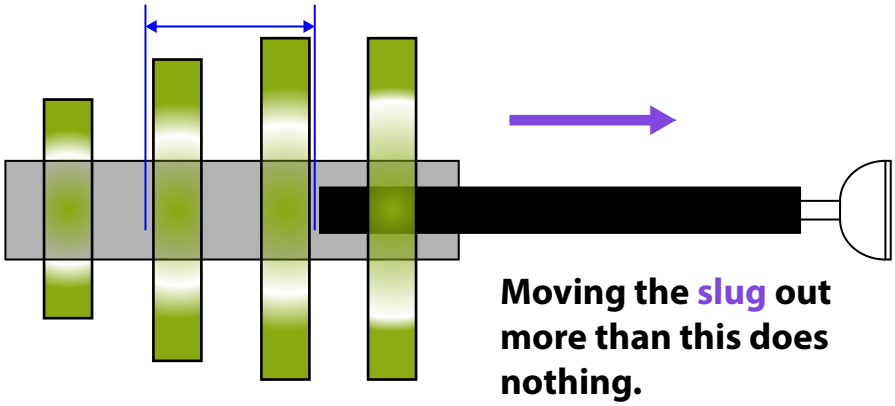


Move the Slug In and Out to tweak the L.



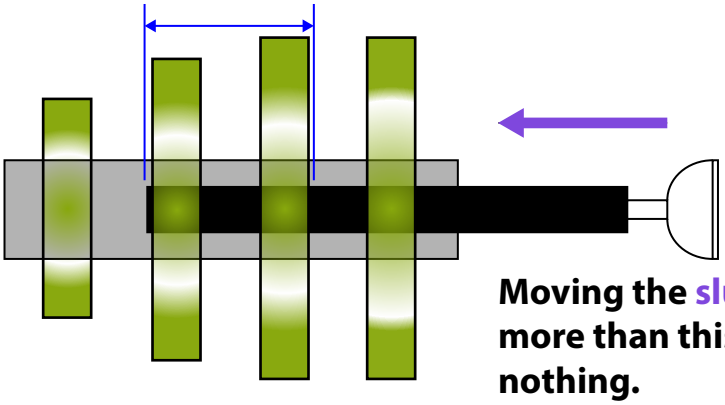
L2 and L3 is used in this wiring setup.

The Blue shows the amount of slug movement that is available for this Strapping.



Moving the slug out more than this does nothing.

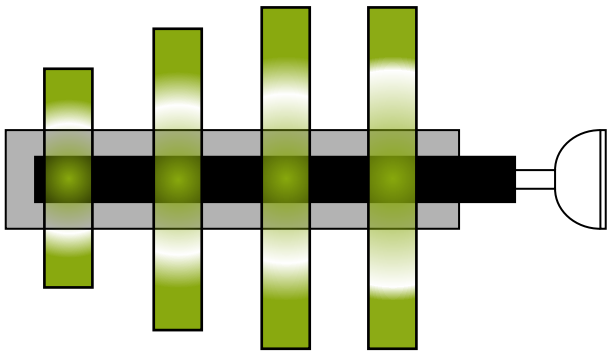
The Blue shows the amount of slug movement that is available for this Strapping.



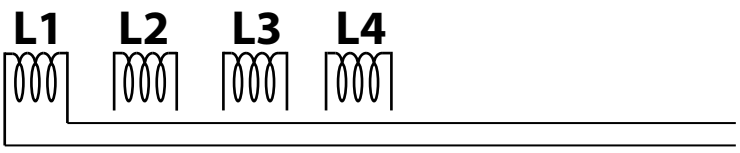
Moving the slug in more than this does nothing.

In this example, the tuner is strapped for L2 and L3 in series. If you need less inductance you could go with L2 only. If you need more inductance you could add either L1 or L4 to the series wiring. Each L1 thru L4 will have unique values based on the model number of the Inductor Unit. Each unit includes a manual that shows you the ranges of different wiring configurations. The wiring is for Coarse adjustments, and adjusting the slug is fine tuning. I typically place the slug in the middle of its movement and adjust the coarse to see which gives you the best SWR.

Line Tuner Unit: Single Frequency Tuner

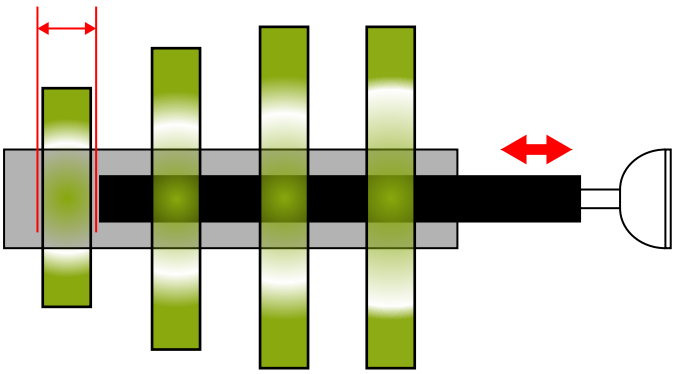


Move the Slug In and Out to tweak the L.



Only L1 is used in this wiring setup.

The Red shows the amount of slug movement that is available for a L1 Strapping. Moving the slug out more than this does nothing.



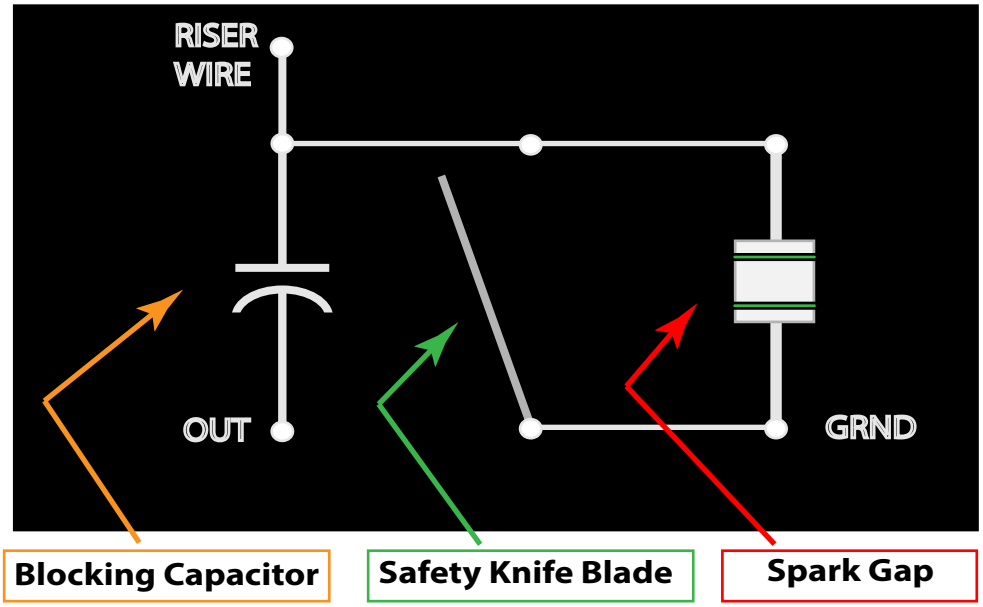
Care needs to be taken when single coils are being used on the inductors. As you can see above, if L1 is the only coil wired, the slug movement for the fine tuning is very minimal and afte the slug leaves the coil you are just moving the slug without effecting the inductance.

When rewiring the unit from say L4 to L2, pay attention to the slug placement on the intital reading. When doing a quick coarse adjusment, I use small jumpers to make quick wiring changes and I always remember to adjust the slug at each location.

If the slug is inside the range of the wired windings, moving the slug one way will increase the SWR and moving the slug the opposite direction will decrease the SWR. Tuning is a trial and error game. One way makes it better and one way makes it worse. If one wiring setup bottoms out with out finding the null point, rewire and try the next wiring range on the list.

Line Tuner Unit: Single Frequency Tuner

Protective Unit



Blocking Capacitor:
Every Protective unit needs a blocking cap. This will help eliminate any 60 Hz noise from entering the tuner. Therefore, the name "blocking" cap.

Safety Knife Blade:
This is used to protect the engineer working on the tuner. It is in the normally open position and is closed when changes are being made to the tuner.

Spark Gap:
This is used to dissipate sudden bursts of noise. This noise could be lightning strikes or switching events. It is to protect the tuner and equipment in the house.

GRND: This is to be tied to the ground field in the station.
OUT: This is the connection to the LC unit located below.
RISER WIRE: This goes to the tie in wire to the CCVT.

Line Tuner Unit: Single Frequency Tuner

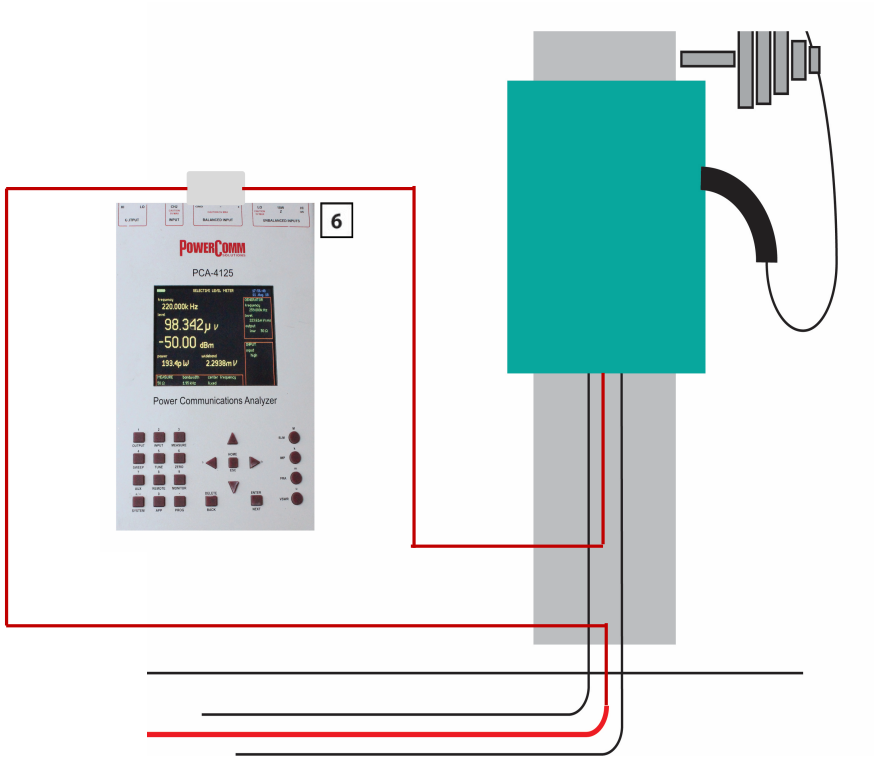


Figure 38.4 – Checking SWR in the yard using Signal from House

To check SWR the test set will be placed in series with the coax and the transmitter in the house will be the source. Most generators are corruptable by noise and other signals on the line. Do not use the source on the test set unless it absolutely necessary.

All company and manufacture safety procautions should be followed before getting into the circuit with the test set.

Line Tuner Unit: Single Frequency Tuner

Tuning a Single Frequency Tuner

Steps should be taken to ensure the scheme is disabled and out of service per your company's guidelines. Anytime you are connecting or disconnecting cables / jumpers on the tuner, the grounding blade on the Protective Unit should be closed. For best results, tuning should be done with the line networked and in service. Remember, tuning at one end of the line can affect the tuning at the remote end. Tune at Station A by the procedure below. Connect everything back normal and then Tune at Station B. Go back and forth in this manner until neither end makes any changes.

1. Disable the Scheme at both ends.
2. Close the Grounding Blade on the Protective Unit as needed.
3. Disable the radio transmitters on both ends of the line as needed.
4. Connect the Power Comm: PCA-4125[6] for tuning at the tuner. Use the connections in Figure 38.4 or 38.5 per your preference.
5. Determine the Geometric Mean Frequency that will be used for the generator or set up to use the radio's transmitter. I prefer to use the radio's transmitters for tuning.
6. Make note of the initial strappings of the Matching Transformer and Inductor Unit.
7. Refer to Figure 38.7. Start turning the dial on the Inductor. One way will make the SWR go up and the other direction will make the SWR go down. Keep turning the knob in the direction that makes the SWR go down until it starts going up again. This is the balance point. The balance point will be where the SWR is the lowest. If the knob will no longer turn in one direction, the bottom or top of the inductance range has been reached. Locate the manufactures instruction manual and find the current strapping in the Inductor section. Try strapping it to a higher or lower range of inductance. Remember, the dial is either topped out or bottomed out at this point. Clockwise is more inductance. Counter Clock-wise is less inductance. If you leave the dial in this position when you re-strap, you will be at the max or min of the new range. Keep turning the dial and re-strapping as needed until the balance point is found.

8. Once the balance point has been found, move down to the Matching Transformer. The first adjustments will be with the high side of the transformer. I usually use a small jumper and move to each position looking for the position with the best SWR. Even the smallest amount of improvement in SWR will be beneficial in the overall tuning. Any tap on the high side of the Matching Transformer is acceptable except at the lowest tap. If you are on the lowest tap go to step 9, else skip to step 10.

Line Tuner Unit: Single Frequency Tuner

9. Use this step if you are on the lowest tap on the high side of the transformer, and you still haven't found the balance point. Adjust the low side of the transformer from 50 to next higher tap. If this improves the SWR, there is probably a Line Trap problem. In this case, the Line Trap is not adjusted correctly and the equipment behind the line trap on the bus is bringing the line impedance down real low. It is okay to leave the tuning at whatever gives you the best reflected power. Refer to the white paper at the end of the book for more on finding bad traps. Proceed to step 10.
10. Once the matching transformer is happy, move back to the Inductor Unit and try Step 7 again. Once the inductor is tested again, tuning should be the best it can be.
11. Have the remote end of the line tune. Check your tuning when they are complete. Go back and forth until both ends are good and no one changes anything.

You should be able to get an SWR around 1% or better. Tuning is an art and can be mastered only thru lots of practice. When tuning on the bench with a Tuner and a Line Simulator, you should always be able to get to a low SWR. Real life field experience will prove this is not always the case.

When the remote end is tuning, it is important to have the coax tied thru to the house and the radio powered on. The Ametek UPLC[1] needs to be powered on to supply a 50 Ohm low side reference to your matching transformer. Not connecting the coax back thru to the house will lead to incorrect tuning.

>>Term Breakout>>

Balance Point – When tuning, the reflected power is being monitored on the test set. Making inductor changes will make the reflected power go up or down. Down equals good, up equals bad. Once the good direction is found, keep going that way until it starts going up again. This point where the signal goes down and then back up again is the best reflected power, or what I call the Balance Point.

>>

Tuning is an art. Following this procedure for the tuning will help you develop a process that you can rely on. One of the big things about carrier, it there are always exceptions to the rules. Next, I will cover a few things to look for if you can't get to the 1% SWR.

Line Tuner Unit: Single Frequency Tuner

Do's and Don'ts of Tuning

1. The line must be networked and in service to perform tuning. If you tune it tied thru but not energized, you may get away with it. The best, most accurate, method is to tune with breakers and all disconnects closed with the line energized.

2. If you tune at one end, you need to have someone at the remote terminal to tune that end. If you change tuning at one end, the other end tunes their end. You go back and forth until no one makes any changes.

3. When tuning where TT Rx's are involved, always disable the Reciever end. That is where the damage is done.

4. If you have the correct tuner, 1% SWR should be acheivable . If the line is short or their are alot of tapped loads on the line, this may not be possible.

5. Poor tuning (bad SWR) puts more stress on the transmitters. It can create modulation that will effect the schemes reliability.

6. When tuning at one end of the line, the other end must be tied thru to the radios. Remember the Tx is a 50 Ohm termination and the Receiver will have an external 50 Ohm termination. Without these termianations, the tuning will not be terminated when the other end is tuning. Note that some radios must be powered on for the Tx termination to be in the circuit.

7. The matching transformer final tap position can point to a bad line trap. See the book for a white paper on the subject.

Line Tuner Unit: Single Frequency Tuner

Visit www.PLCExperts.net for More PLC Experts White Papers!

Don't forget to get the first and last book you will need on Power Line Carriers!