Connecting Your Rig To The Aether[1]

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Pacificon '18

1: of course, there is no Aether!

Presentation Goals

Review a common design to reinforce forgotten knowledge.

Use that design to demonstrate tools for exploring design space.

Antenna Projects

Probably the most common ‘homebrew’ project in amateur radio.

They are inexpensive projects
They are easy to build
They have nearly infinite variety
There is no lack of advice
They can have a tangible effect on operation

an Antenna's Purpose

Transfer power between your rig
and the aether.

Antenna System

Think about Antenna/Feed Line/Tuner as a system.

Fundamental Goal: DON'T FRY YOUR RIG!

More gently: provide operating environment expected by the manufacturer… so you get the performance you purchased.

Secondary Goals (no particular order)

Wide receive Bandwidth to ease operation

Best power out

Best signal in

Antenna System

System (probably) has 4 parts:

- (for today) dipole antenna
- some form of balun
- feed line
- tuner (probably)

Assumed:

Most of us...

- want multi-band operation
- use a dipole of some sort
- use coax as a feed line
- use a tuner of some kind
- work mostly in 80m to 10m bands

Today

Look at two different solutions:

‘divide and conquer’...
design each part independently.

‘wholistic approach’...
make trade-offs between parts.

Will use EZNEC for antenna simulation
Will use Smith chart for displaying impedances
Will use SWR, Power, and component value charts

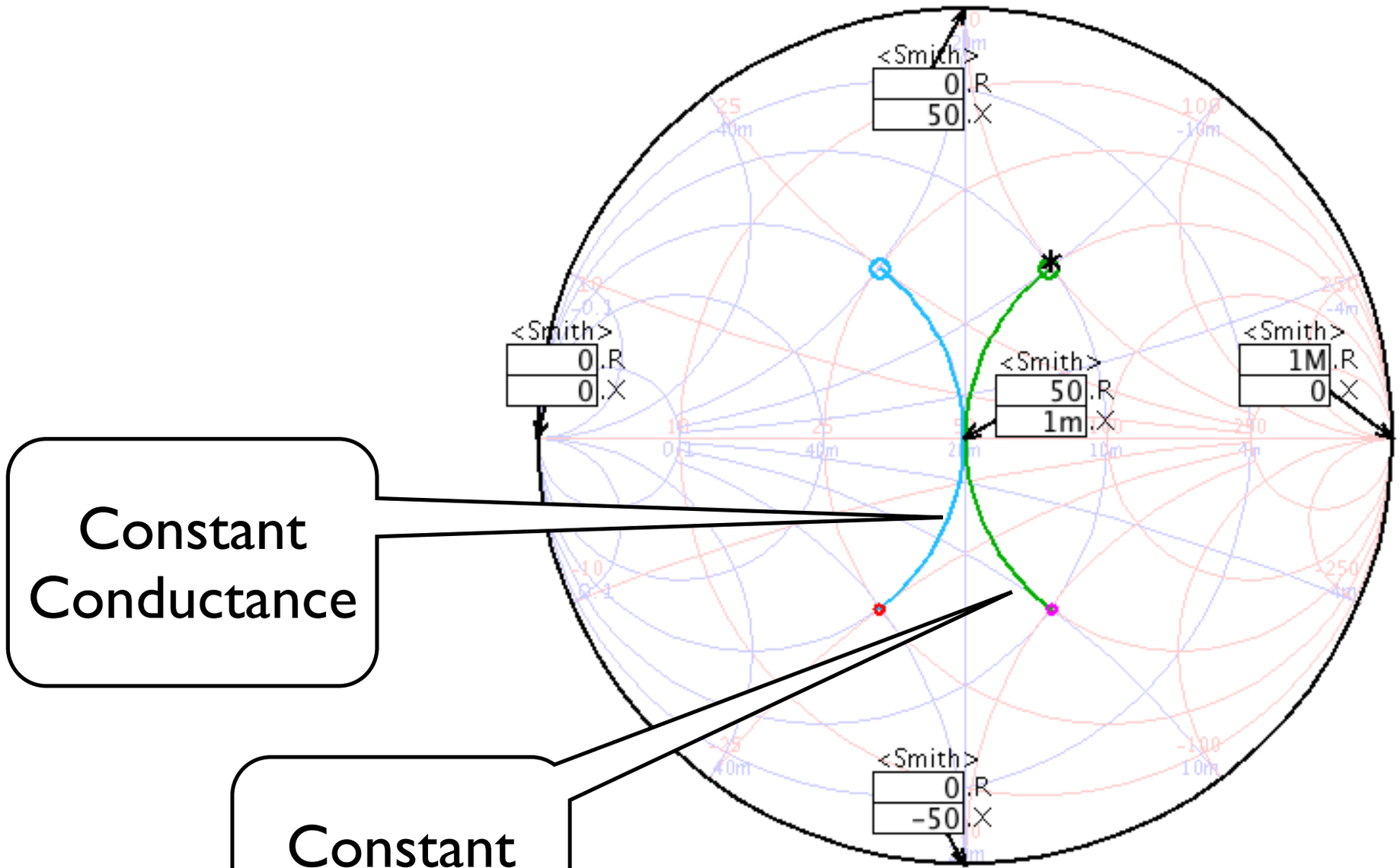
Smith Chart Review

Used to plot impedances

Can be used as a design tool:

- visualize patterns in sets of impedances
- guides circuit design

Smith Chart Display



Smith Chart Review

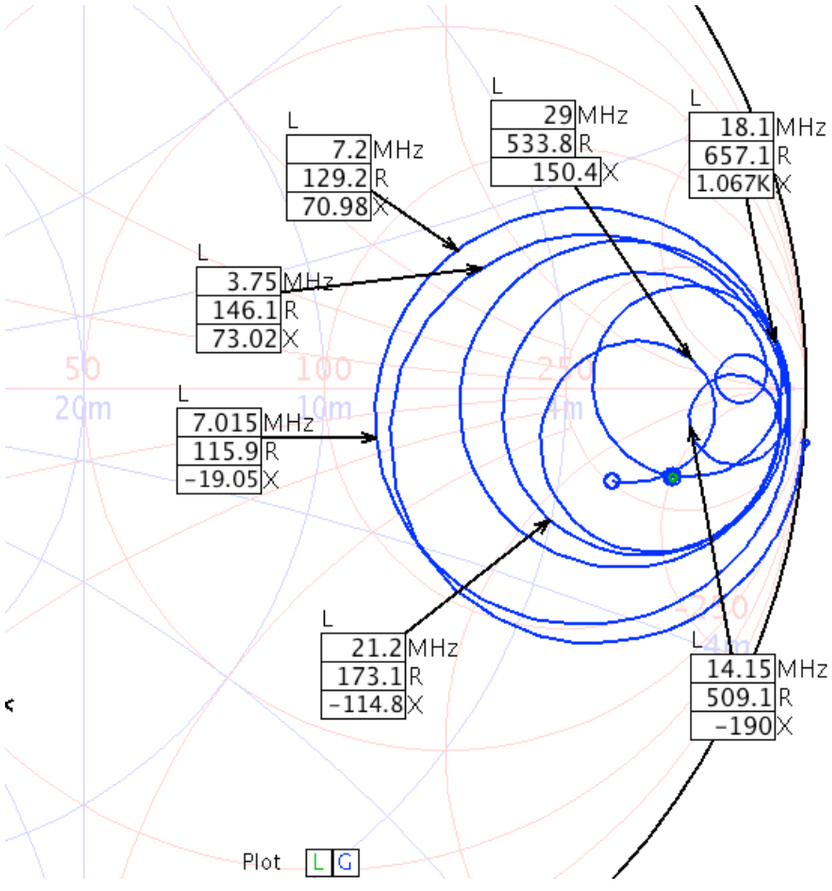
Sets of Impedances

Only part of chart shown here

Sweep by frequency

Can sweep by almost any circuit parameter, even multiple parameters at once.

sweepMHz.ssx

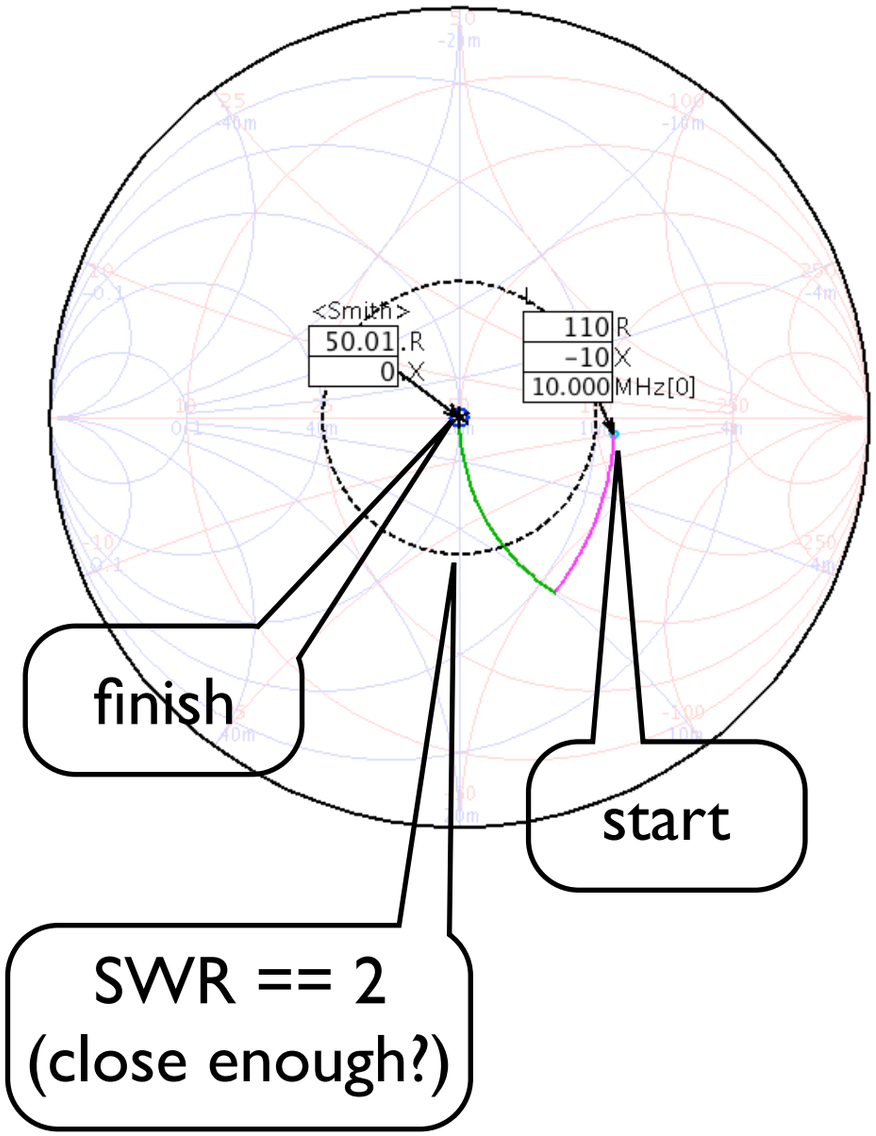


Smith Chart Review

When manipulating an impedance there is a goal in mind.

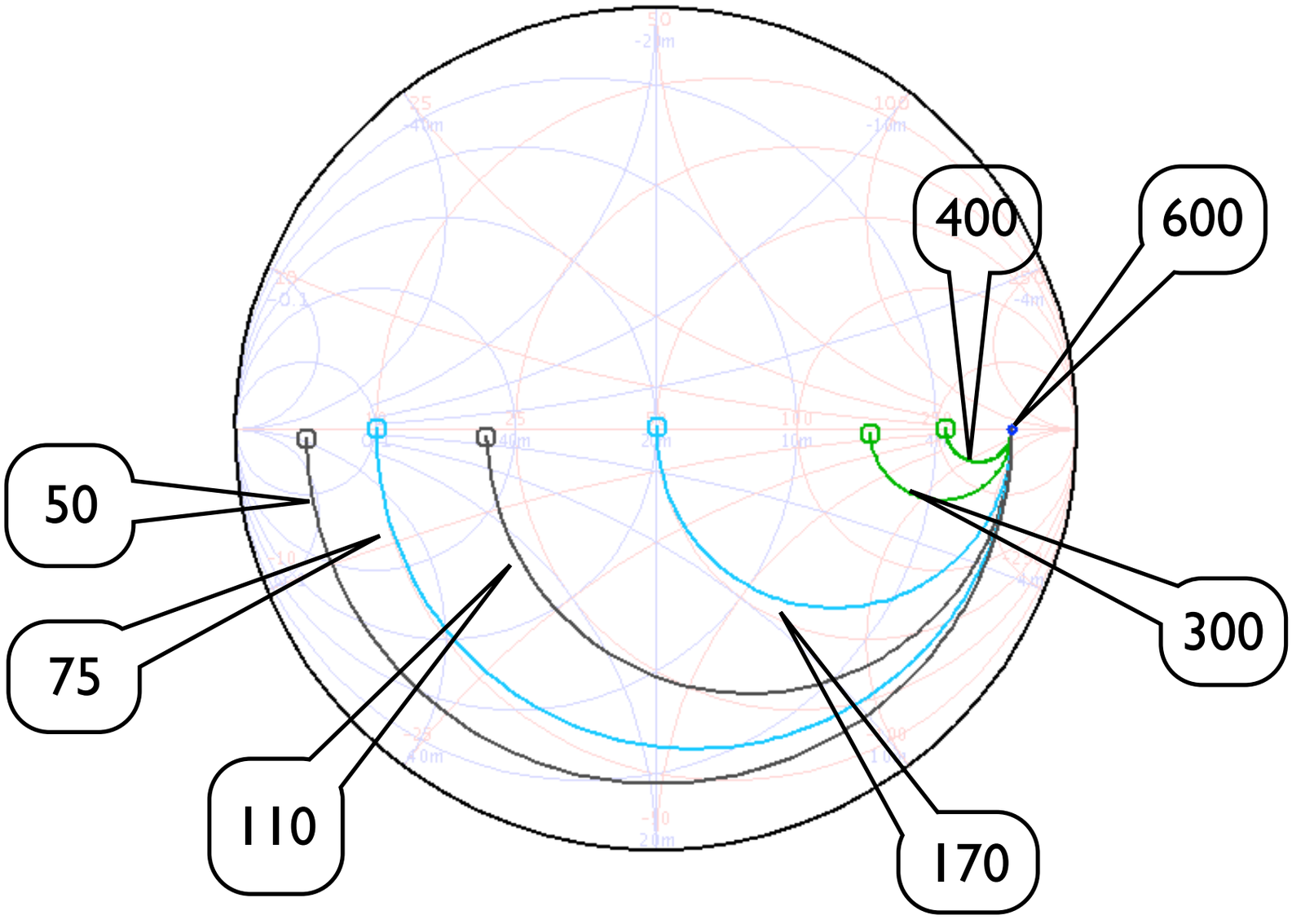
Goal can be anywhere but is usually:

THE CENTER
(or close enough)



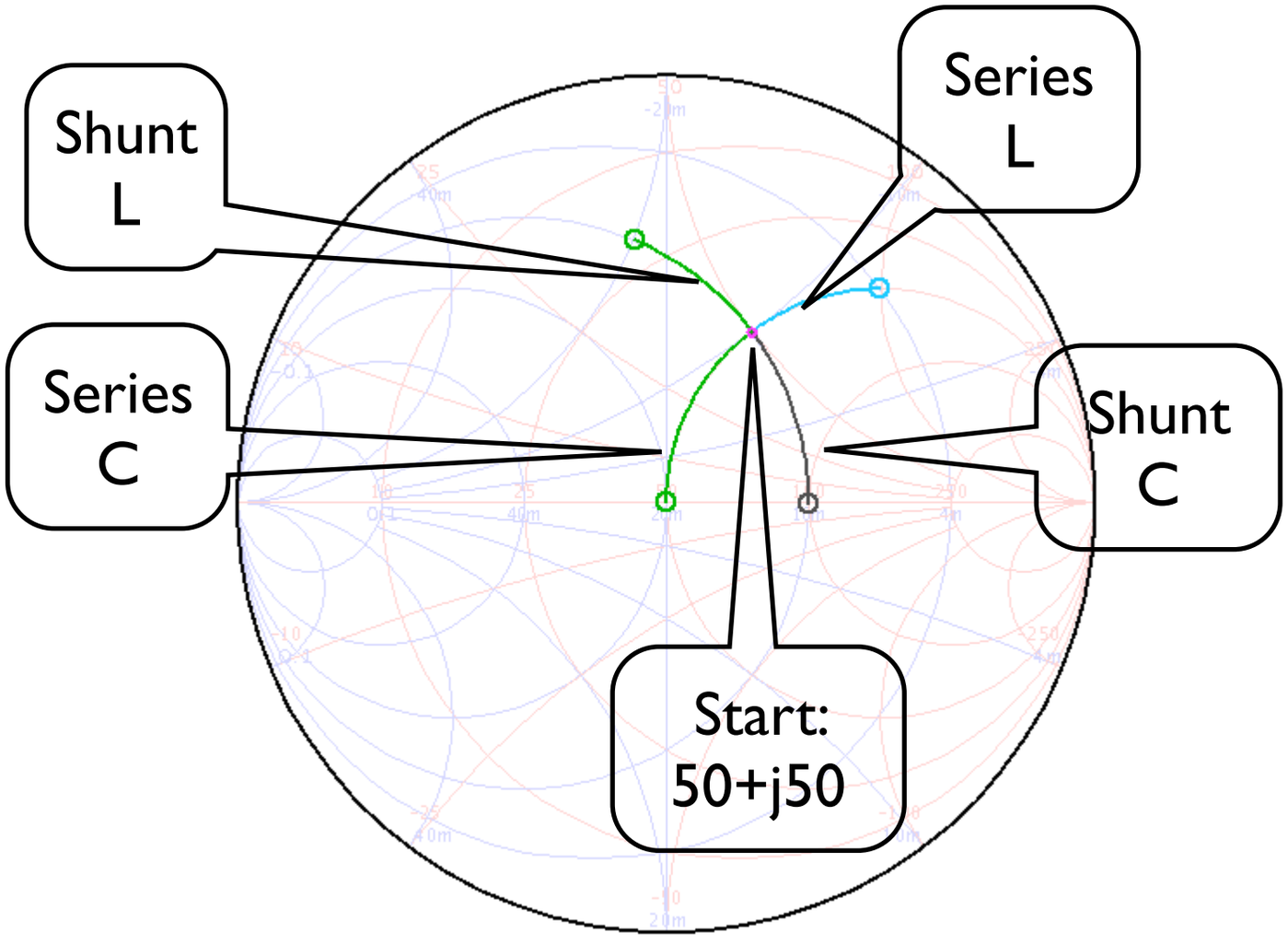
Smith Chart Review

Effect of Feed Line Zo



Smith Chart Review

Effect of Discrete Components



This chart is wrong in the handouts!

Up Front Disclaimer

Today's presentation:

Intend to present techniques

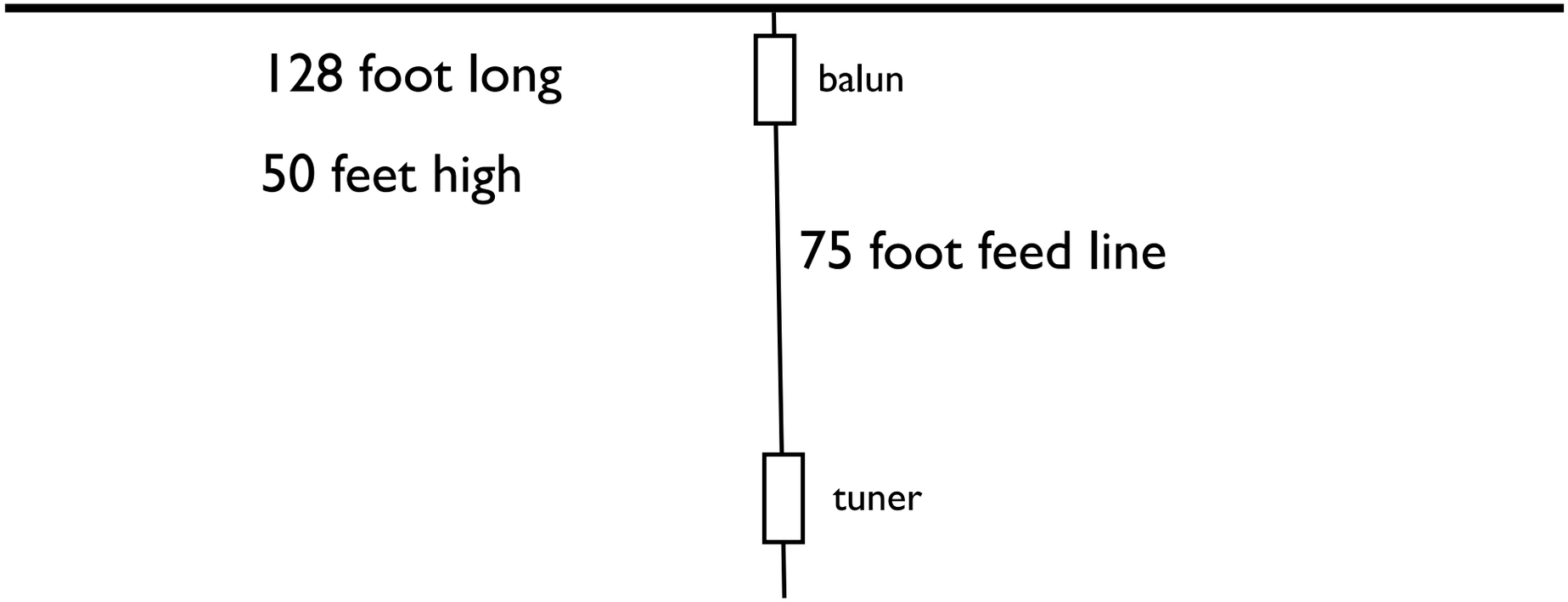
demonstrate how they may be leveraged

may not be comprehensive

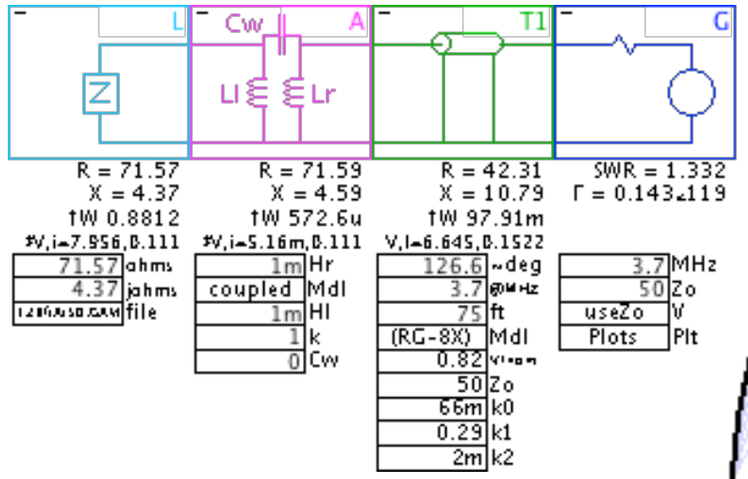
NOT intended to recommend any particular solution

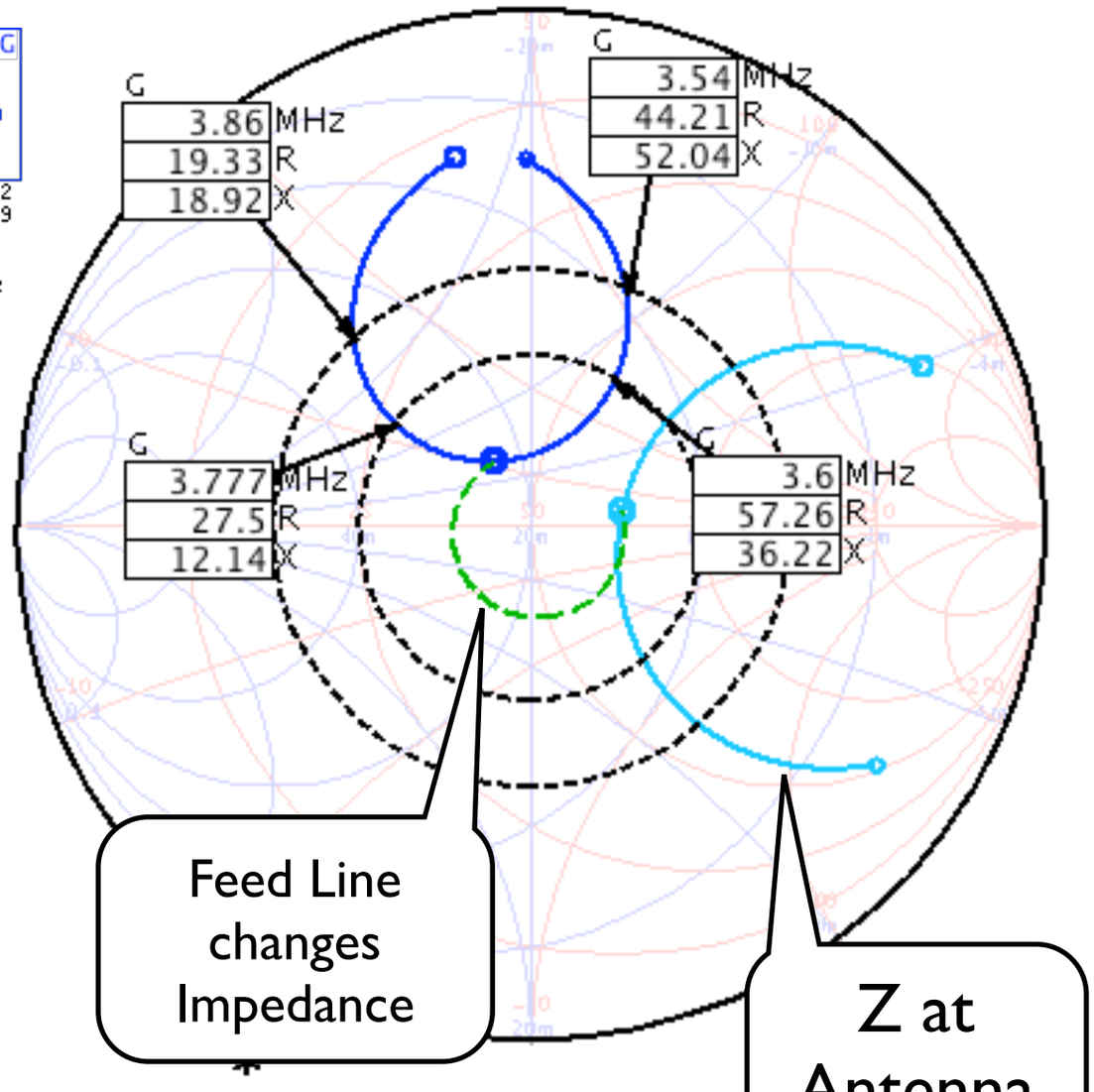
Starting Point

(1/2 Lambda at 3.75 MHz)



3.7 MHz Results



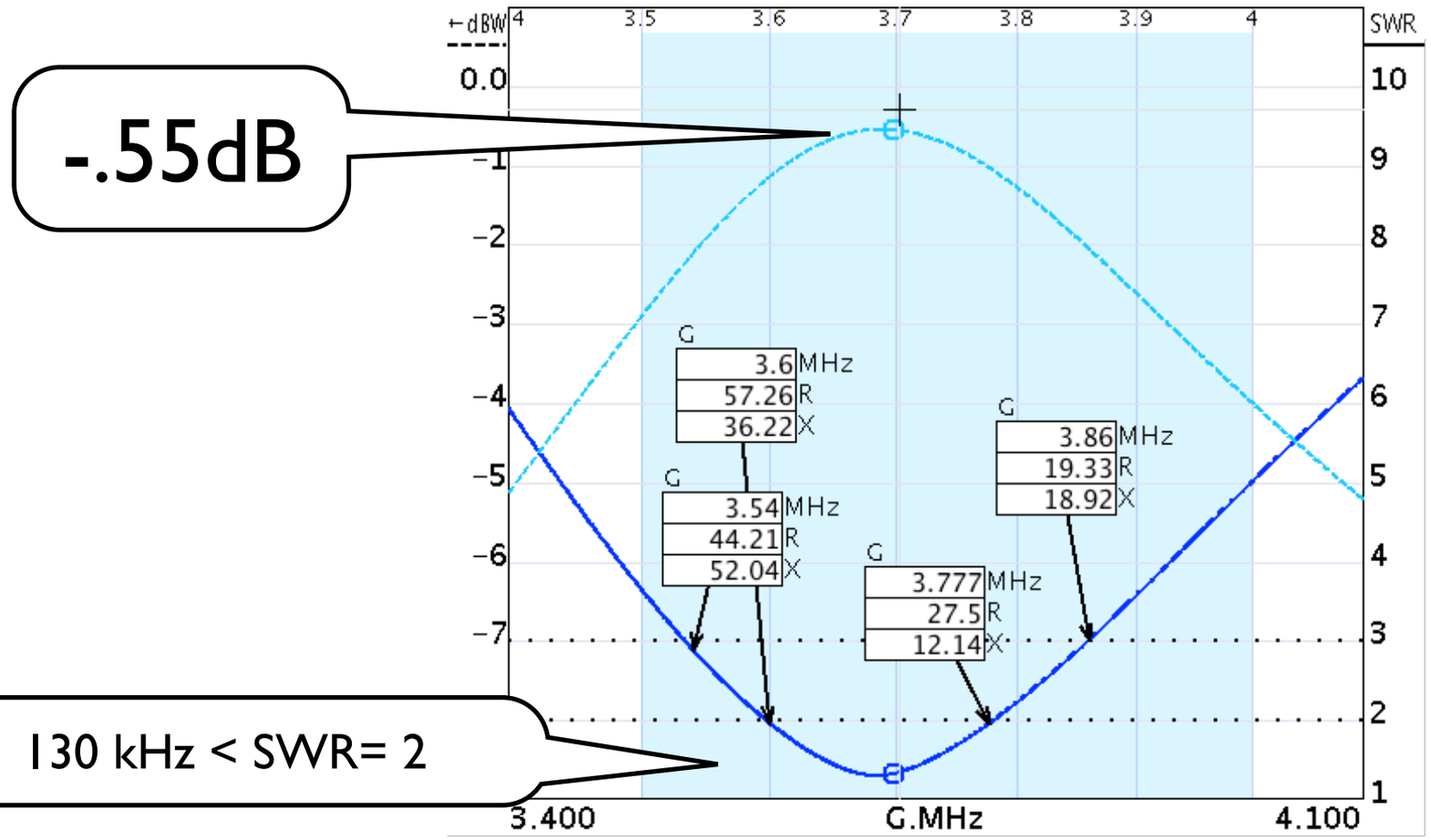


NO TUNER YET

(close enough?)

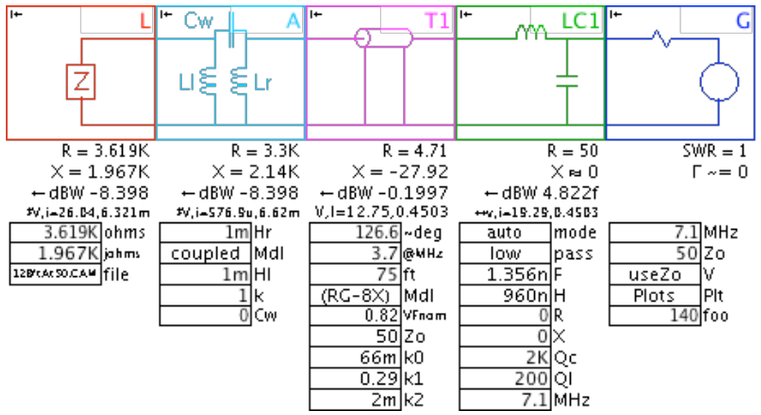
128cfRG8x.ssx

Results

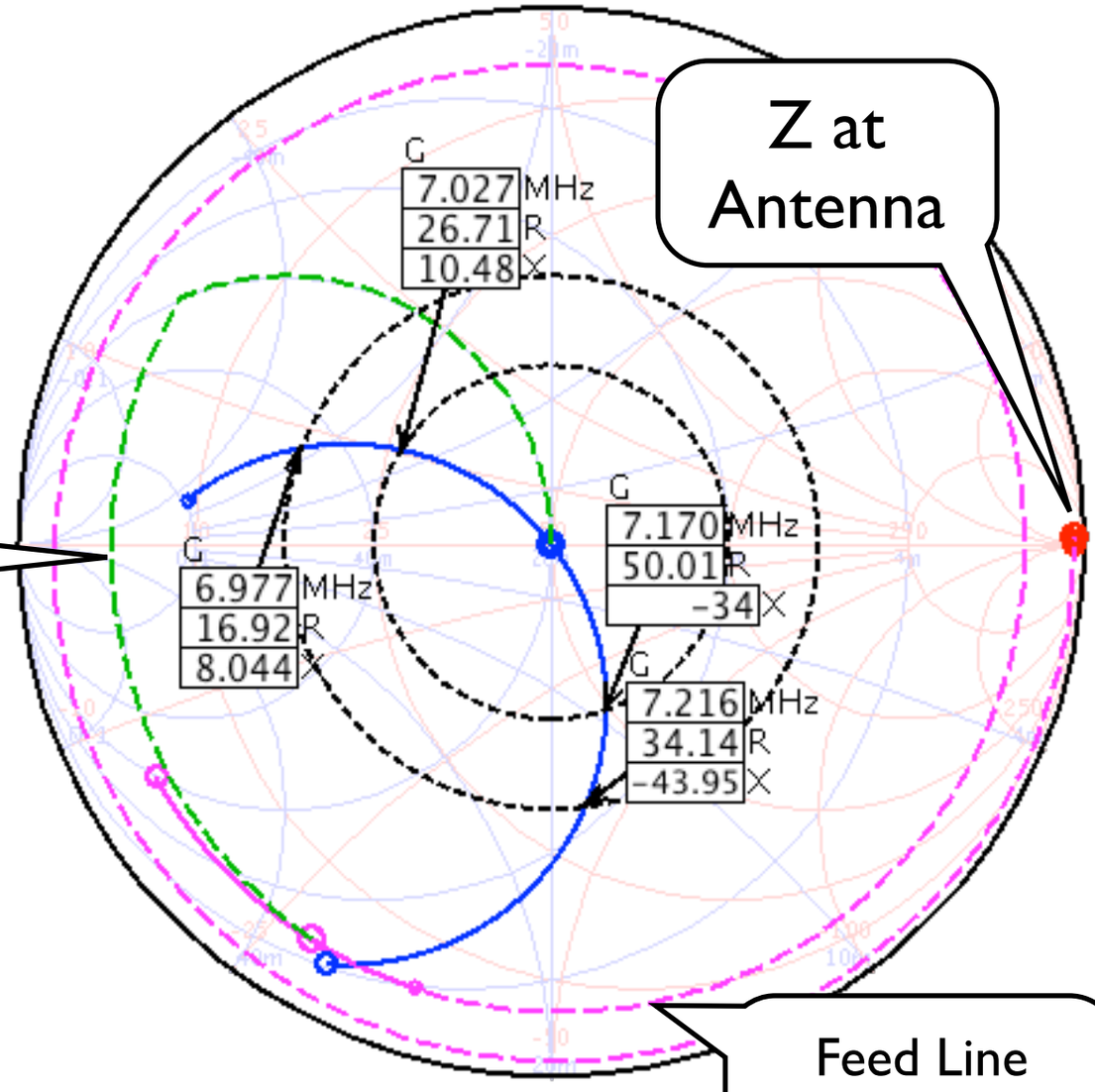


128cfRG8x.ssx

7.1 MHz Results



LC tuner
Does Match



Z at
Antenna

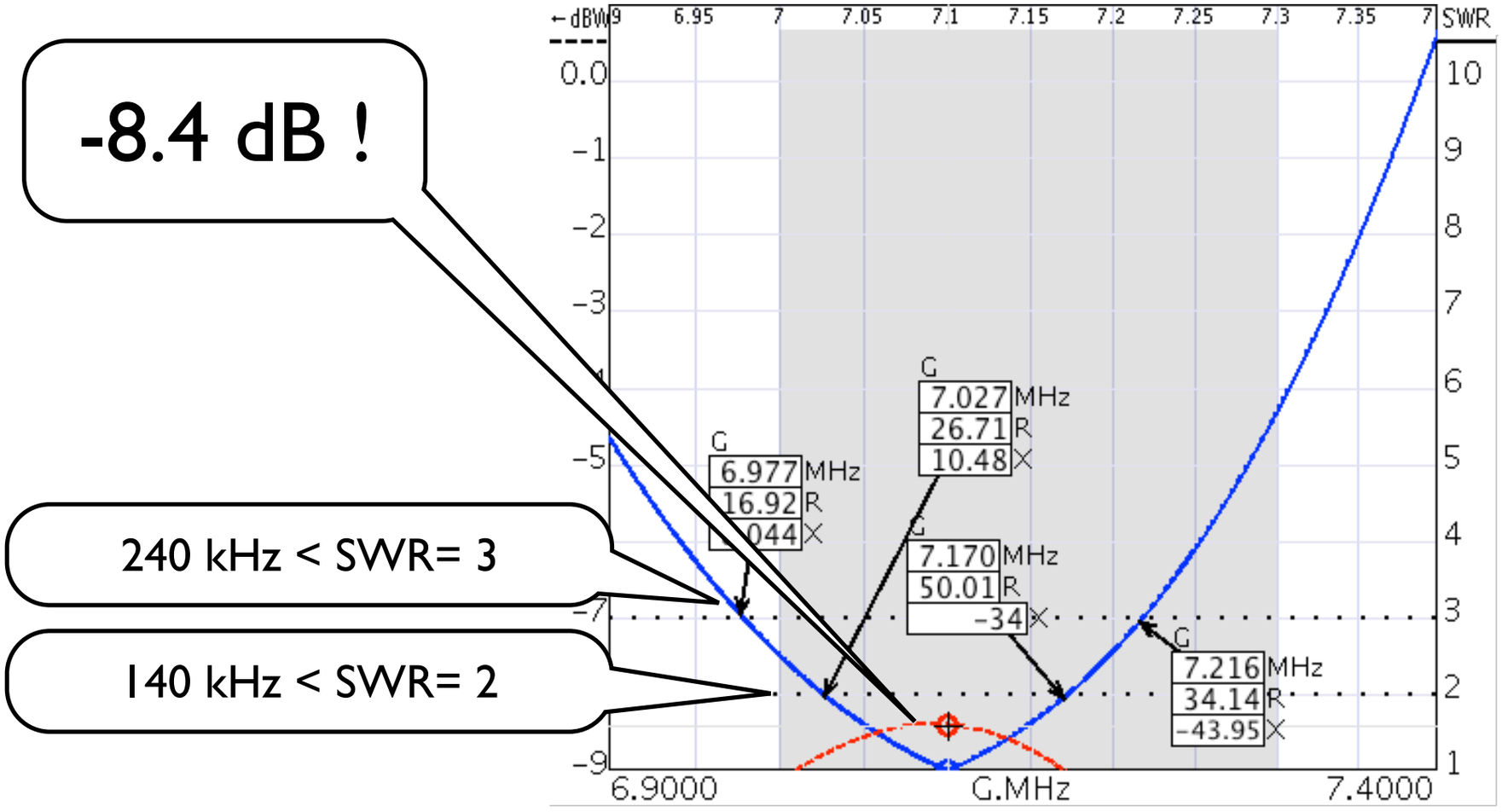
Feed Line
changes
Impedance

140 kHz SWR < 2

240 kHz SWR < 3

128cfRG8x-7p1.ssx

7.1 MHz Results



128cfRG8x-7p1.ssx

7.101 MHz ←dBW=-8.40

7.1 MHz Awful

Power all being lost in Transmission line.

Well understood problem:

Driving dipole at 2nd harmonic at center.

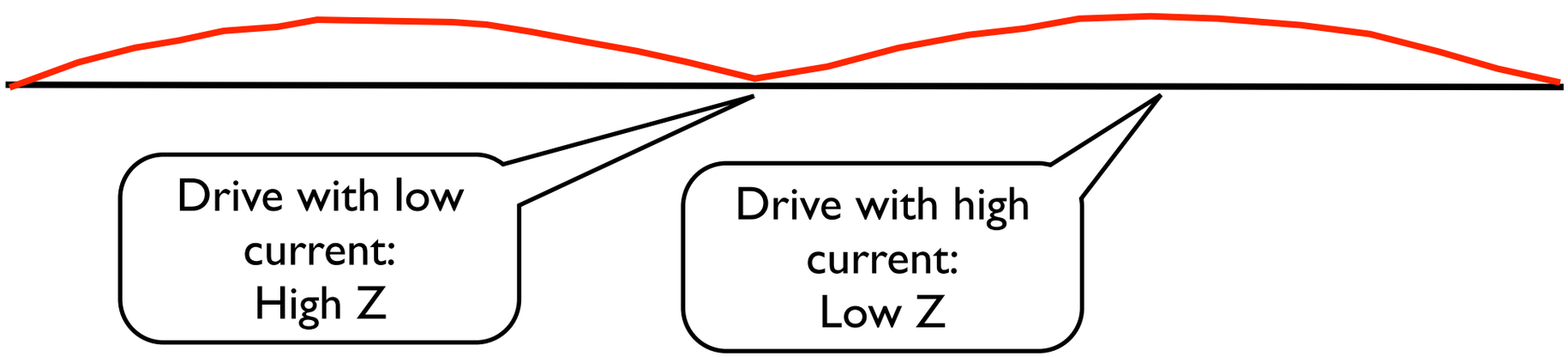
Well understood solution:

Move Feed Point.

128cfRG8x-7p1.ssx

Why this Works.

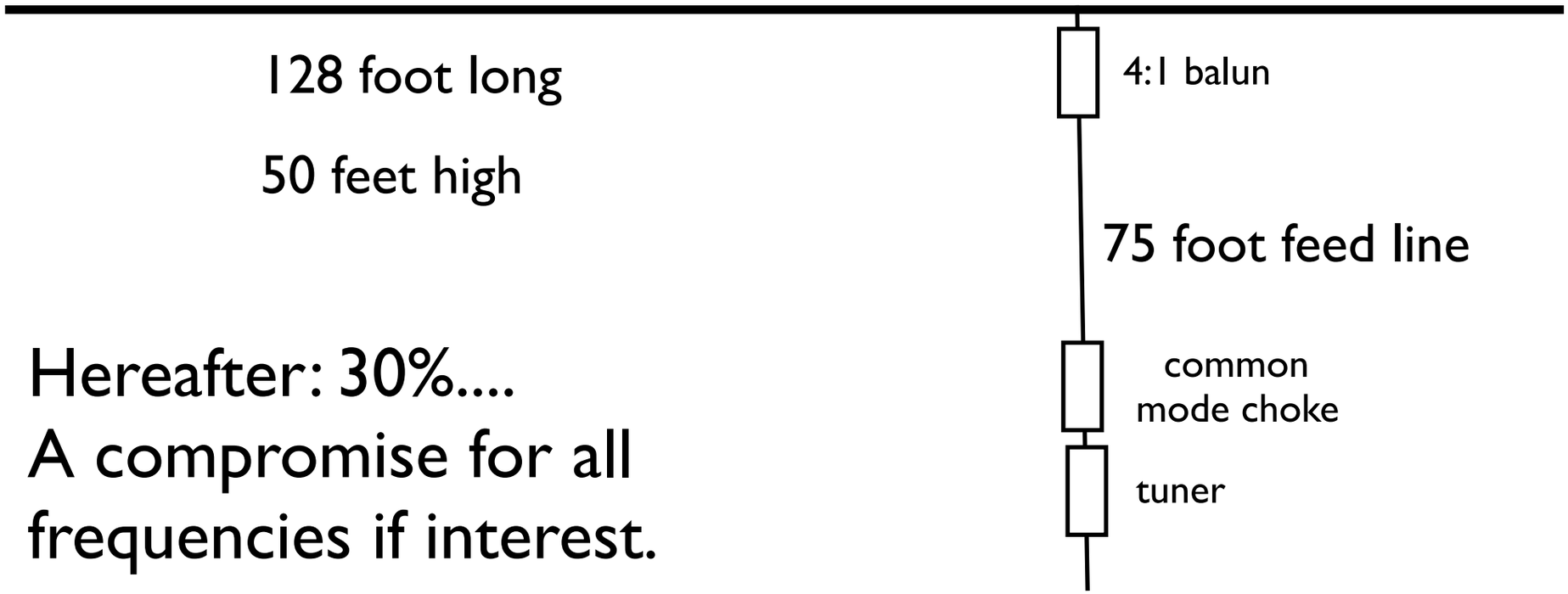
Current on a dipole at second harmonic
Constant power implies.....



Might indicate best point is 25%

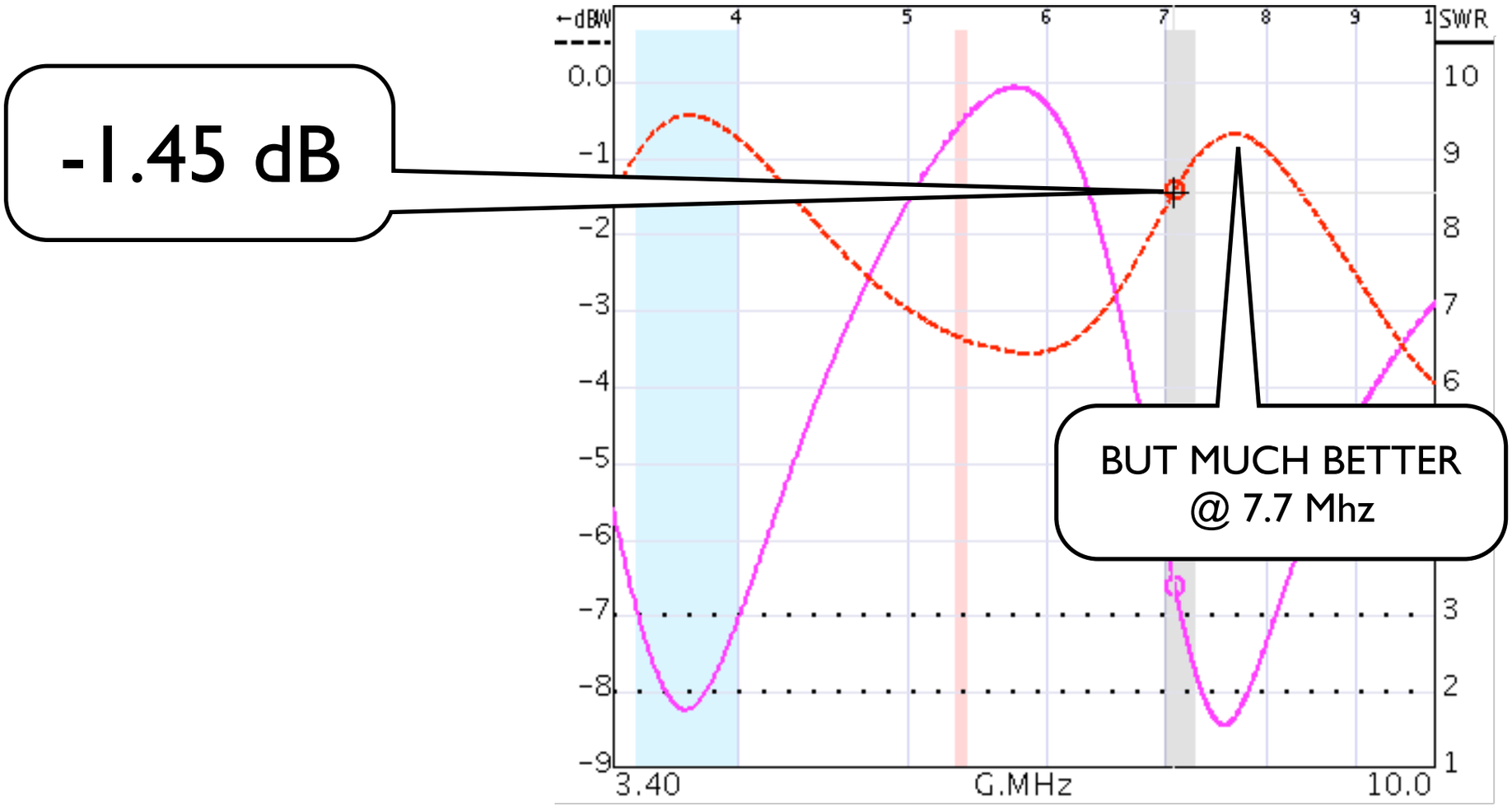
Off Center Fed

(1/2 Lambda at 3.75 MHz)



Hereafter: 30%....
A compromise for all
frequencies if interest.

7.1 MHz Results



128ocfRG8Xtuner.ssx

7.088 MHz ←dBW=-1.45

Improve 40m

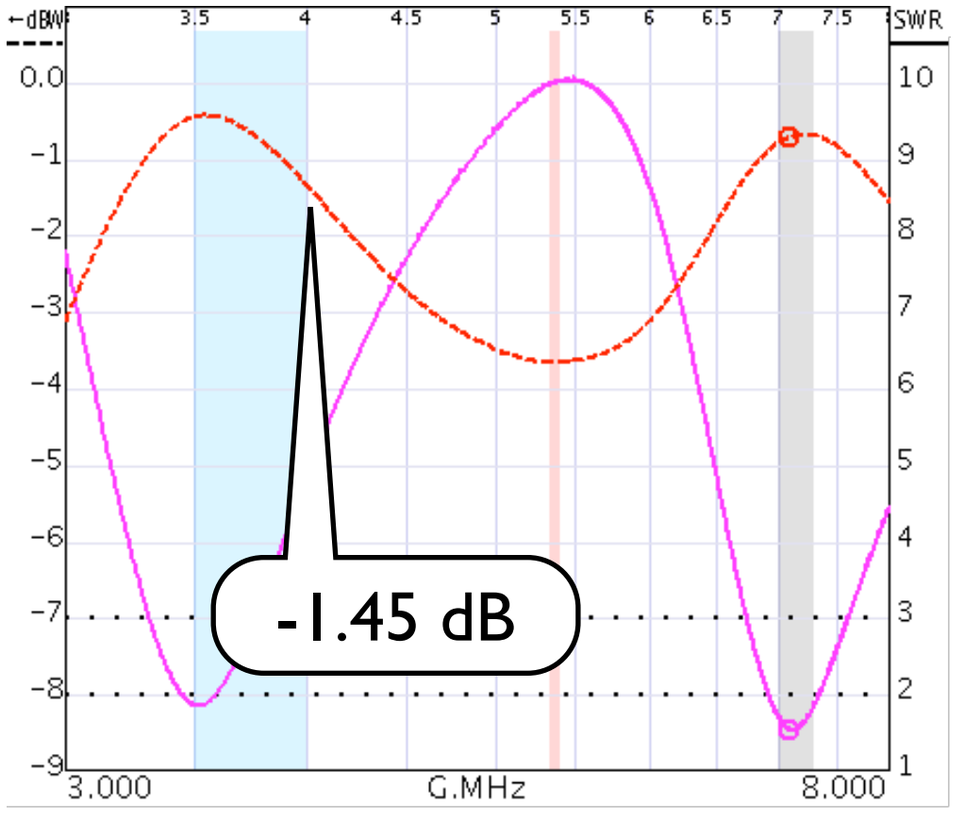
Power much better at 7.7 MHz...

Lengthen the Dipole

BUT: messes up 80m

Reduces power at upper end of 80m!!!

128ocfRG8Xtuner.s



How to solve this?

ON4AA proposed adding a center loading element:
a Series LC element.

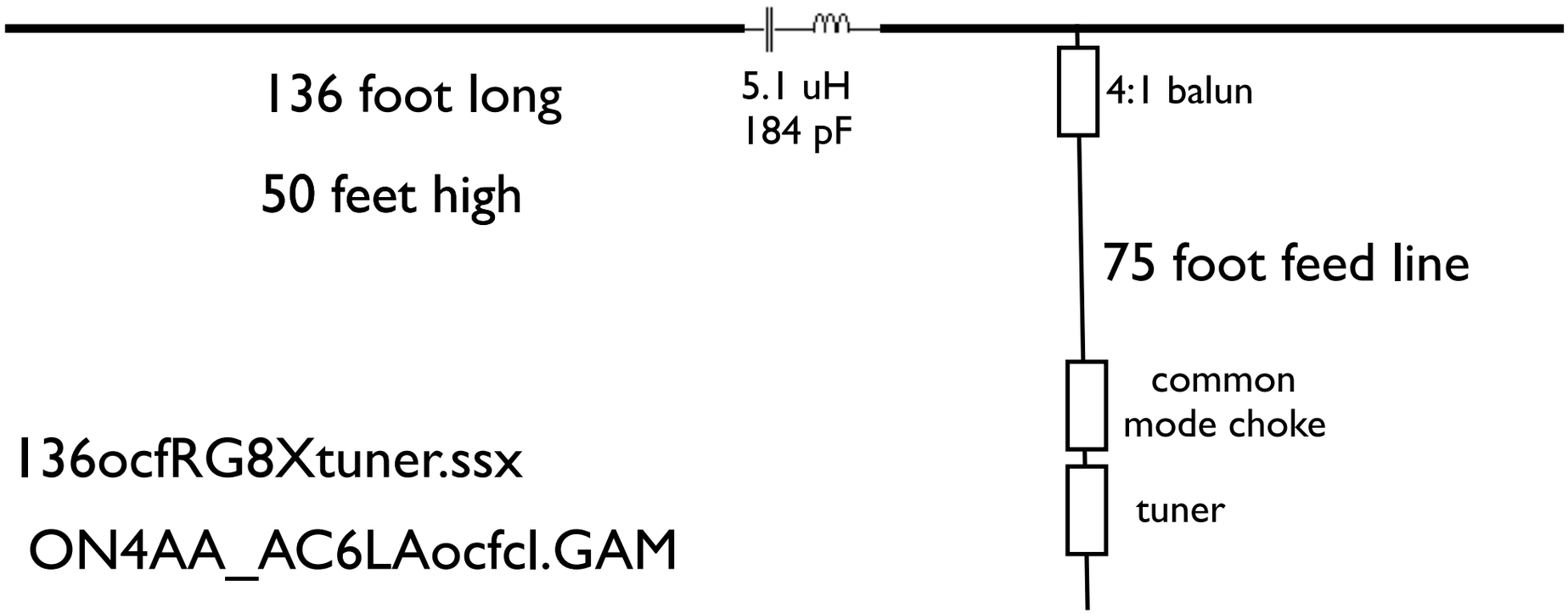
How does this WORK???
Everyone knows inductors lower resonance
Less well known, capacitors increase resonance

AND the series LC is inductive at higher frequencies and capacitive at lower frequencies.

AC6LA did a bunch of optimizations and got:

OCF and Center Loaded

(ON4AA proposed, AC6LA optimized)



136ocfRG8Xtuner.ssx

ON4AA_AC6LAocfcl.GAM

capacitor bleed resister
left out for clarity

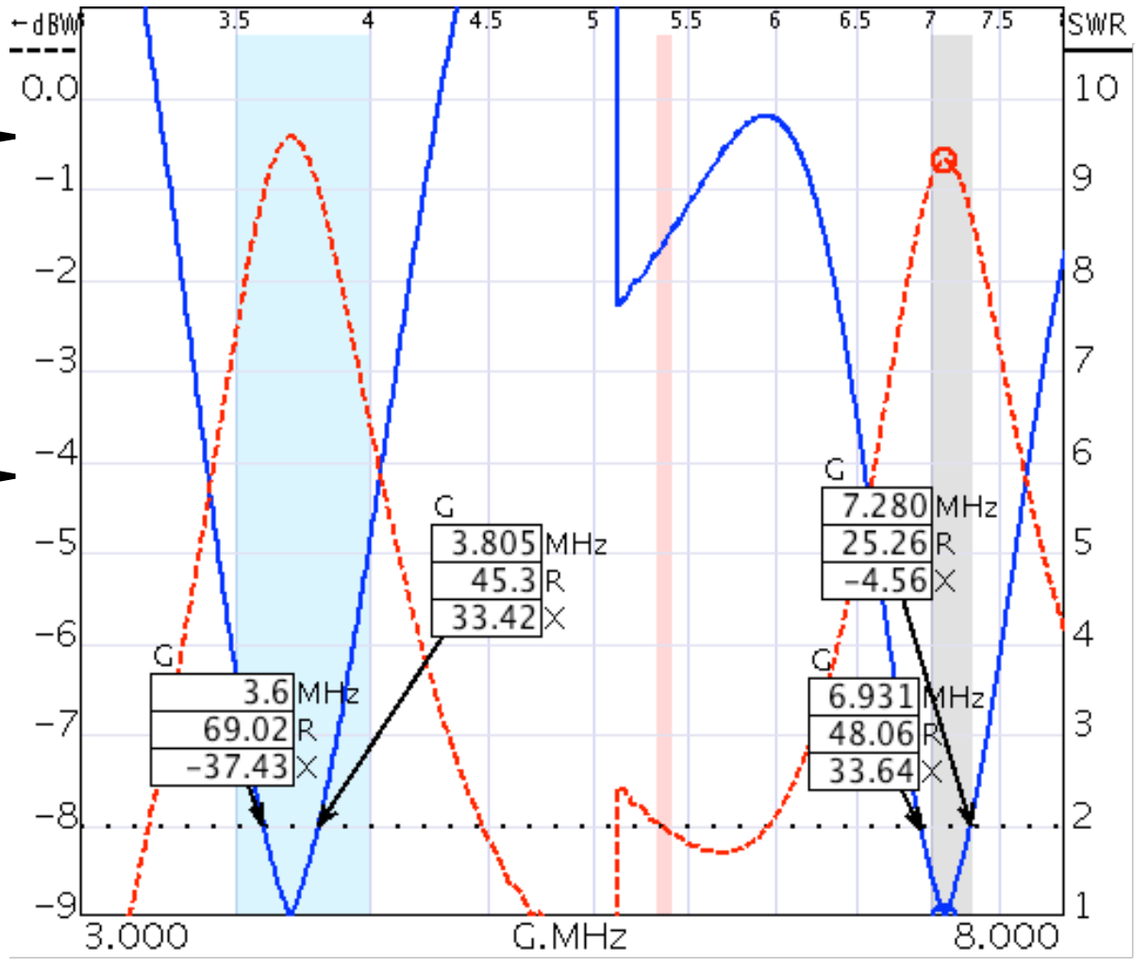
Dual Band Results

Good balance between 80m and 40m power

80m BW = 200 kHz
40m BW = 300 kHz

136ocfRG8Xtuner.ssx

ON4AA_AC6LAocfcl.GAM



Now Multiband...

Doing well in 80m and 40m band.

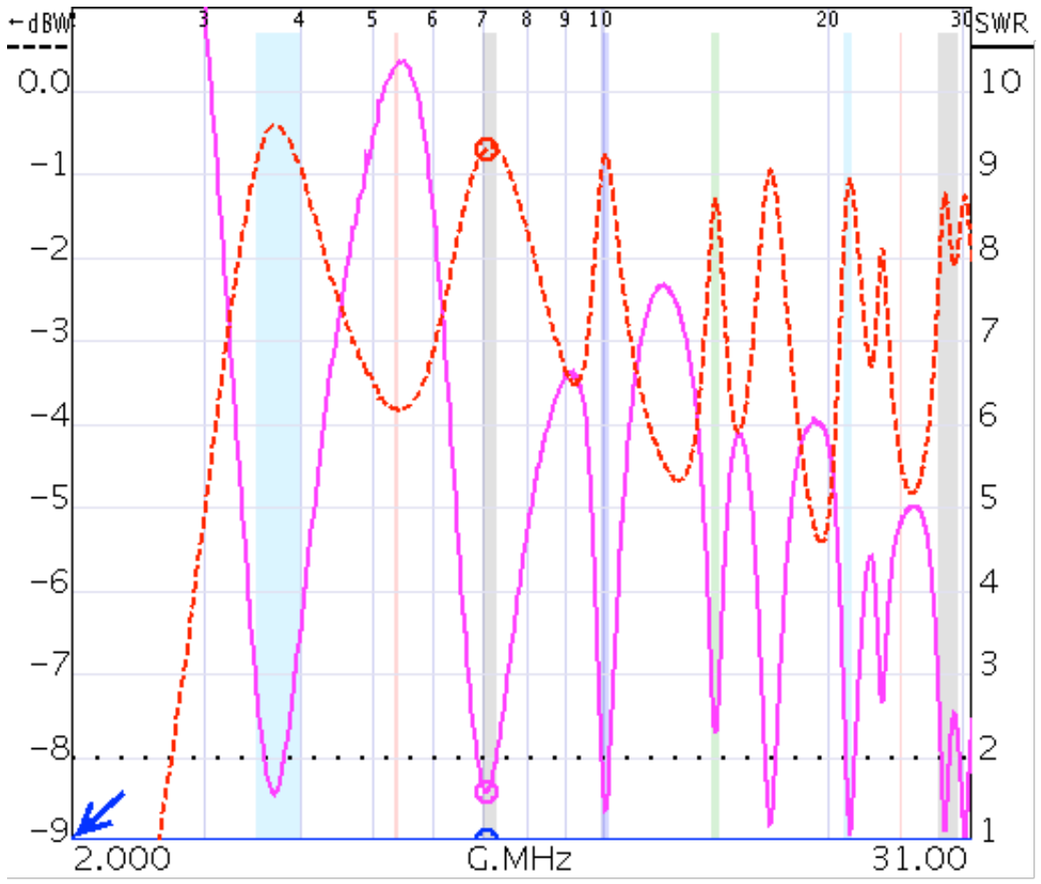
Let's look at all the bands...

Seems to cover 30m,
20m, 15m, and 10m fairly well.

Still need modest tuner.

Probably good enough for casual operation BUT....

let's try to do better.



Where we are:

Antenna

- Off Center Fed
- Center Loaded
- Resonant on bands of interest

Feed Line

- RG-8X, 50 ohm coax.
- 4:1 current balun at feed point.

Tuner

- modest tuner, no more than 3/1 needed.

Coverage

- 6 bands

Modestly efficient.

Tuner Demands

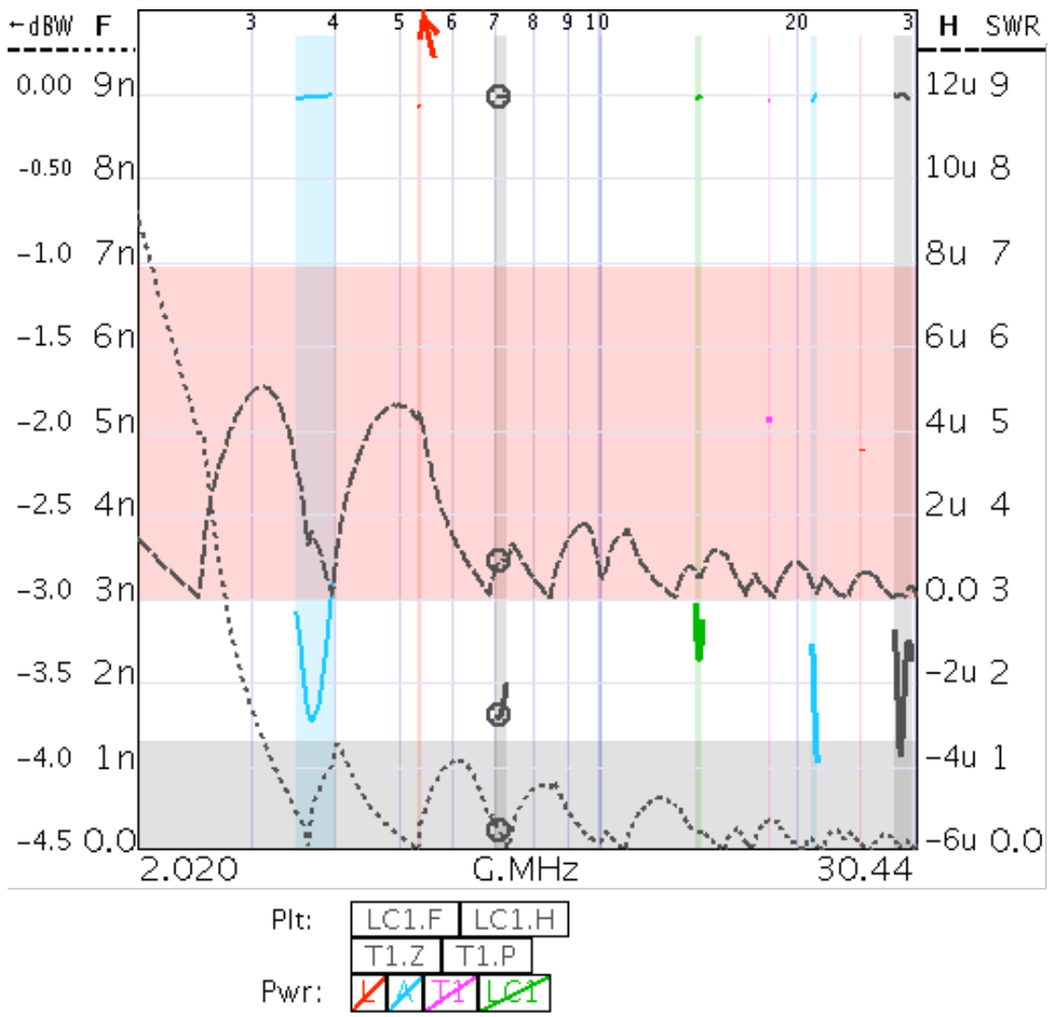
This shows power and SWR demands only in bands.

The required inductance and capacitance are shown.

The horizontal bands are the supported ranges of an Elecraft T1 tuner.

Close on the capacitor but otherwise fine.

136ocfclRG8XtunerLimited.ssx



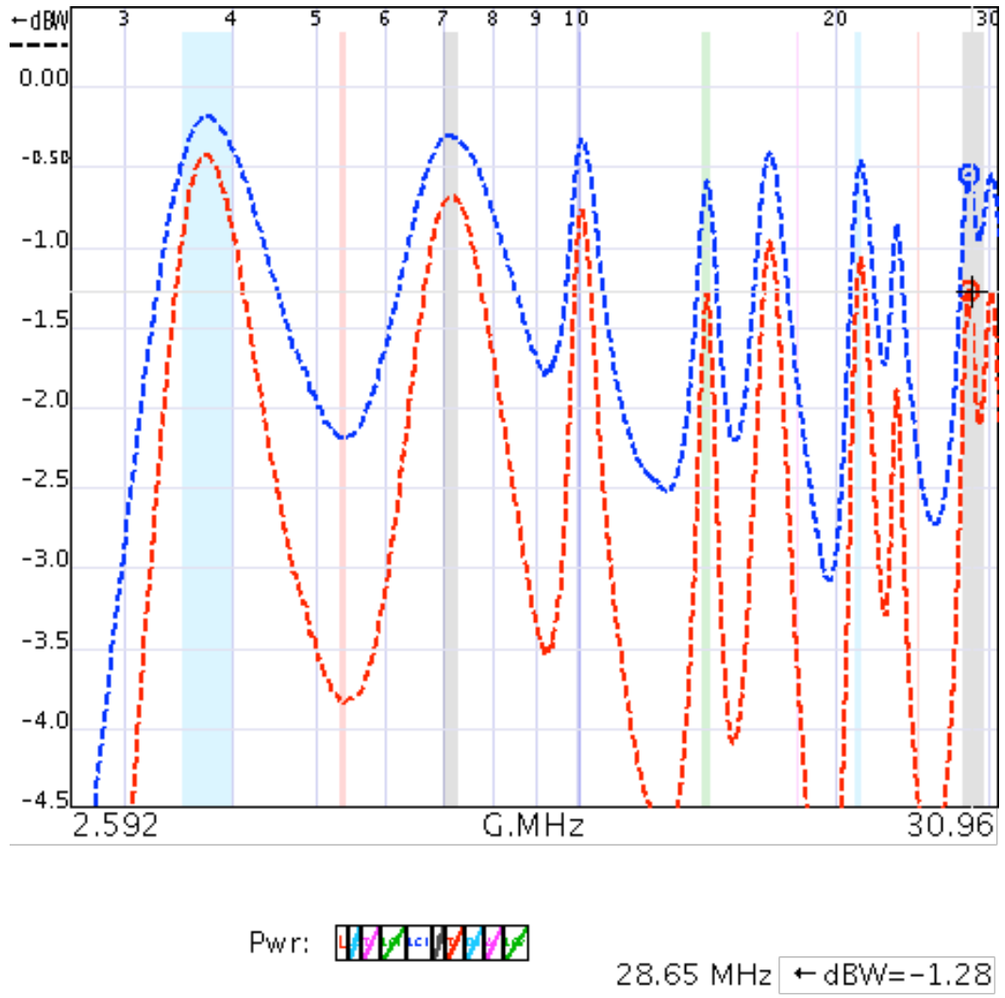
Lowering Feed Line Loss

We could use better coax.

Just to see how far one might go, here's LMR-400 compared to RG-8X.

Up to 1 dB in 10m band.

Improvement largely due to larger center conductor.



Change Feed Line Technology

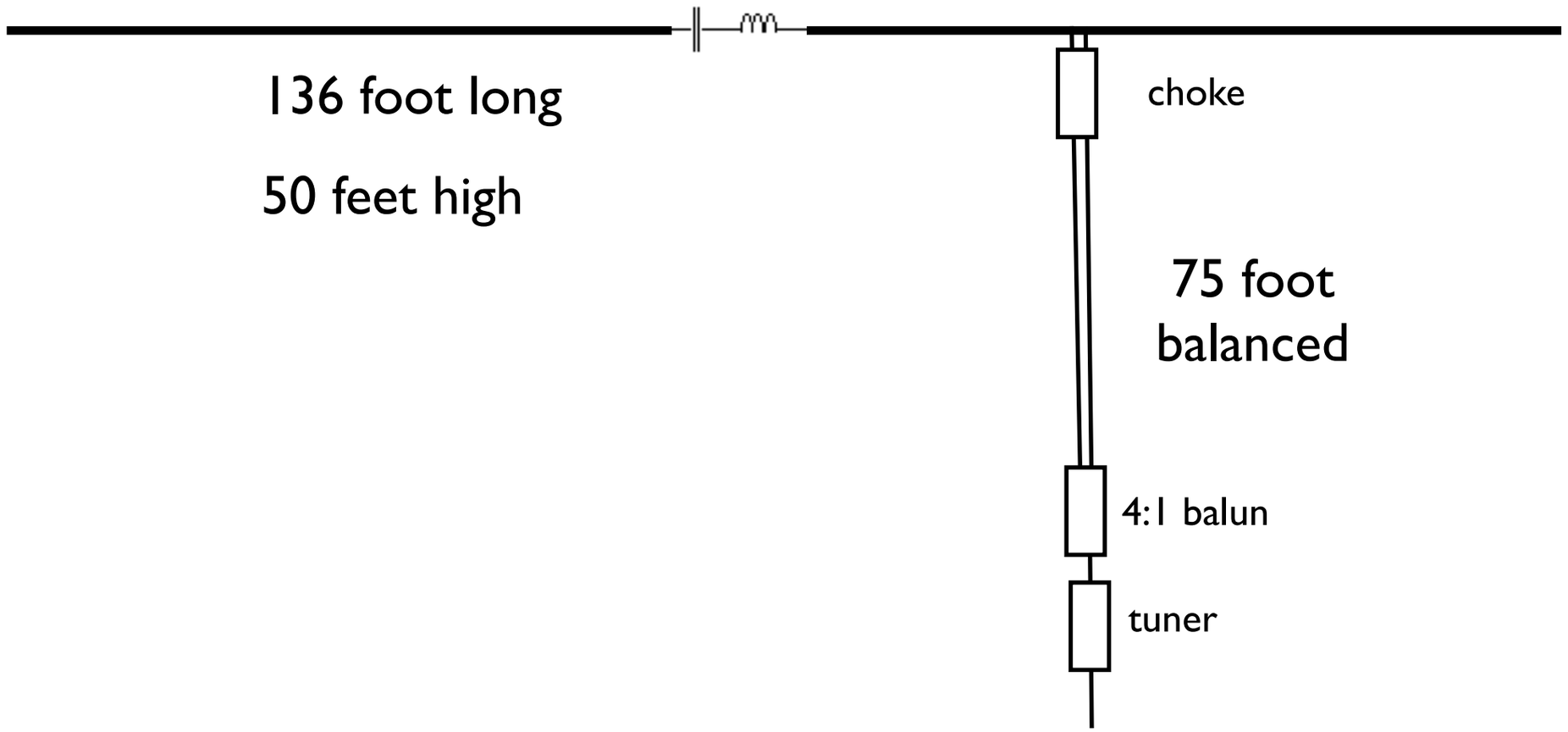
In the ‘good old days’, feed lines were often balanced, high impedance (>300) ladder lines.

Still need balun but now its just a choke.

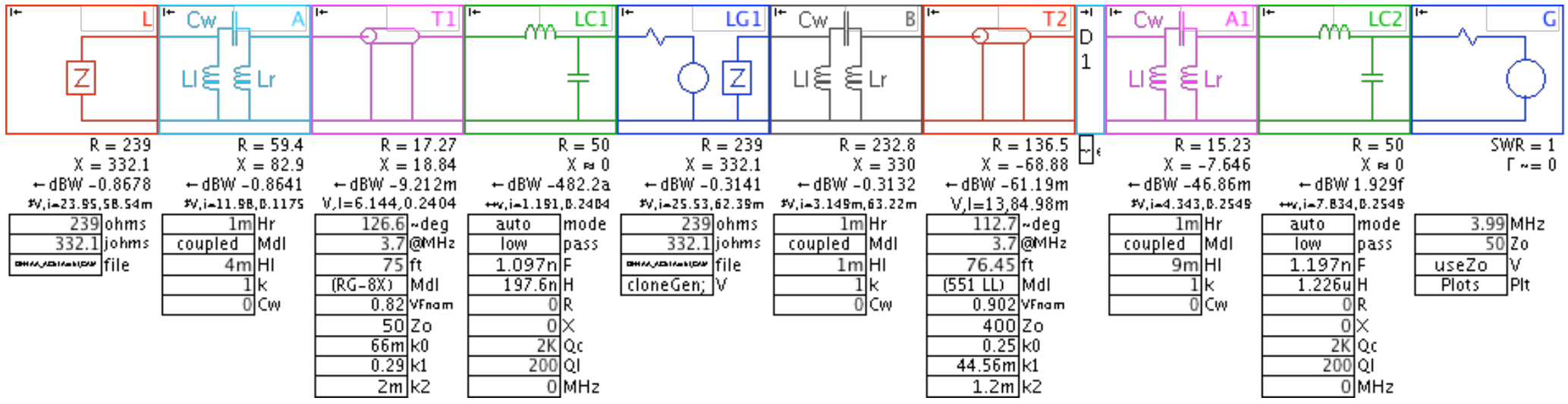
Let’s start out with something simple:

window line...

Window line


136 foot long
50 feet high
choke
75 foot
balanced
4:1 balun
tuner

Comparison Circuit



Two copies of the circuit:
On the left: the antenna/balun/RG-8X/tuner.
On the right: antenna/choke/windowLine/balun/tuner

Really would like a tuner with balanced output!

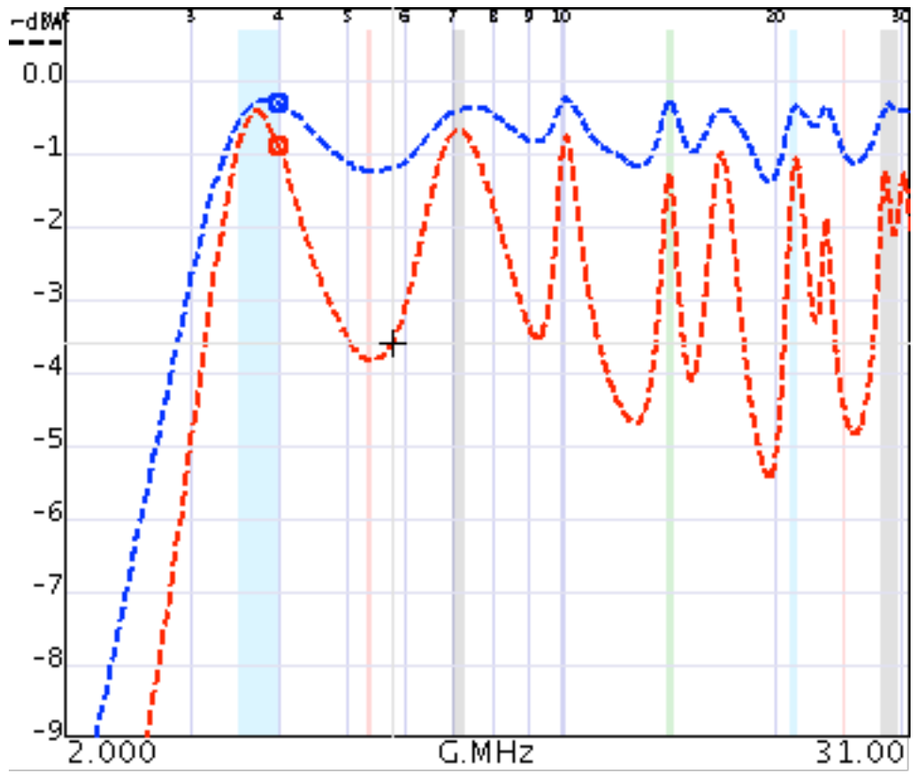
compareUsingLadderLine.ssx

Compare 551 with RG-8X

Significantly better.

Covers every frequency.
(Tuner losses not included)

So... maybe we could lose the center loading LC network?



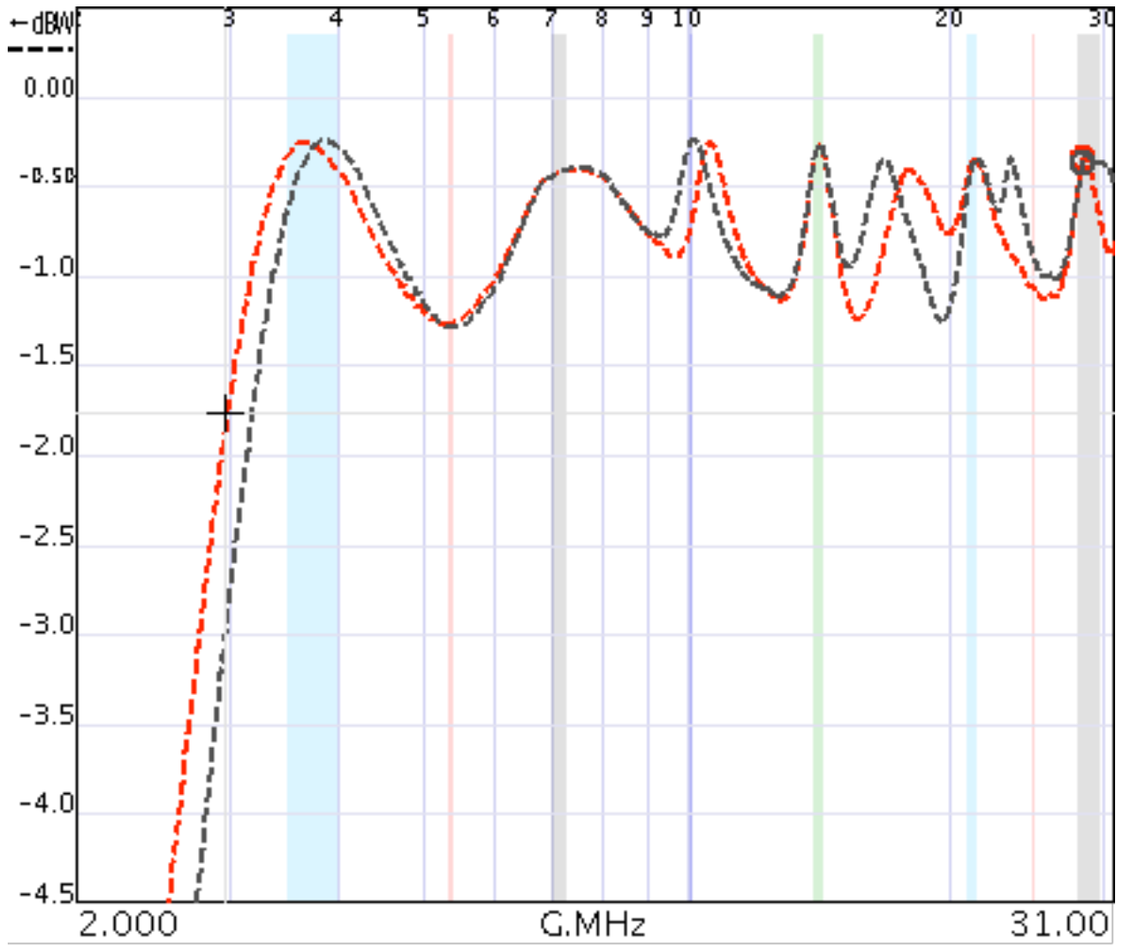
With/Without Center Load

Black trace is with center load.

Red trace is without center load.

Let's leave it out for now.

compareLoadedAndUnloaded.ssx



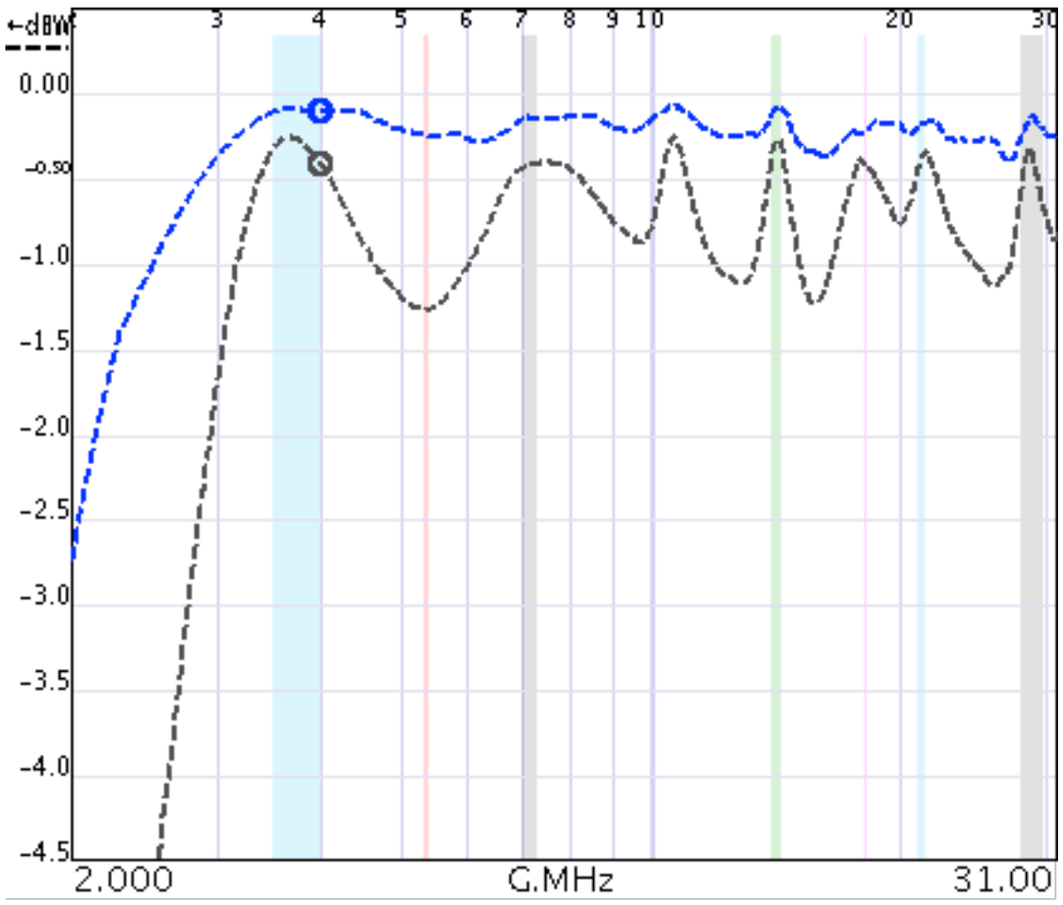
Ladder Line vs. Window Line

Window line is easy to get but...

We should check out true ladder line.

Blue: 600 ohm ladder
Black: 551

compare551toLadder.ssx



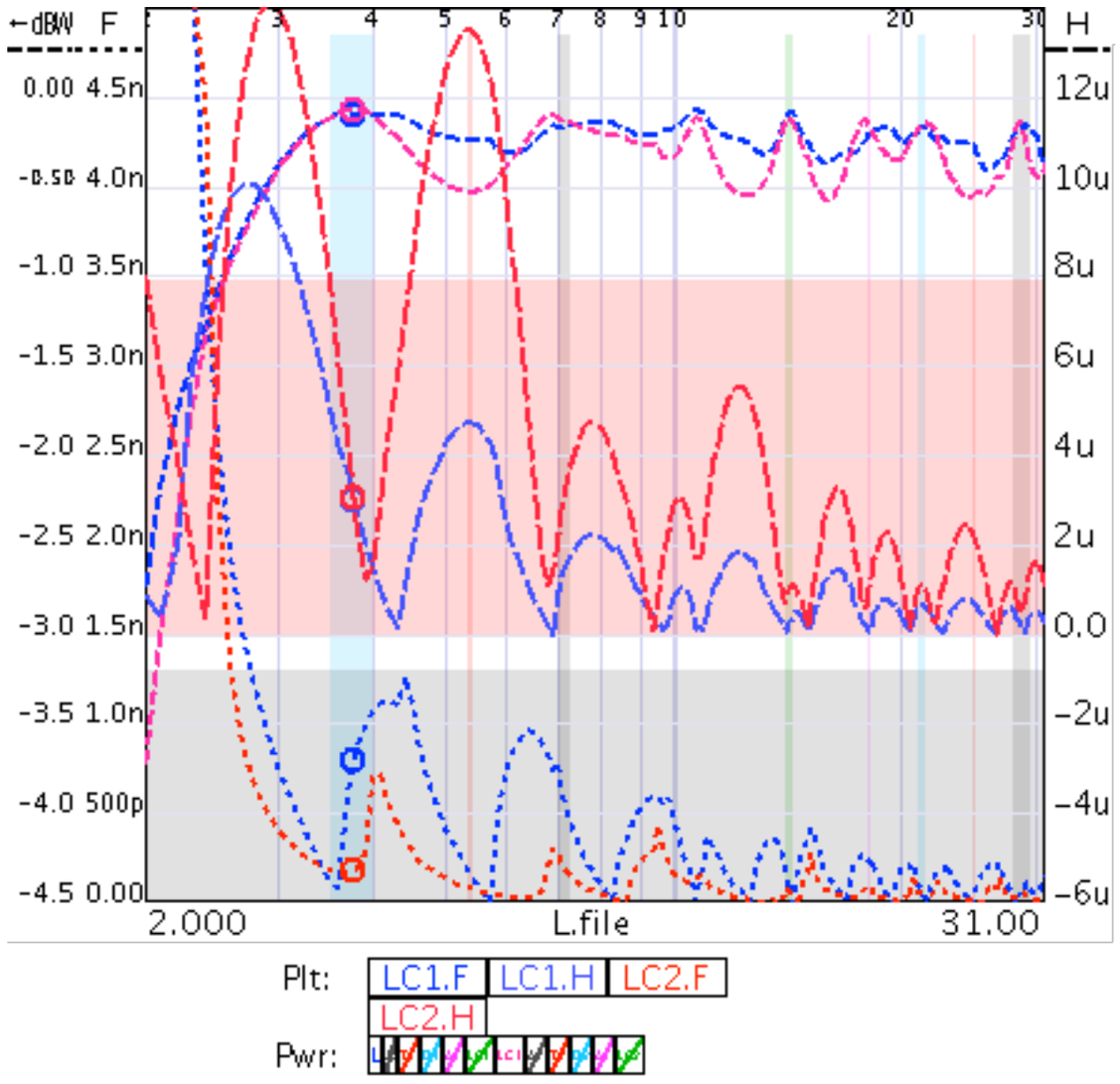
Tuner Demands:

Different ladder line impedances place different demands on tuner. Is this an issue?

Here is 600 (blue) and 300 (red)

Shows Elecraft T1 limits.

playWithLadderZo.ssx

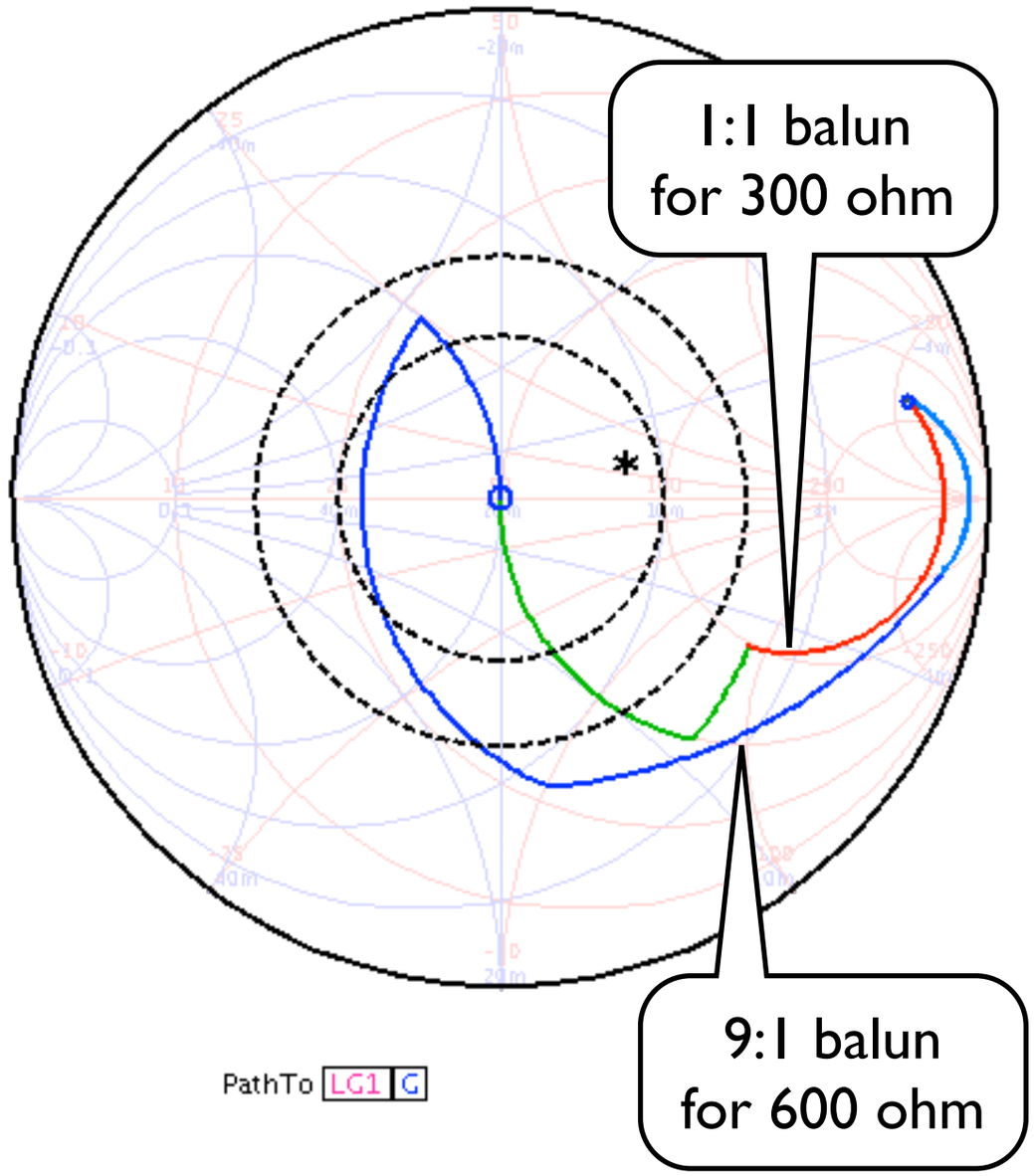


Tuner Demands:

Note that the balun at at the bottom may be different.

600 ohm blue
300 ohm multicolor

playWithLadderZo.ssx



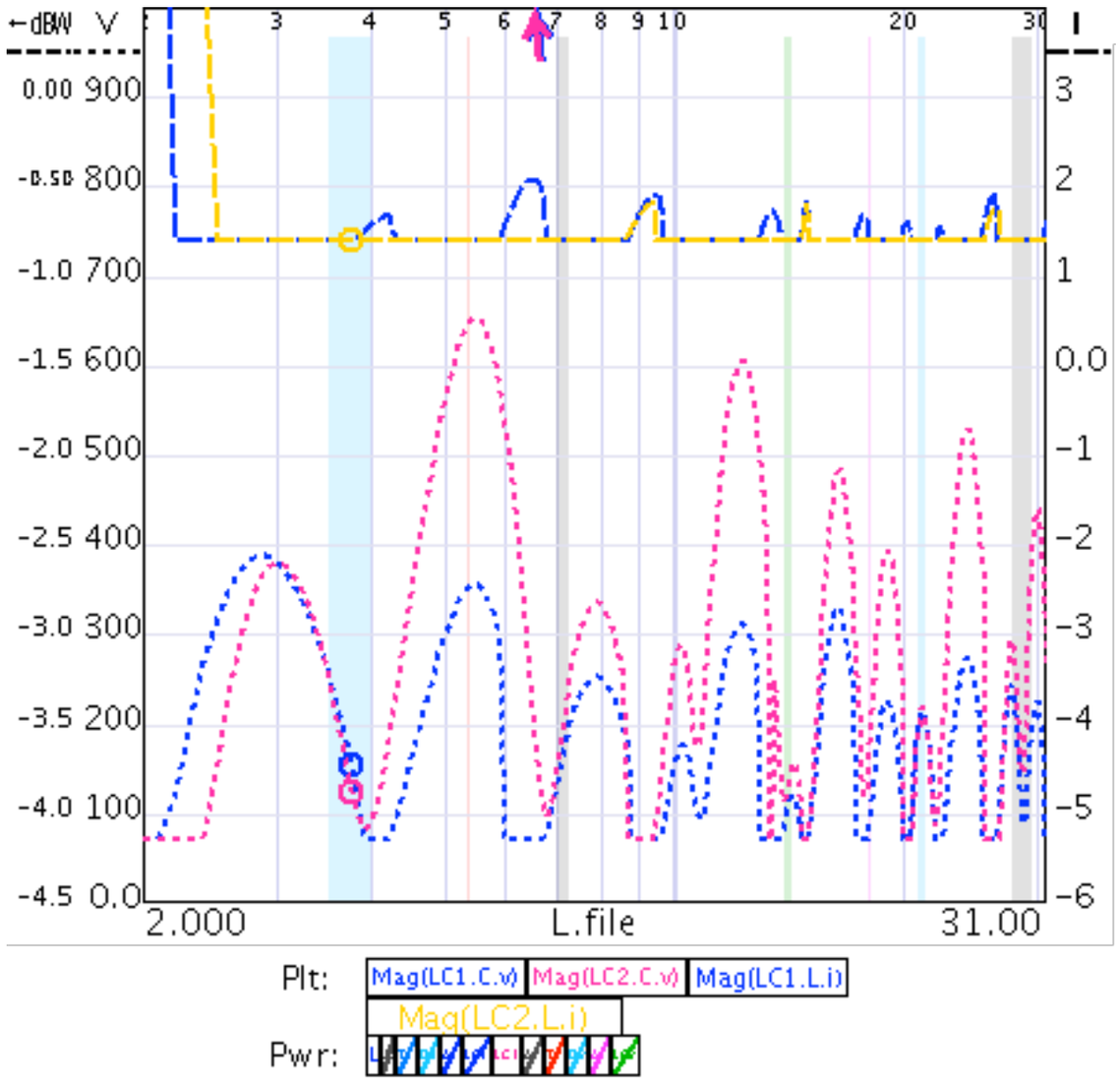
Tuner Demands

voltages and currents for 100 watts.

Note that the balun at at the bottom may be different.

600 ohm blue
300 ohm red

Voltages get pretty high out of band!



So Now Where Are We?

Antenna
- Off Center Fed
- NO Center Load
- 1:1 balun at feed

Feed Line
- 300 to 600 ohm ladder line
- 4:1 balun at tuner

Tuner
- Somewhat more powerful tuner required.

Comparison

Divide and Conquer

- Construct center load
- build/buy 4:1 balun/choke
- Commercial feed line... can be expensive
- ‘Built In’ tuners will work fine
- Modestly efficient at various bands

Wholistic Approach

- Simple wire dipole
- Build choke balun
- Construct ladder line
- build/buy 4:1 balun or build choke balun
- Built in tuner may/may not be sufficient
- Much more efficient on higher bands.

Which Way?

Are you and Assembler

136 foot dipole (> 1/2 at lowest freq)
window line
buy baluns
buy tuner

Are you a Constructor

136 foot dipole (> 1/2 at lowest freq)
build choke balun
build ladder line
build 9:1 balun
build tuner.....

Disclaimer(s)

Didn’t take tuner losses into account.
Didn’t explore dipole length much.
Didn’t explore dipole height.
Didn’t explore ladder line construction.
Didn’t explore tuner topology at all.

Lots of exploration left to be done....

Can’t build them all....

Use simulation!

simulation tools are not perfect but...

they can help understand trends and tradeoffs.

Personal Note: if a simulation says something is a VERY BAD idea... it probably is, at best, BAD.

Let’s do some simple exploration now…

What Is Happening to Zo

What happens to impedance sweep when we play with Zo.
Interactive demo…

playWithZo.ssx

Smith chart:

plot L.Z: dotted lines

now plot T1.Z: solid and wider lines.

Notice:

display Path

play with topology with Zo < 200

What Is Happening to L & C

square chart: playWithZo.ssx
display power into L
    demonstrate Q.
notice lowest band is the problem
    try adjusting Zo to make things easier.
    notice ‘bump’ in L when topology changes.
    topology change helps L but not C very much.

Adjust length
    (restore to single topology)
    eases L but not C

Hey… we left balun out!

Smith chart: playWithZoWithBalun.ssx

play with Zo and length.
watch impedance out of balun.

How about Power?

square chart: playWithZoWithBalun.ssx
display power into L

increase length….
watch what happens to power at 28 MHz
watch what happens to L & C at

increase Zo of balun
watch power and L & C

Thanks

These slides are available on my website.

Informal video of dry run available on my site.

Videos related to Smith chart on youtube.

Search for ae6ty or w0qe.

website:

www.ae6ty.com