VE3KL
Antenna Tuners Revealed
(2010-2014 Study)

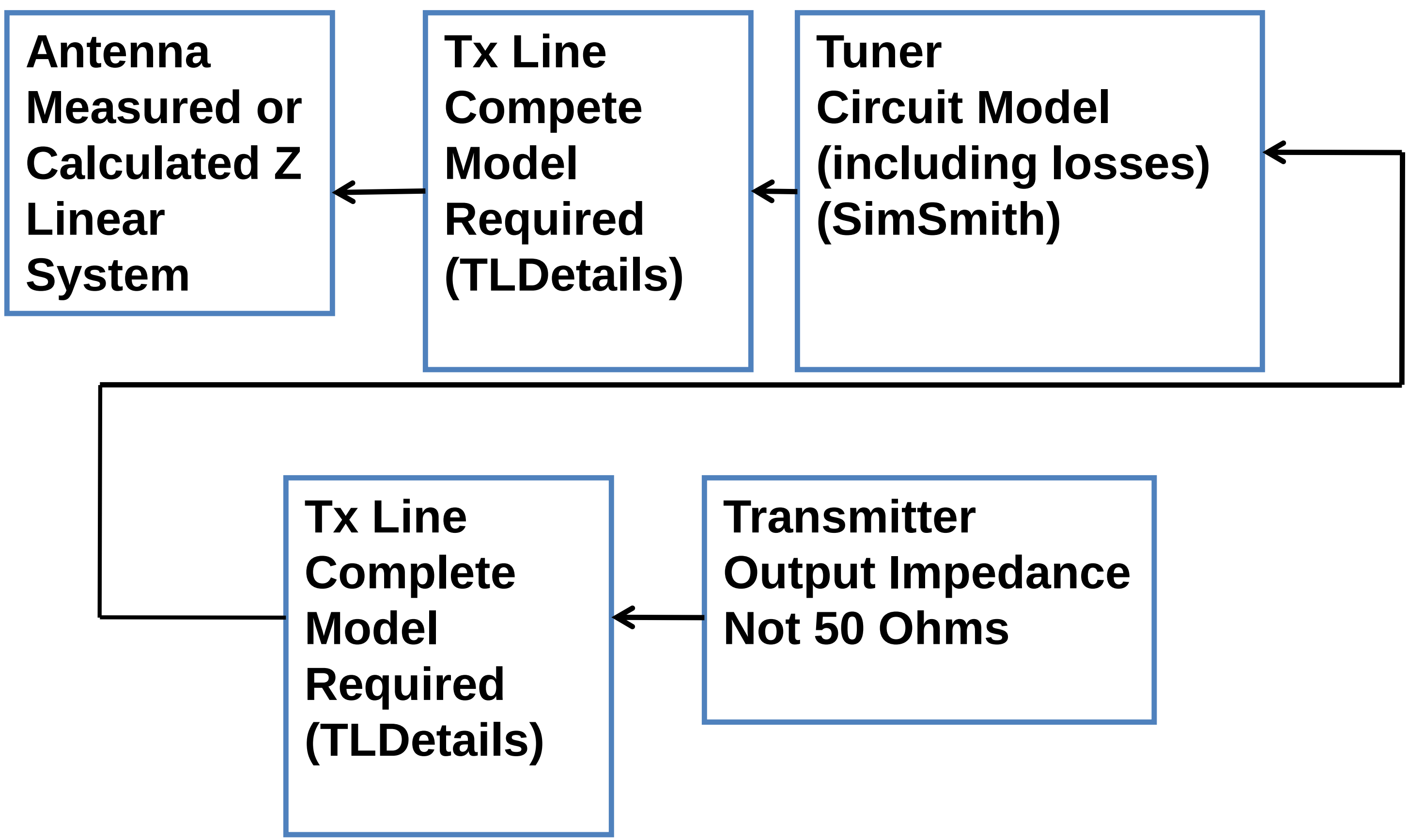
- A General Approach for all Tuners…the goal
- How to Look at Tuners……Smith Chart?? **No.**
- Use the Impedance Z plane
- Use SimSmith for system analysis…4nec2x, VNA for data
- Use the L match as a basic building block
- Several Examples: VE3XK 43 foot Vertical
- *Easy to tune into a bed spring but at what cost?*
- Losses, Bandwidth, Voltages, Currents, Return Loss

Antenna Tuners VE3KL

Introduction

Block Diagram for Analysis

(Note Right to Left Flow)



The Problem & Basic Questions

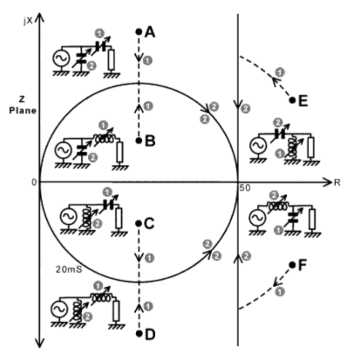
- Transform from any Z to 50 Ohms..usually a filter
- How to Design a Tuner
- Only Two Tuning Elements needed (max)
- What is the best circuit? There isn't one!
- Components? Roller Inductors have Low Q if not maintained very carefully
- How to analyze the complete system?
- How to use real data.. Spice does not do well with transmission lines

Many Tuner Types since 1955
Need a Common View

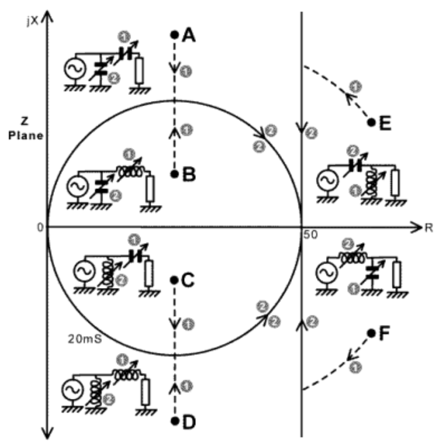
- L Match….. Six Types
- T Match….. Two Types (many variations)
- PI Match…..Two Types (many variations)
- Z Match…….A few variations
- EF Johnson Match Box Tuner…Several Types (Some Capacitors not needed)
- Transformer type for resistive loads..end fed half wave antenna

Match Box Tuner

Design Method


jX
Z
Plane
A
B
C
D
E
F
0
50
R
20mS

Z Plane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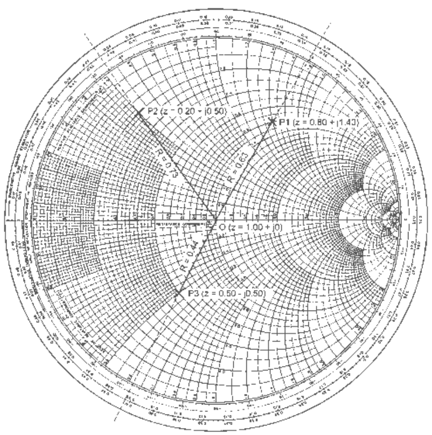
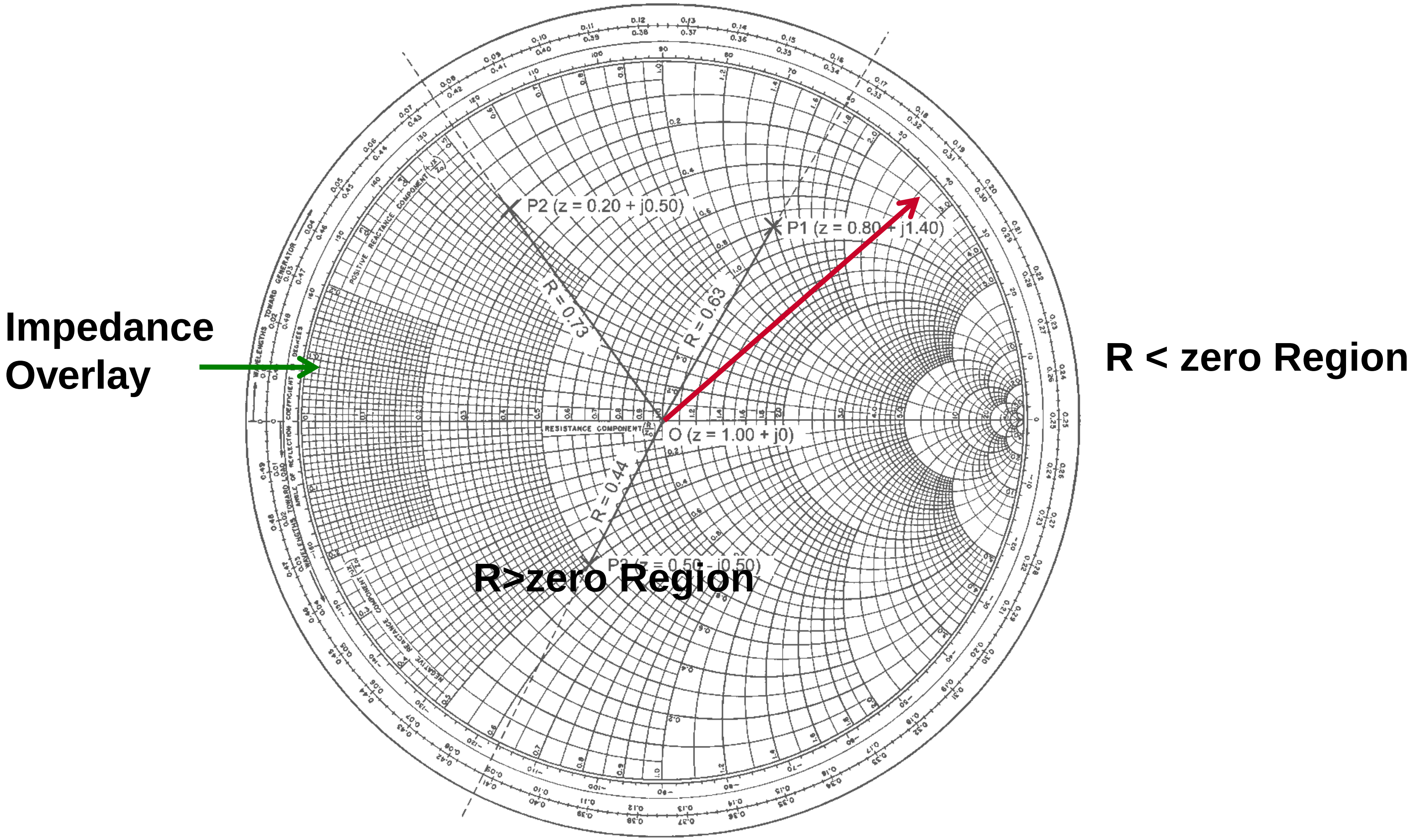
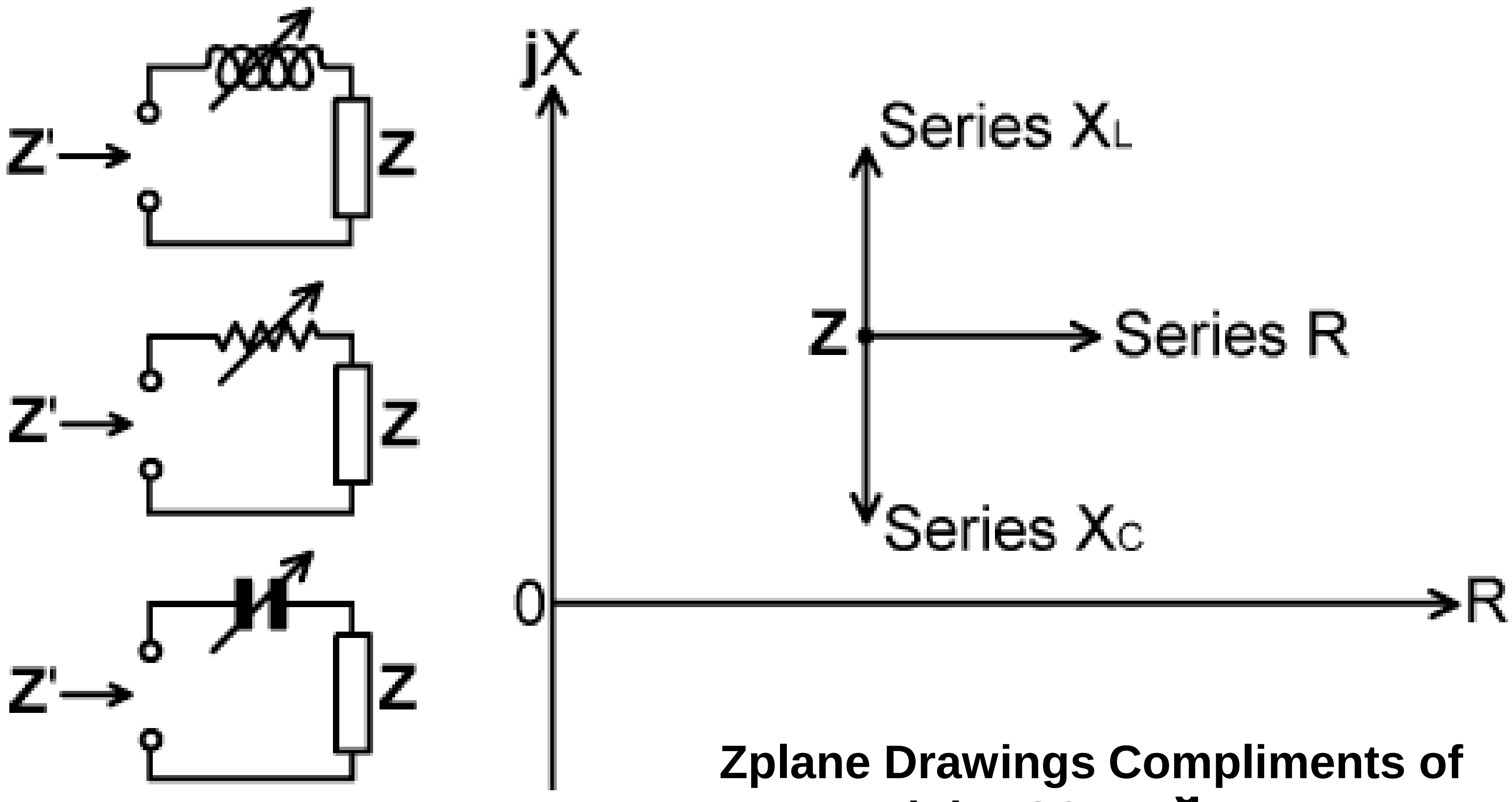

P2 (z = 0.20 + j0.50)
P1 (z = 0.80 + j1.40)
O (z = 1.00 + j0)
P3 (z = 0.50 - j0.50)

Smith Chart: Reflection Coefficient
Hard to Visualize Using LC Tuners
Many Overlays: Z,Y,SWR,RL,NF,
Max Power, Negative Resistance Parametric Amplifiers



Z Plane Ideal for LC and Simple Matches
Impedance based
Series Loads

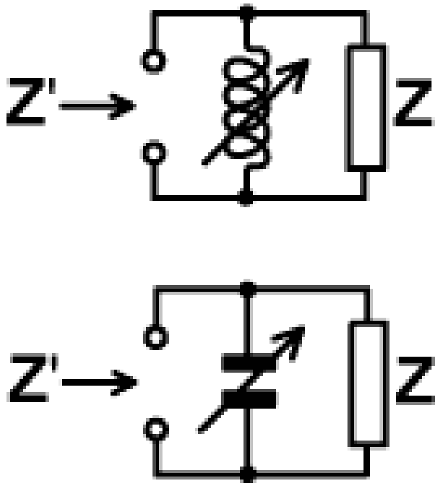


Zplane Drawings Compliments of Dave Knight, G3YNH

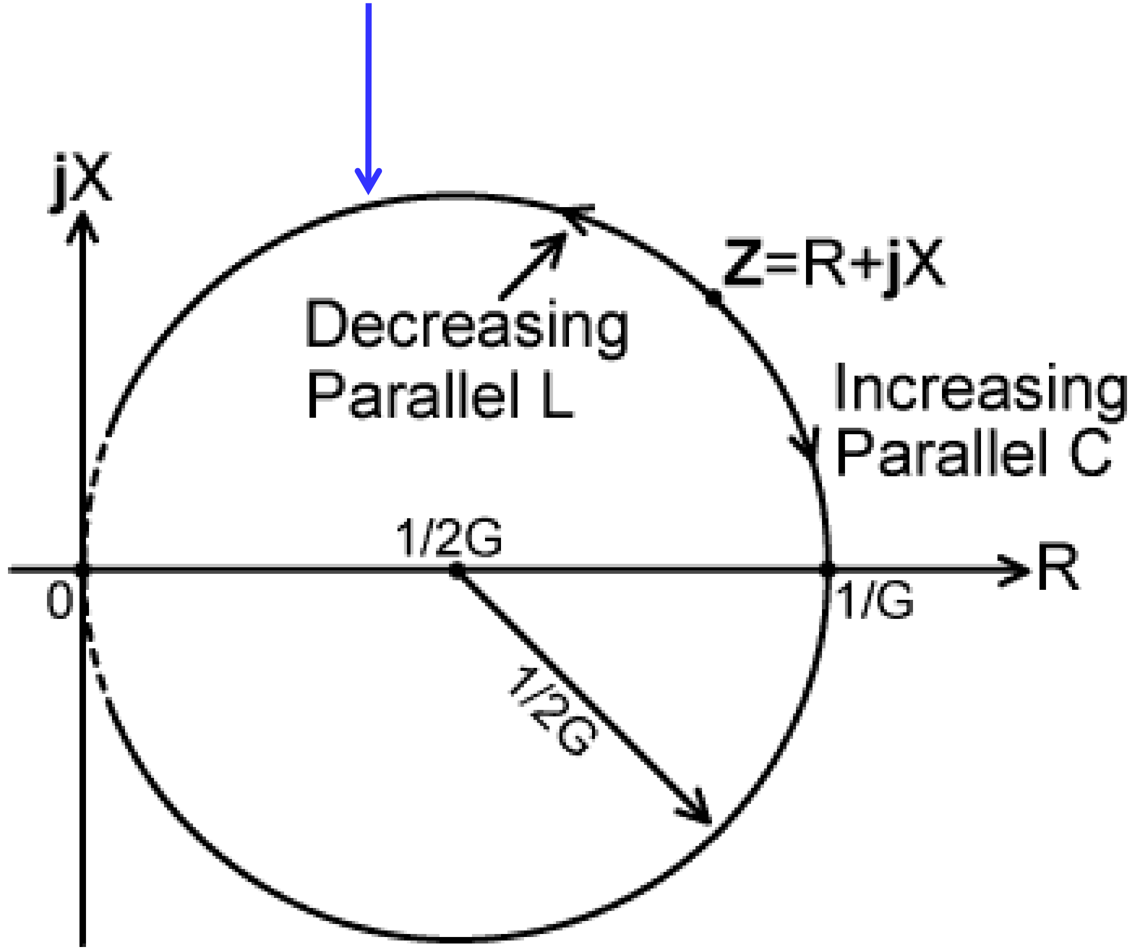
Z Plane Parallel Loads

Z=1/Y   Y = G +jB

Circle of Constant G



$$G = \frac{R}{R^2 + X^2}$$



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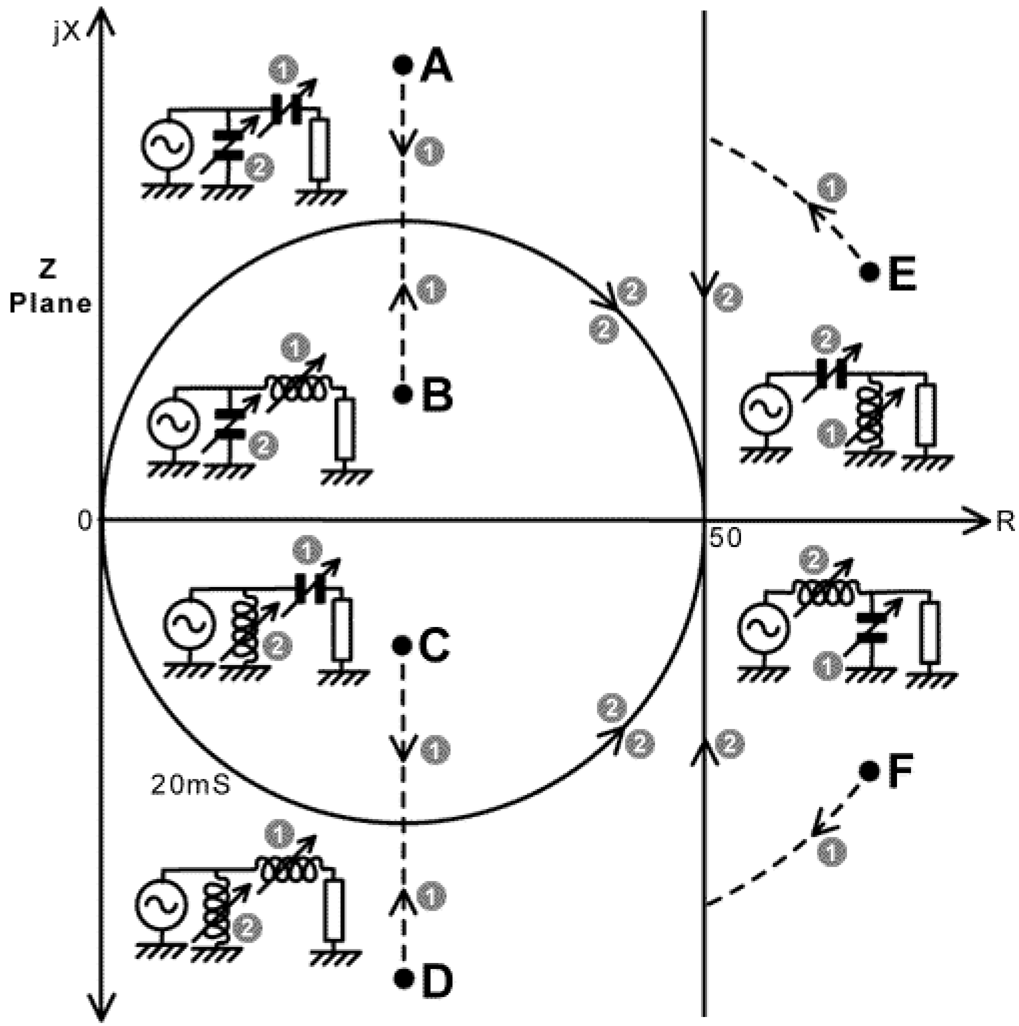
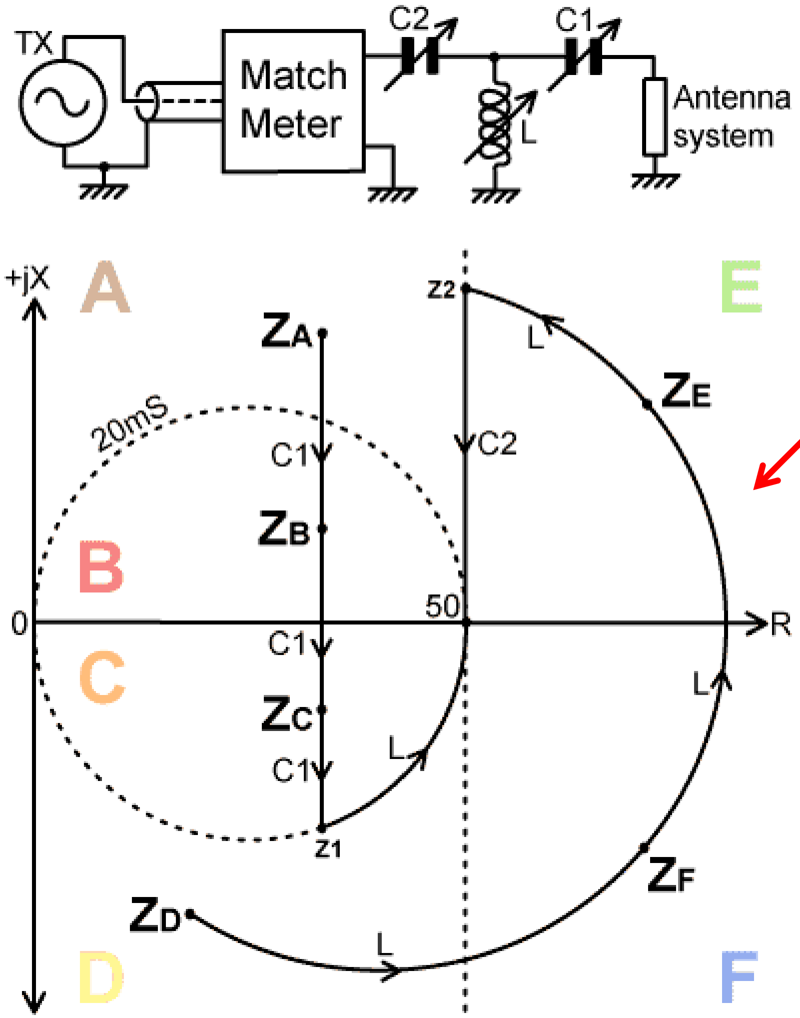
Z Plane Region
L Match Types Six Regions



Z Plane Region TMatch
Regions A,B,C,D,E,F



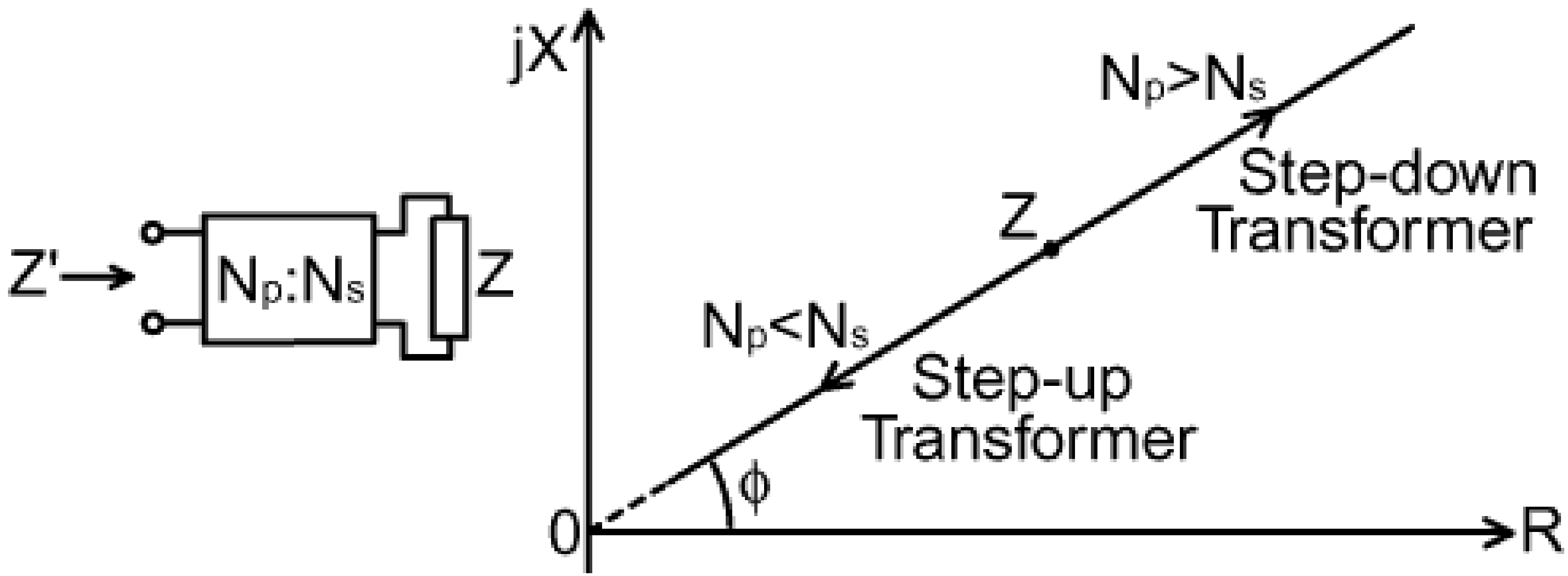
Special Cases

Region A,B,C: C2 = infinity
Region D,E,F: C1 = infinity

Many Other Tuning Strategies

Palstar Differential C Tuner
C1 = kC2…….K variable.

Transformer
Preserves Phase Angle of Impedance
Used in VE3KL End Fed Halfwave 20 Metre Antenna



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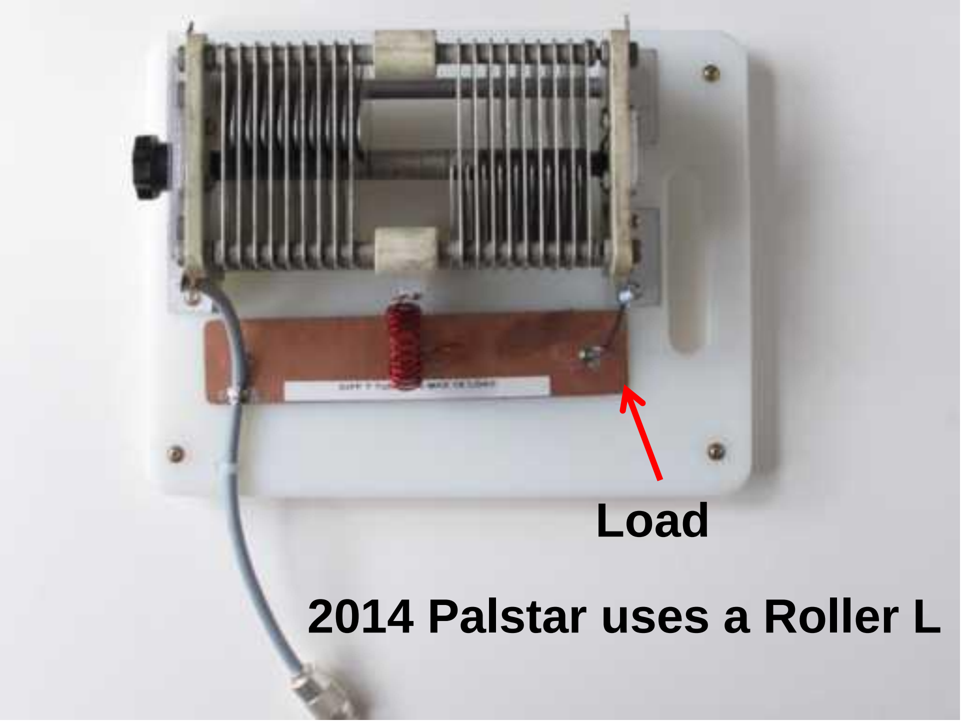
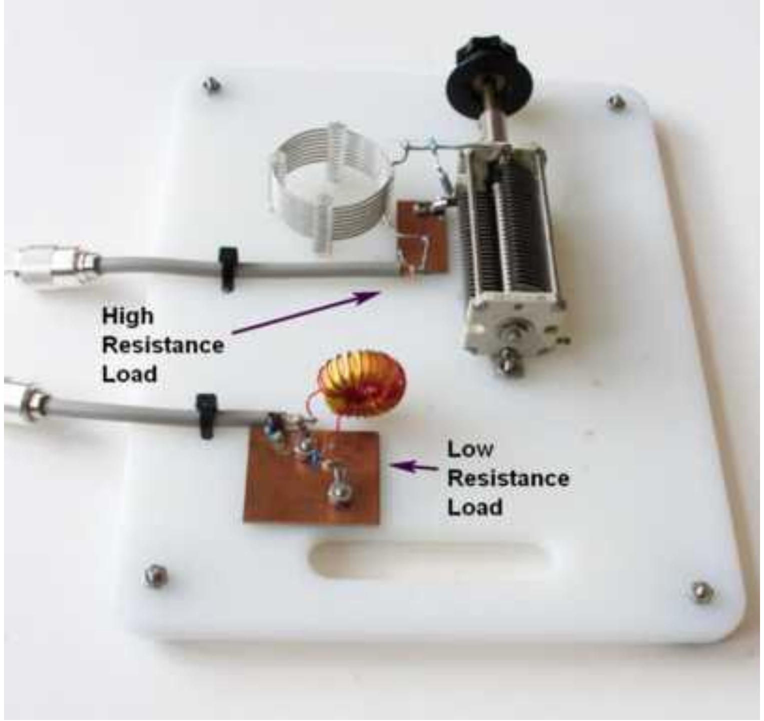
Time for some Measurements

Differential T Type
Rload = 1000 Ω
L = 3.55 uH Powdered Iron

Two L Match Tuners
High R & Low R

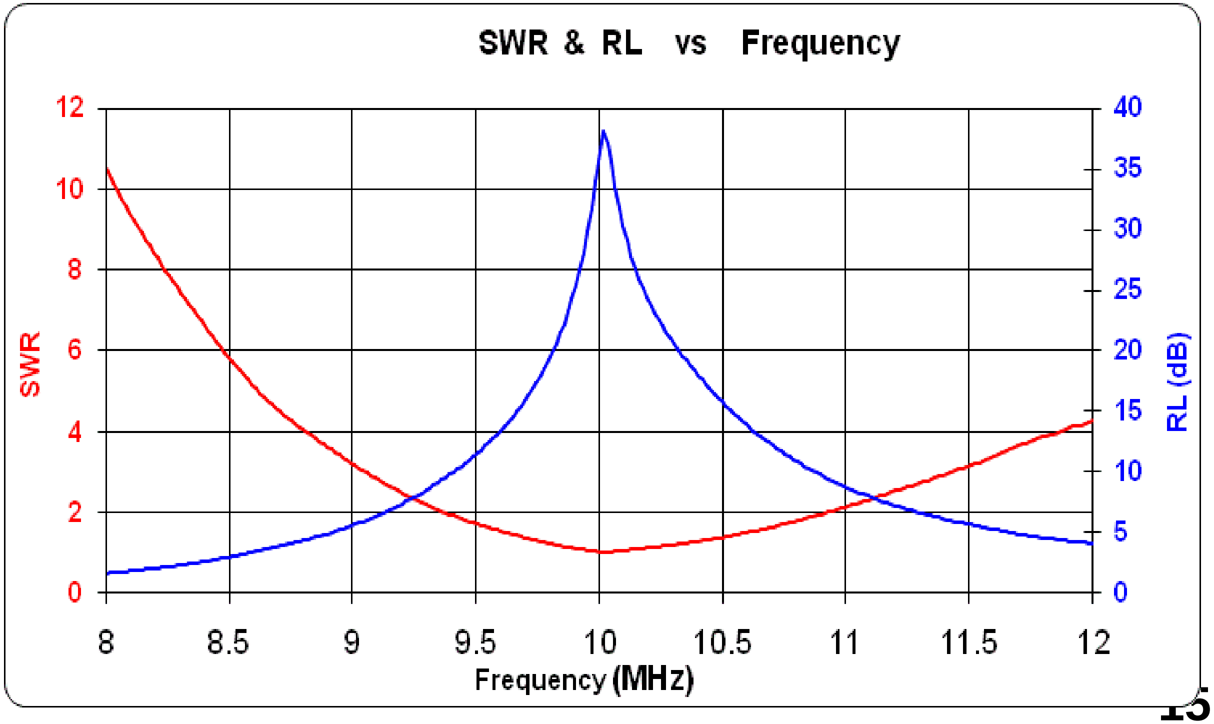




VE3KL
Antenna Tuner Examples
(2010-2014 Study)

Differential T Type....Measured
Rload = 1000 Ω
L = 3.55 uH Powdered Iron

Note the High Return Loss @ 10 MHz



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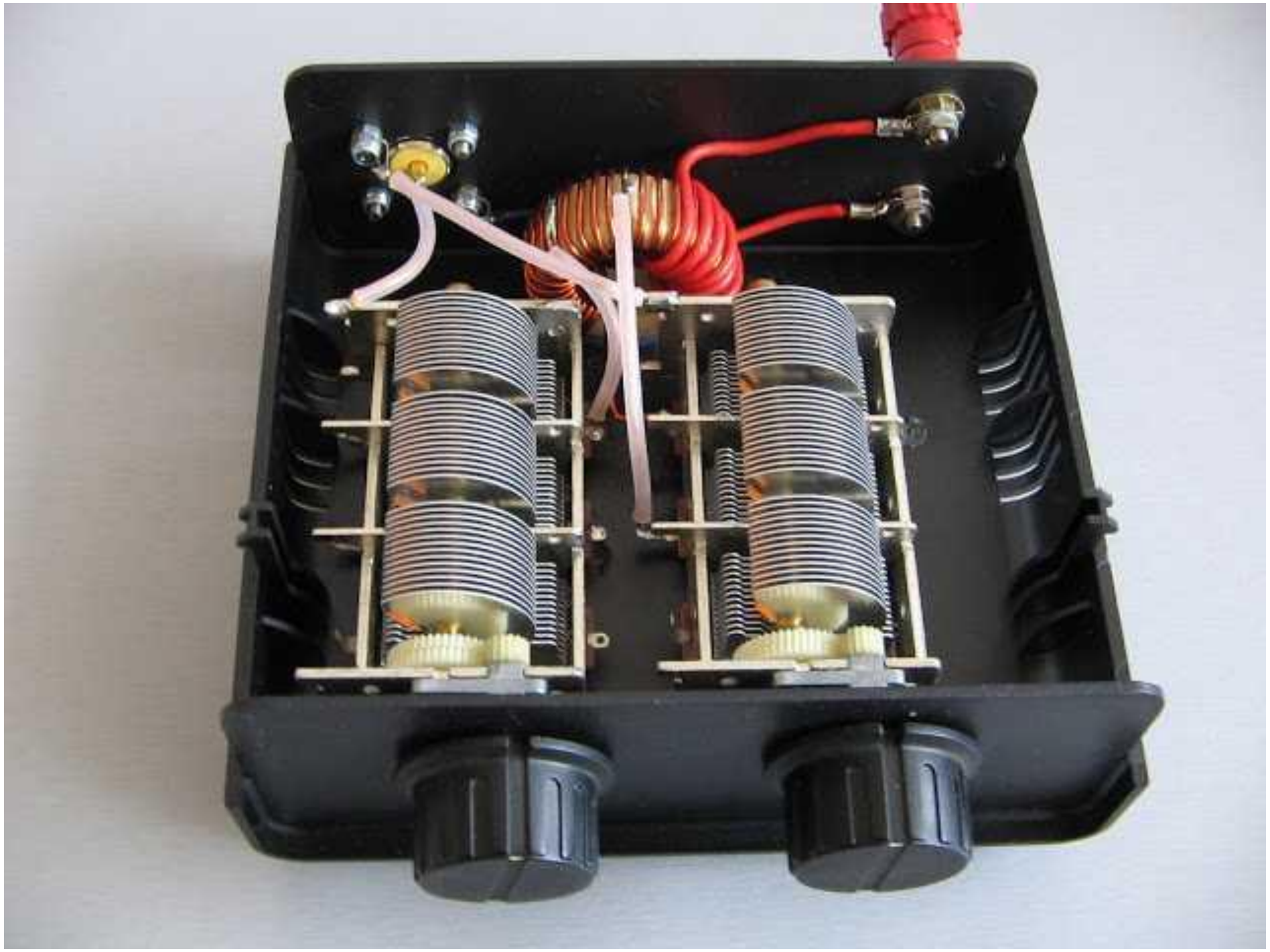
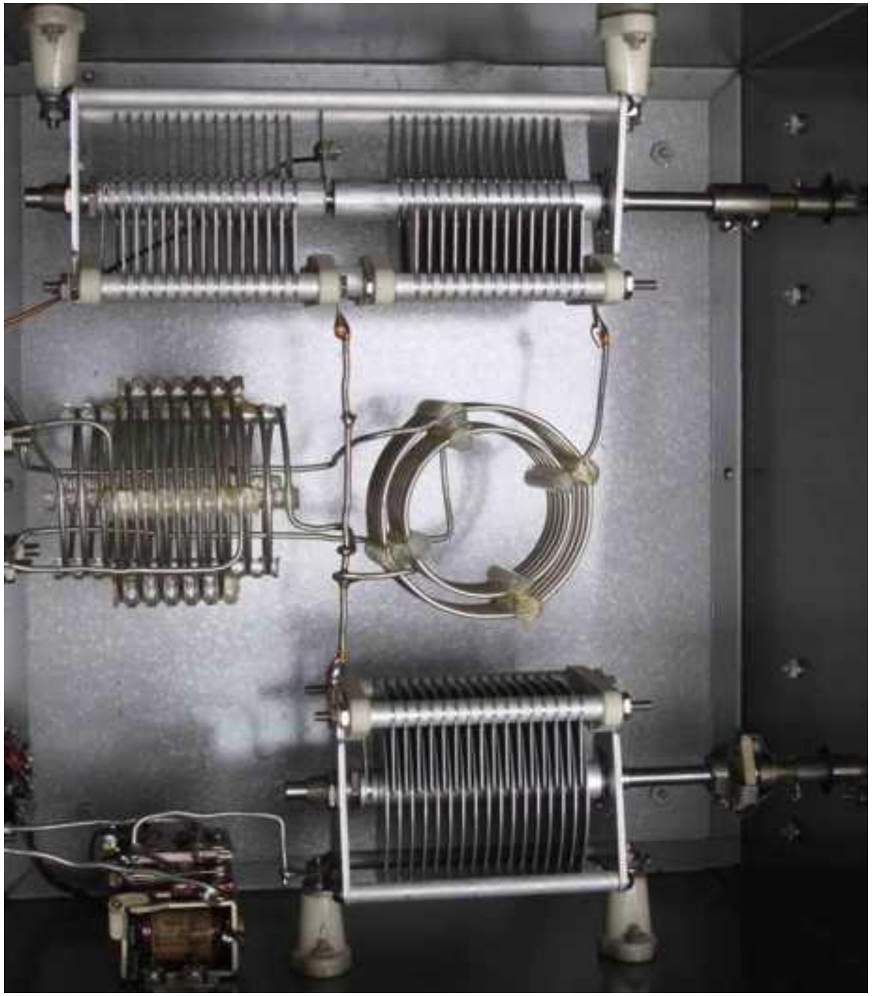
Z Match
Two Tuning Capacitors
PD7MAA 100 Watt T200 Toroid

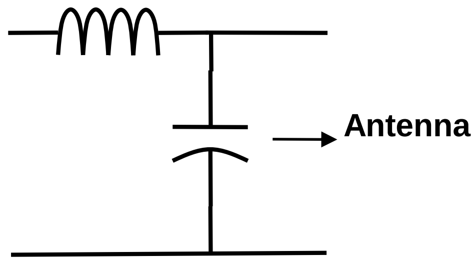


VE3KL
Antenna Tuner Examples
(Zmatch Two Coil Type Jim Dean VE3IQ Built 1957)
Design 1955

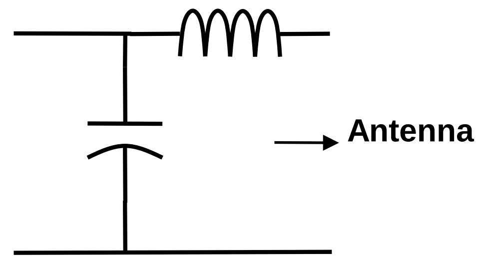


Two Tuning Knobs

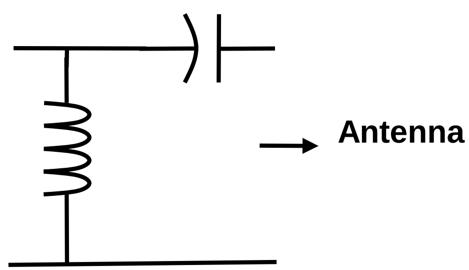
The Basic Circuit… Lmatch Summary



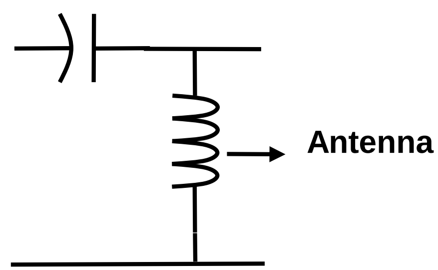
(a) Low Pass L-C
High Resistance Antenna
> 50 Ohms, All Reactive Loads



(b) Low Pass L-C
Low Resistance Antenna
< 50 Ohms, Drop-Out for some Inductive Loads



(c) High Pass L-C
Low Resistance Antenna
< 50 Ohms, Drop-Out for Some Capacitive Loads



(d) High Pass L-C
High Resistance Antenna
> 50 Ohms, All Reactive Loads

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Simulation Tools and Data Collection

- Measured or simulated antenna impedance
  - VNA such as an AIM 4170
  - EZNEC or 4nec2 for Antenna Simulation
- TL Details for Transmission Line Data
- SimSmith for System Simulation

Imports data from VNA, Antenna Simulators, TLDetails

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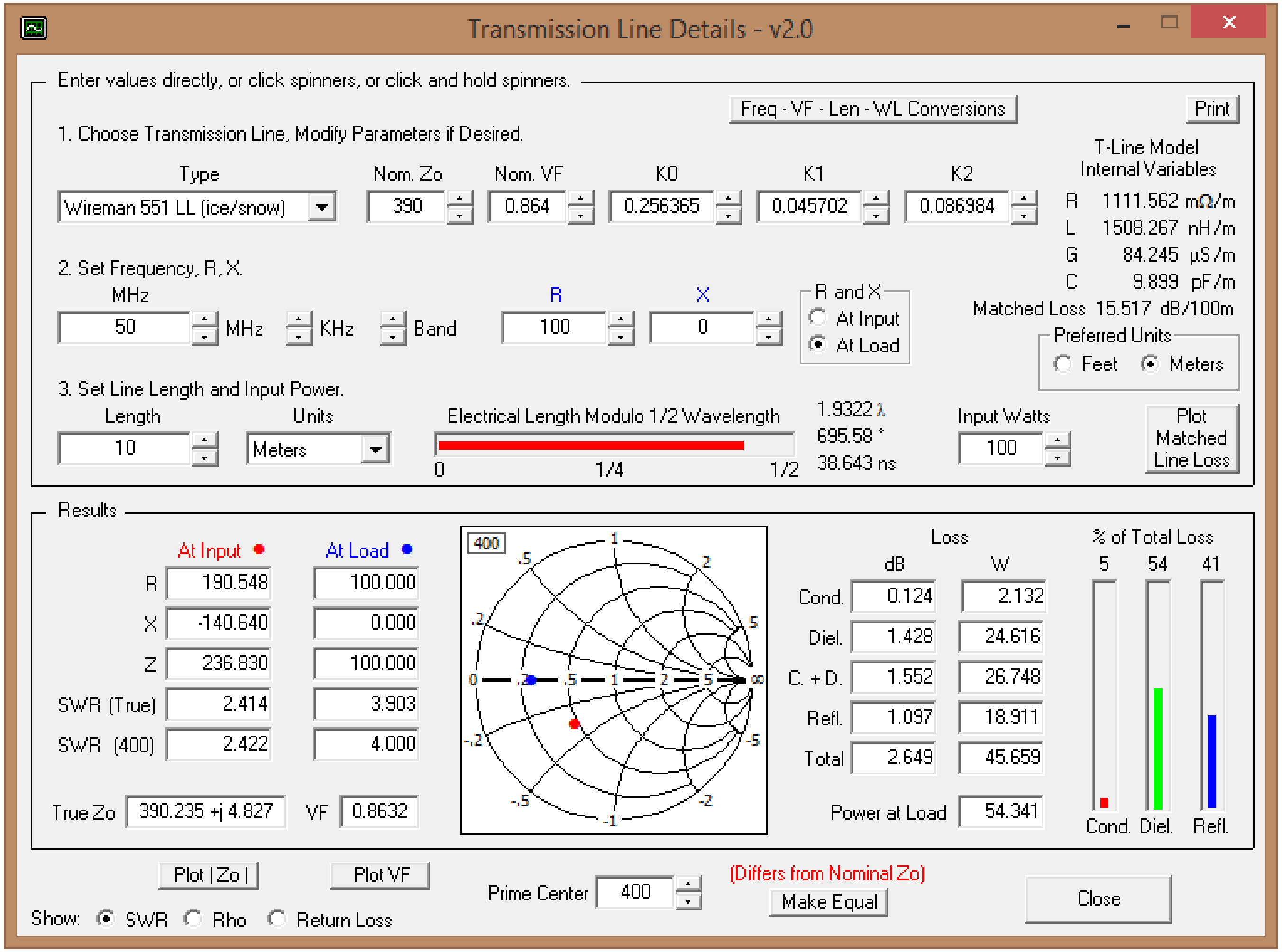
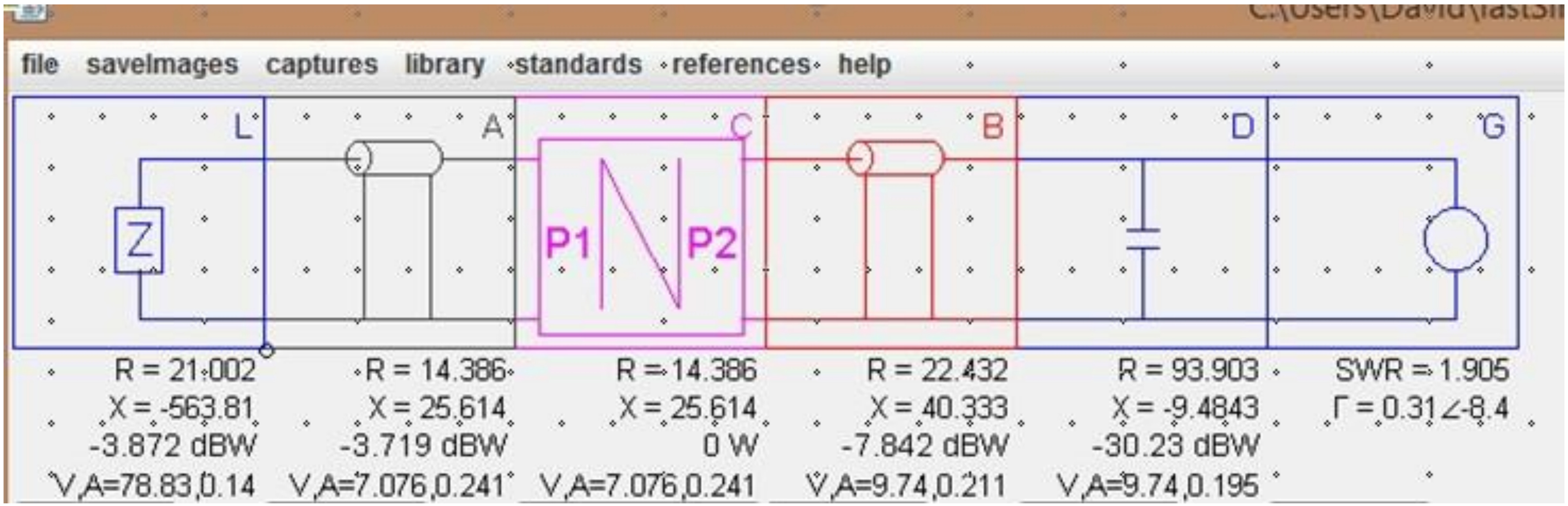
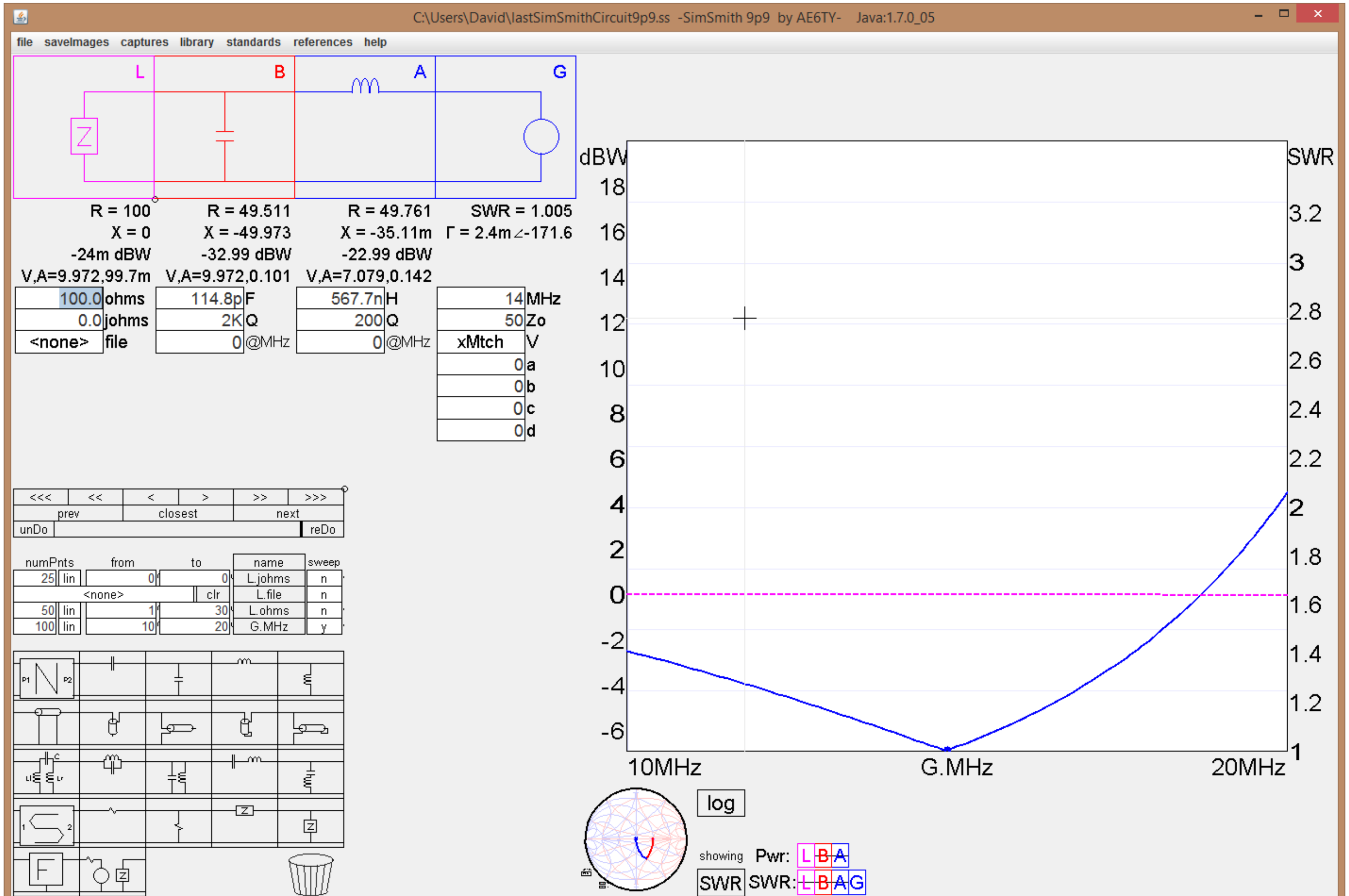
TLDetails
Example Wireman 551 Window Line
Loss 2.6 dB 50 MHz Ice Covered 10m
Tx Modeled as a zero Z impedance



SmithSmith
The Cascaded System tool
Uses TL Details
Imports Antenna Data from VNA,EZNEC ,4nec2



SmithSmith
LC Example 100 Ohm Load
Type (a) L Match



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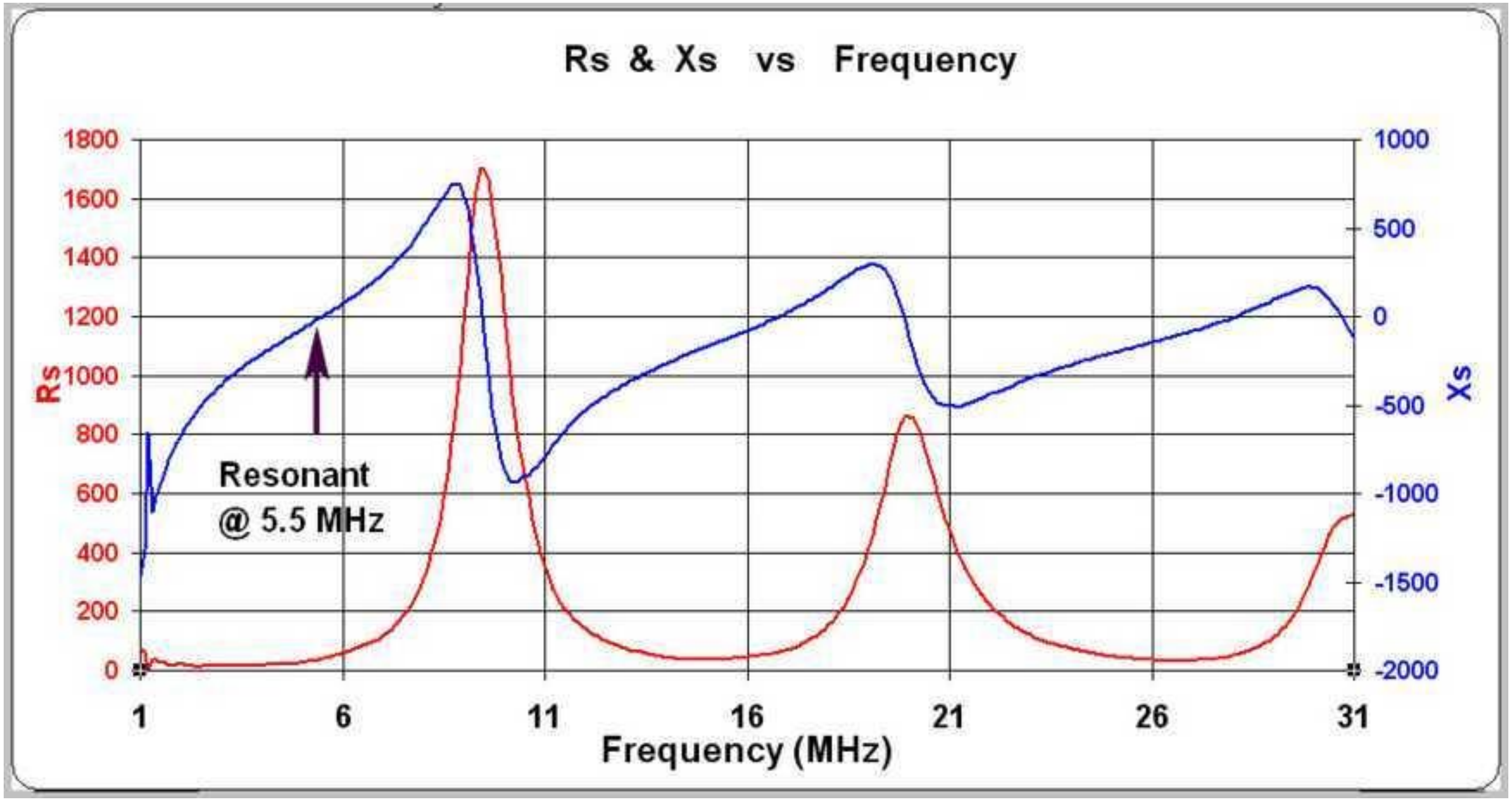
VE3XK Vertical ..An example
1.9 MHz Low R 18.1 MHz High R
Measured Impedance 1-31 MHz



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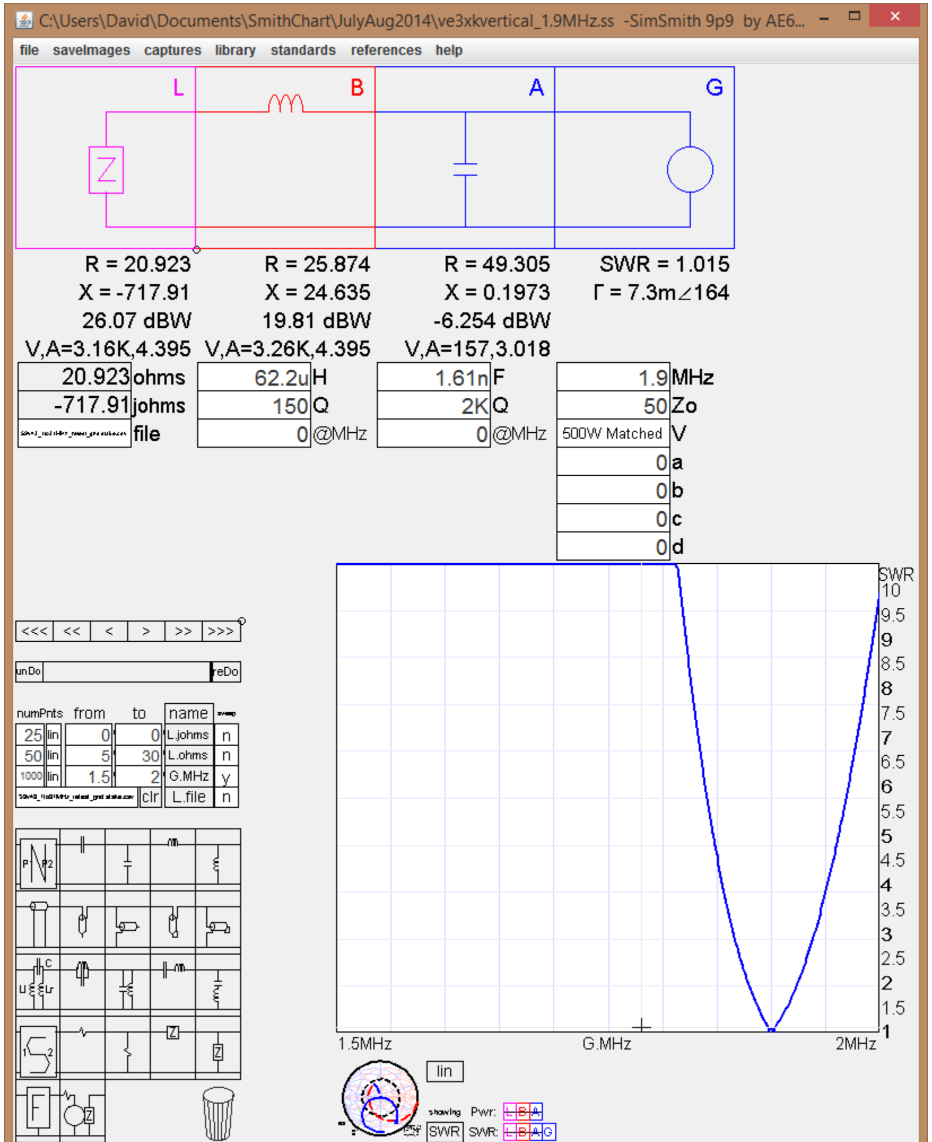
SmithSmith

VE3XK Vertical Antenna Using Measured Impedance Values

1.9 MHz R Load < 50 Ohms B type LC



- •Good Match
- •L = 62 uH
- •Very Narrow Bandwidth
- •High Voltages (>3KV RMS)
- •0.96 dB Loss
- •96 W loss in Inductor
- •500 WattsTx

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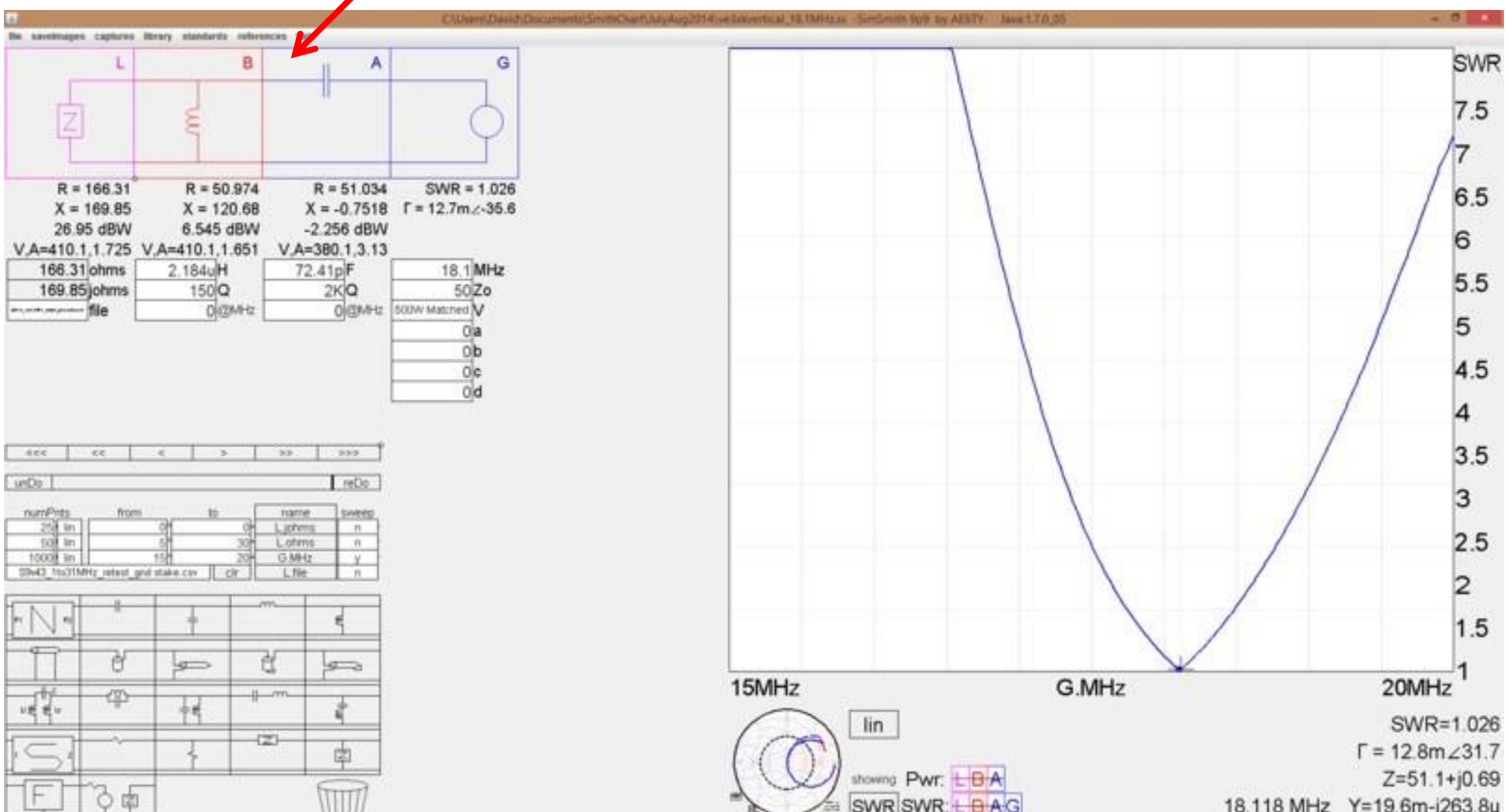
SmithSmith
VE3XK Vertical Antenna Using Measured Impedance Values
18.1 MHz

- Good Match
- Wide Bandwidth
- Low Voltages (<410RMS)
- 0.05 dB Loss
- 6 dBW loss in Inductor

New Topology Based on Z Plane
R Load > 50 Ohms D Type LC

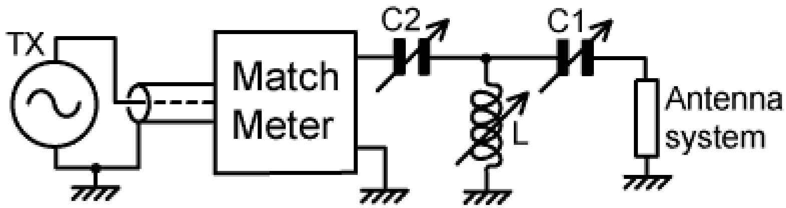


SmithSmith
VE3XK Vertical Antenna Using Measured Impedance Values Summary

Transmitter Power 500 W Continuous, VE3XK Vertical				
Frequency [MHz]	Tuner Type (See L Match Summary)	Load Power [W]	Power Lost in L [W]	Voltage across L [V]
1.9	(b)	405	96	3260
3.7	(d)	425	73	1330
5.3	(b)	495	5	191
7.1	(a)	488	12	552
10.1	(d)	476	22	940
14.2	(b)	484	16	908
18.1	(d)	495	4	410
21.2	(d)	480	19	709
24.9	(d)	472	27	672
28.5	(a)	496	3 26	150

T Match.. A Closer Look

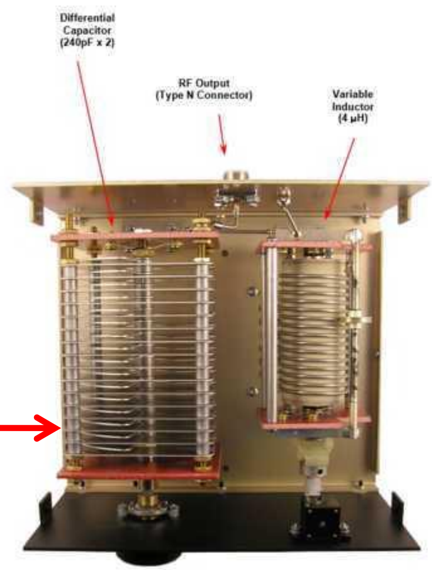
Three Tuning Elements only Two Needed..but



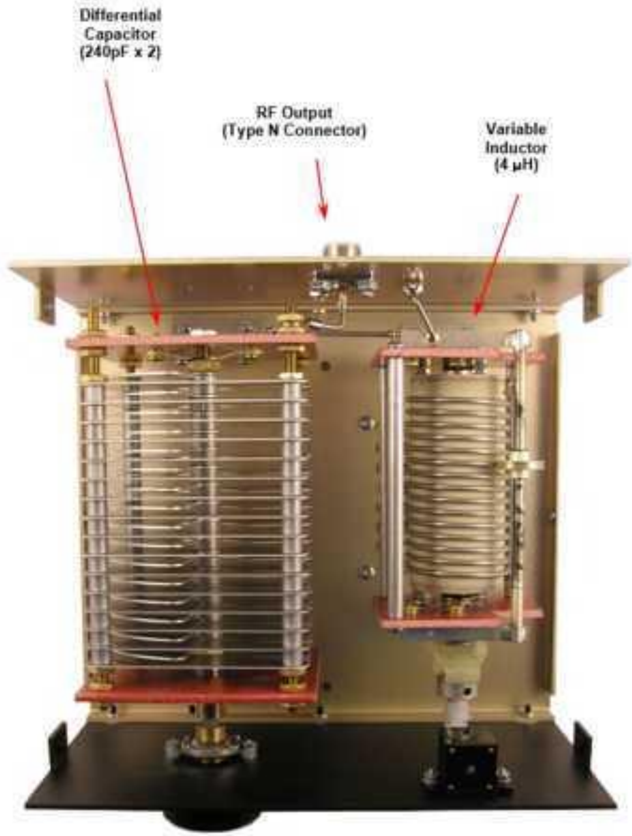
- Three gives a broad range if a tuning method can be developed
- Three needed if L is a switched inductor
- C1 and C2 can be part of a Differential Capacitor (Two knobs to tune)

C1=K1*C2 + K2   0<k1<1

Palstar Diff. Cap T Tuner



Palstar AT 1500 Manual Tuner
Two Tuning Elements: Easy to Tune



Note the Use of a Fan
To Cool Roller Inductor

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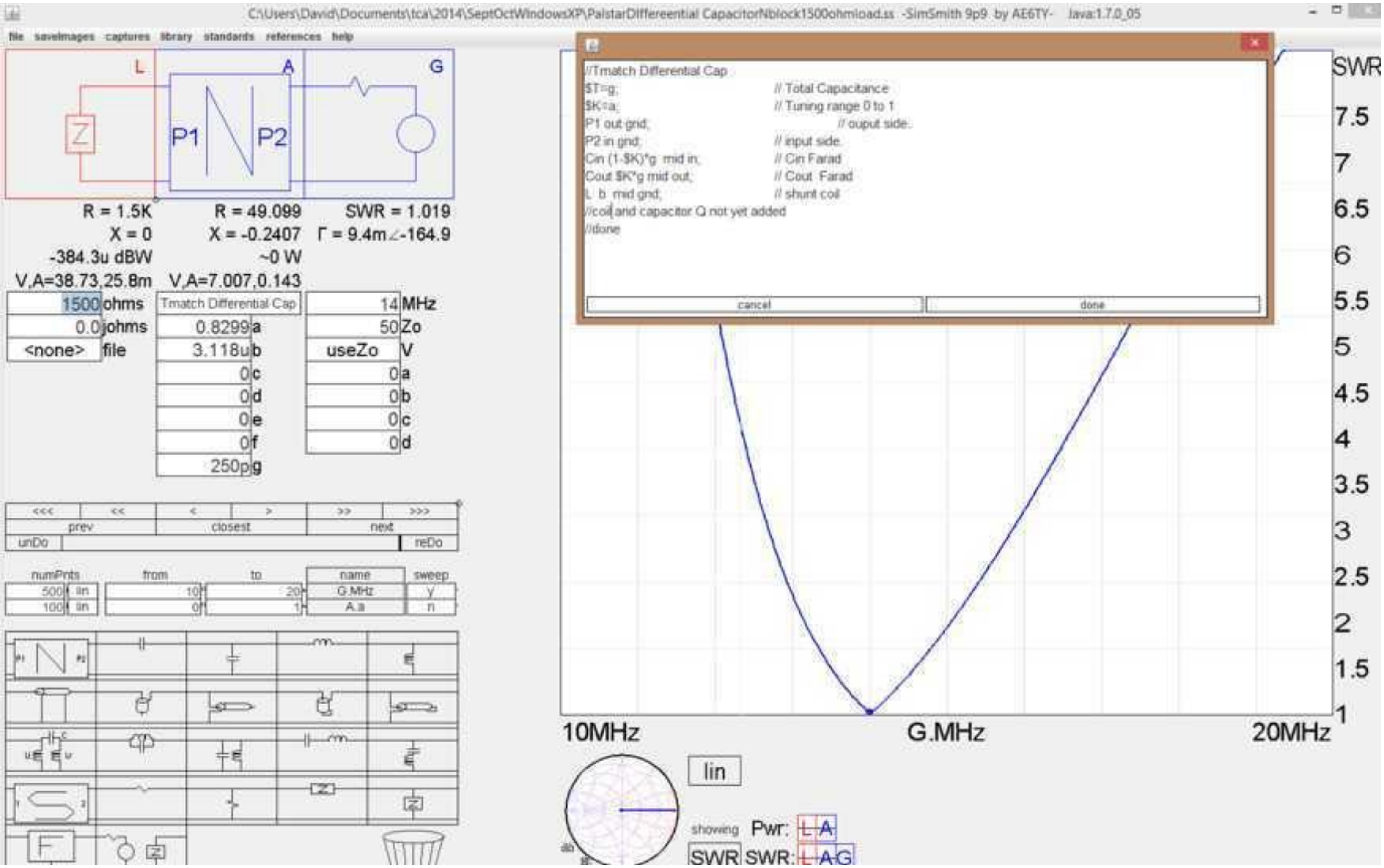
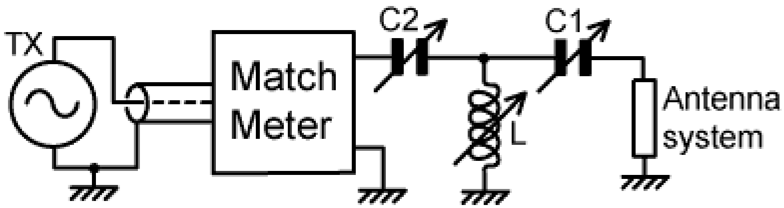
Palstar AT 1500 Manual Tuner Performance SimSmith



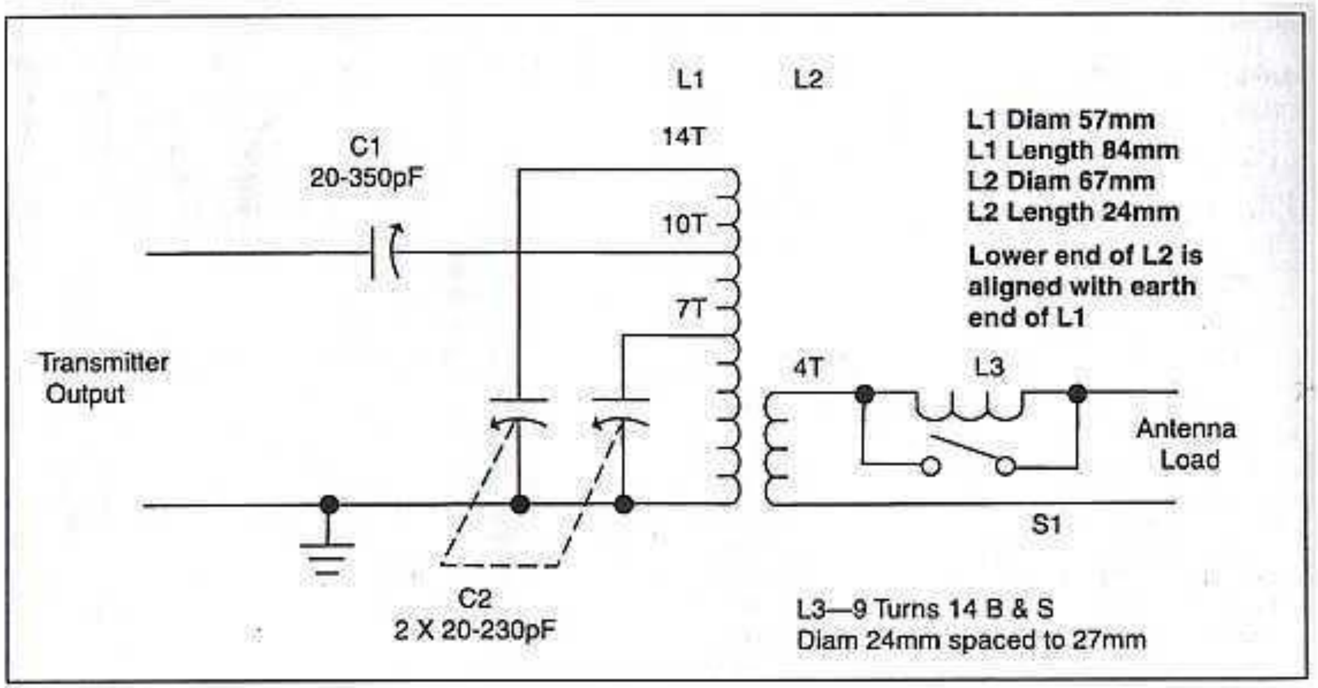
T Match.. A Closer Look
Three Tuning Elements…Some Examples



T Type Tuner Simulation Transmitter Power 500 W 10 MHz Inductor Q = 200 Capacitor Q = 2000						
Tuner #	*RL [Ω]*	*C_S [pF]*	*L [uH]*	*C_L [pF]*	*Power in L [W]*	*Circuit Q*
1	300	15	12	6	72	15
2	300	45	4.1	19	31	5
3	300	113	2.0	75	9	2
4	25	22	5.1	28	82	15
5	25	66	1.7	88	29	5
6	25	452	0.56	450	5	1
7	0.1	18.6	1.48	152	391	Not calculated
8	50	225	0.84	225	7	Not Calculated
9	50	24	5.4	23	63	Not Calculated

Short Circuit

Z Match
Single Coil Type VK5BR
Two Tuning Knobs
Essentially a Series C Shunt L Match
Rp Reflected from Antenna > 50 Ohms
Possible Drop Out Regions
Type (D) Circuit



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Summary

- Z Plane Clarifies the Design Process
- SimSmith Does the Number Crunching
- TLDetails Supplies Transmission Line Data
- VNA Collects Measurements
- EZNEC, 4nec2 does the antenna simulation
- See references TCA, VE3KL, July/Aug..Sept/Oct 2014

Tools Now Available to Evaluate Most Tuner Types

73 Dave VE3KL

References

- Dave Knight, G3YNH..Impedance Matching
- SimSmith Simulator, AE6TL
- TLDetails AC6LA
- EZNEC, W7EL
- See references TCA, VE3KL, July/Aug..Sept/Oct 2014

Tools Now Available to Evaluate Most Tuner Types