Lessons From
the
Smith Chart

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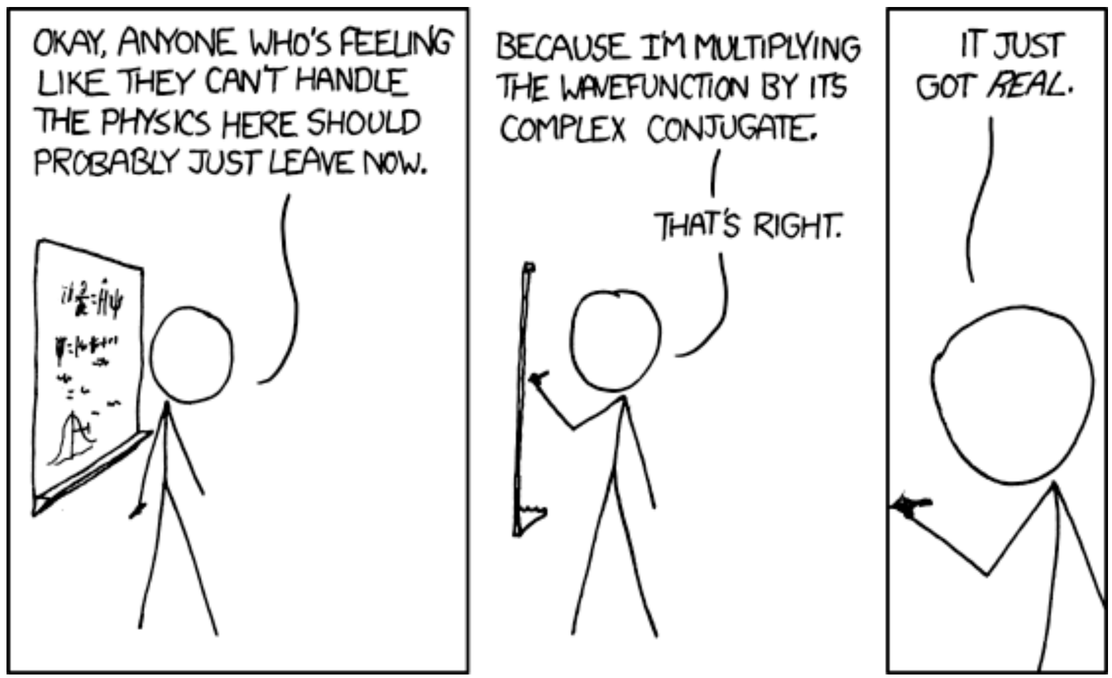
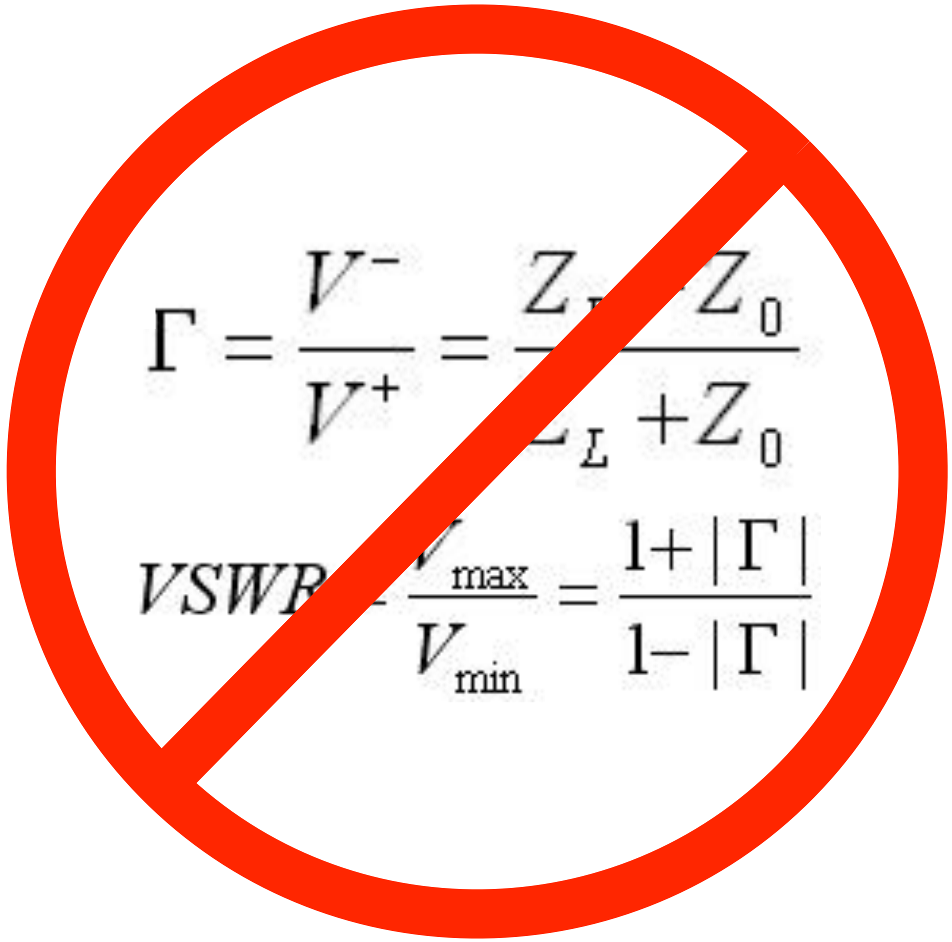
Pacificon '13



Modified from http://xkcd.com/849/

The Smith Chart…
A Pragmatic Presentation



Simple device

Don't muddy the waters with equations of 'Standing Wave Ratio' and 'reflection coefficients' or 'complex math'...

Smith chart is just an unusual form of graph paper.

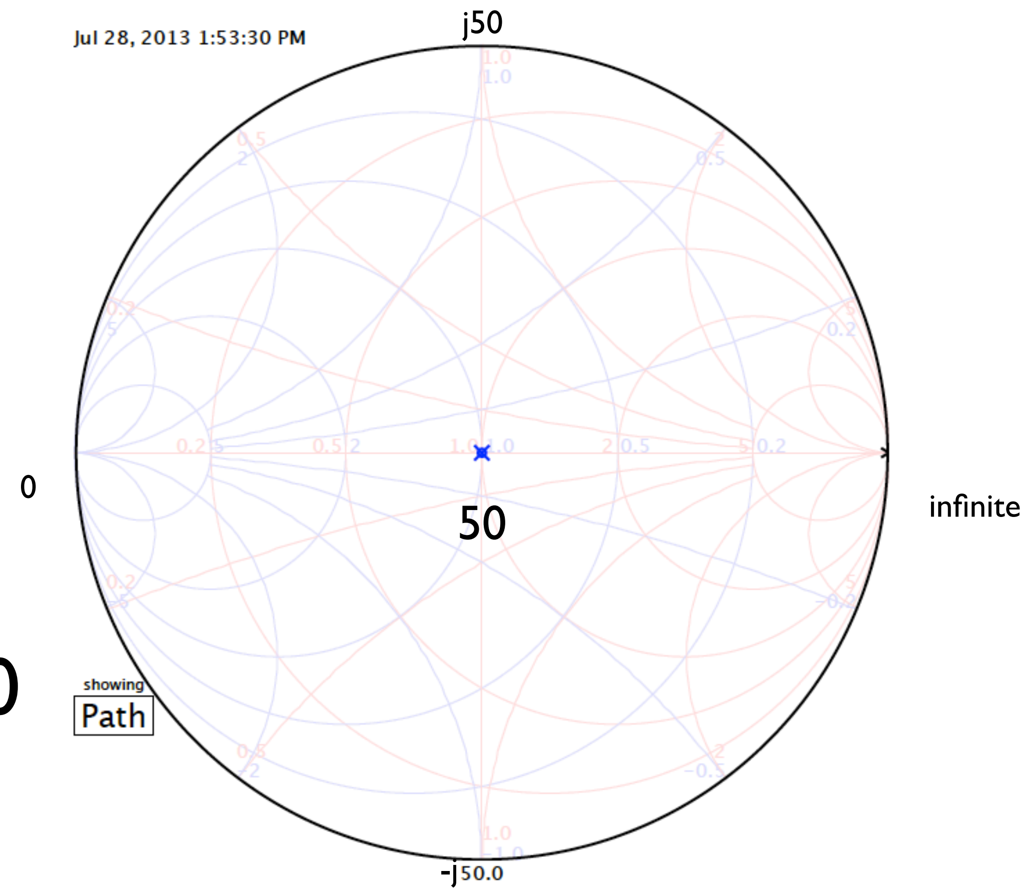
Used to plot complex impedances.

Complex impedances are just impedances with both a resistive and reactive component.

All graphics here-in are produced using "SimSmith", a Computer Aided Smith chart program.

The Center

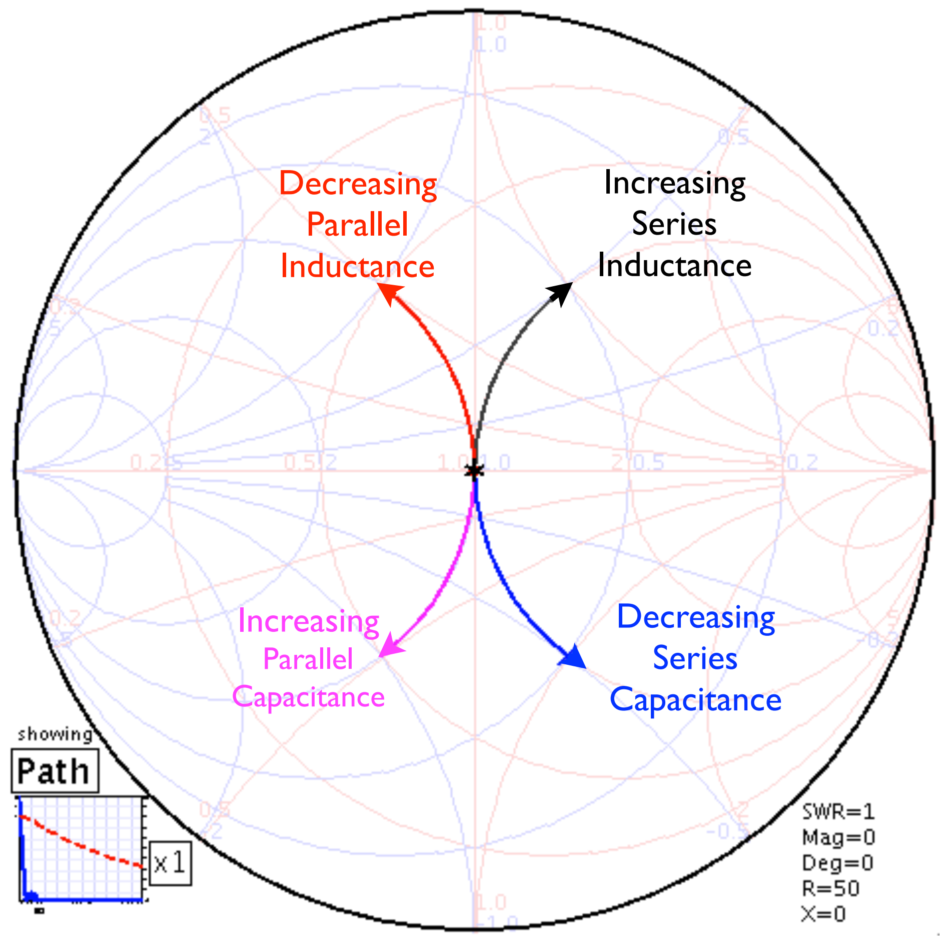
This Smith Chart is quite simple: The center of the chart represents a impedance of 50 ohms. Other important points are 0, infinite, +j50 and -j50



Adding Reactance

Adding a series reactance causes movement along the red circles...

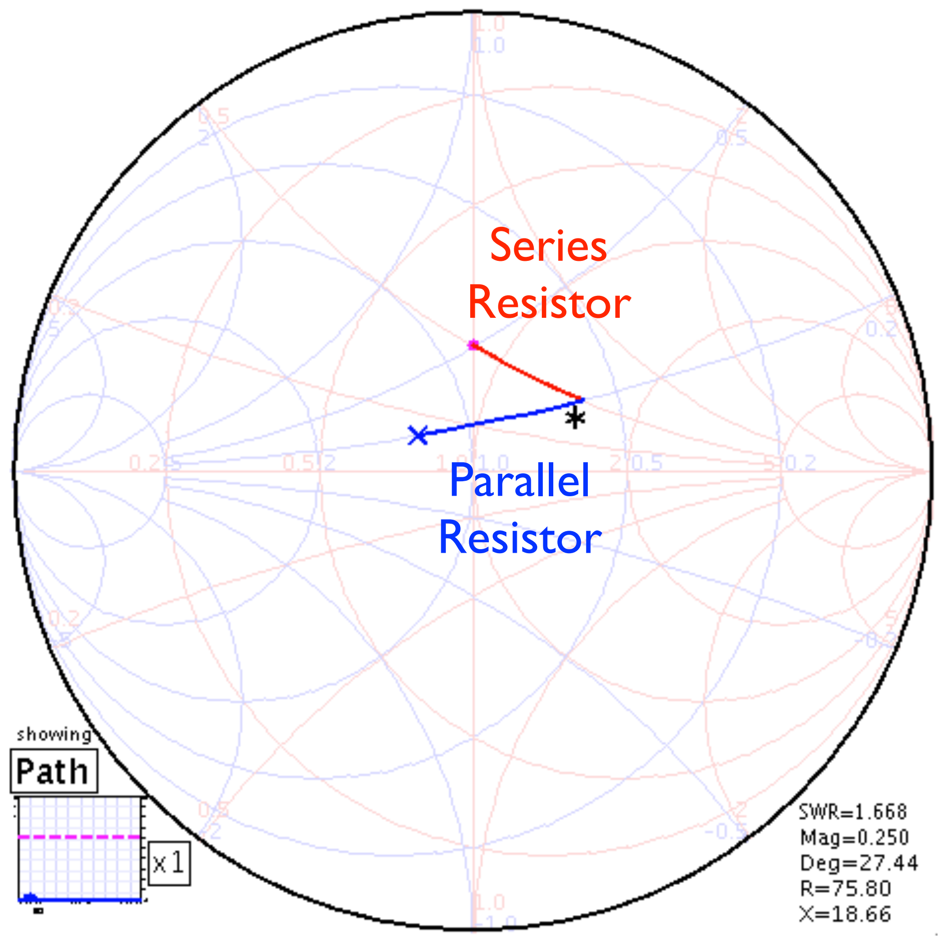
Adding a parallel reactance causes movement along the blue circles.



Adding Resistance

Adding series resistance causes movement along the red arcs.

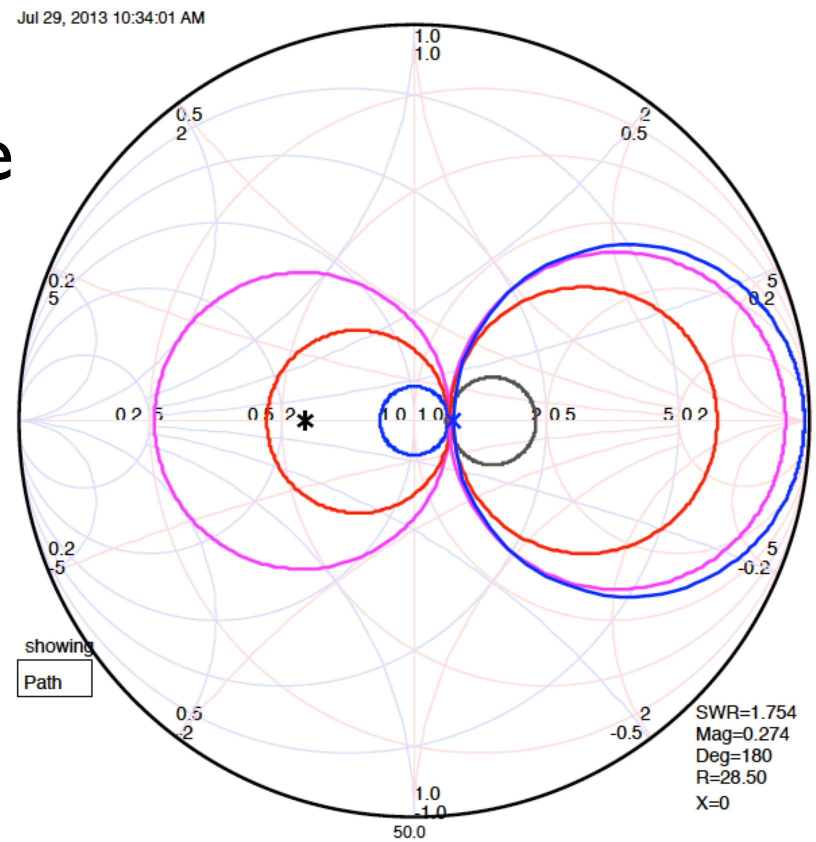
Adding a parallel resistance causes movement along the blue circles.



Lesson 1

Transmission lines translate impedance through rotations around their Zo.

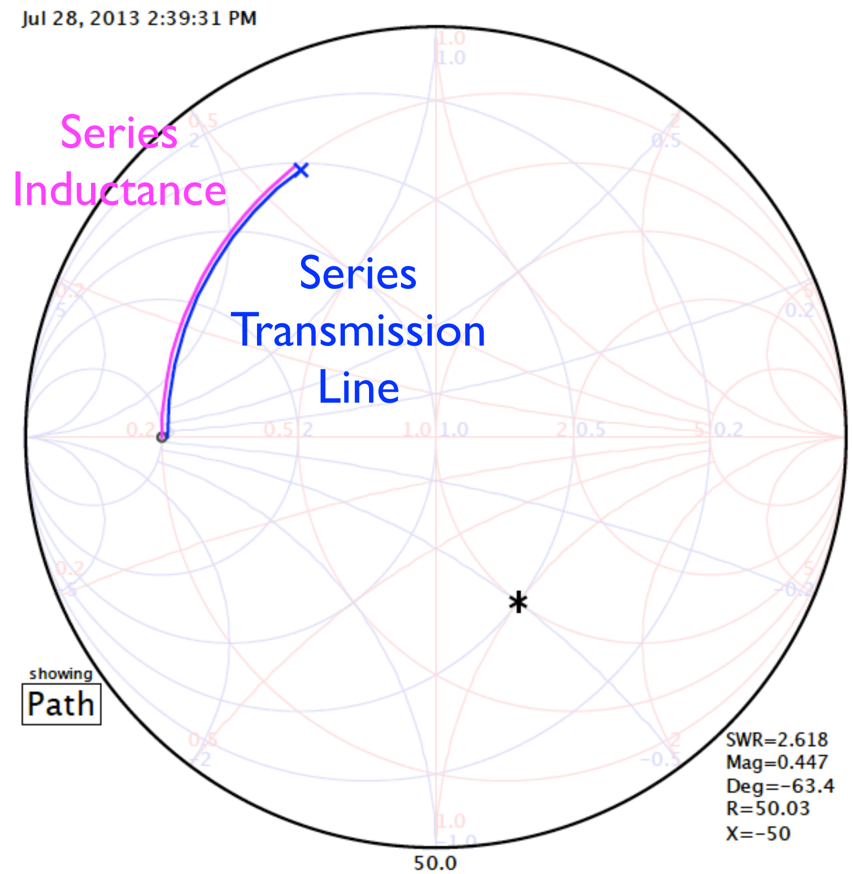
Here are 25,37,50, 75,150,300,600 transmission lines.



Lesson 1
(cont)

Transmission lines can act much like capacitors and inductors over small ranges in frequency.

Here we show an inductor and a series transmission line...



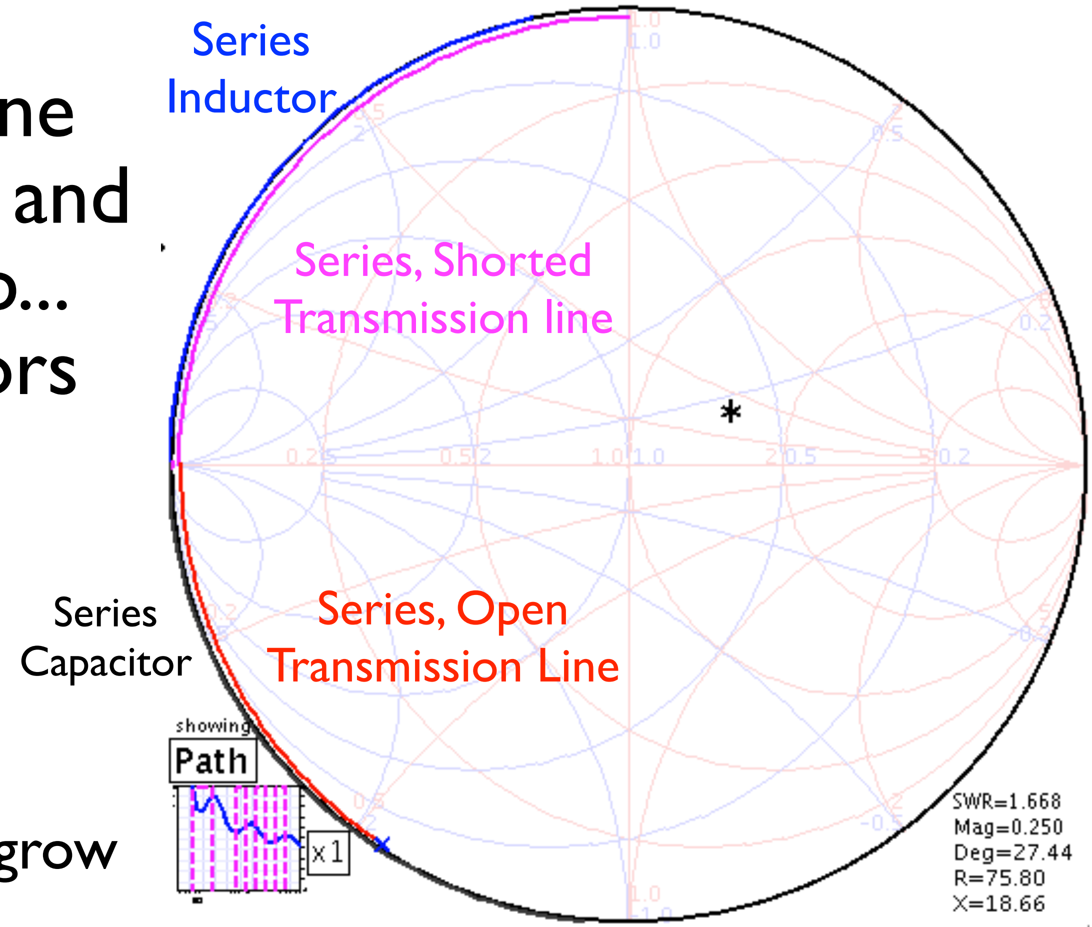
Lesson II

Series Stubs as Reactances

Transmission line stubs (shorted and open) can... yep... act like inductors and capacitors.

Shorted Tlines increase inductance as they get longer...

Open lines increase capacitance as they grow

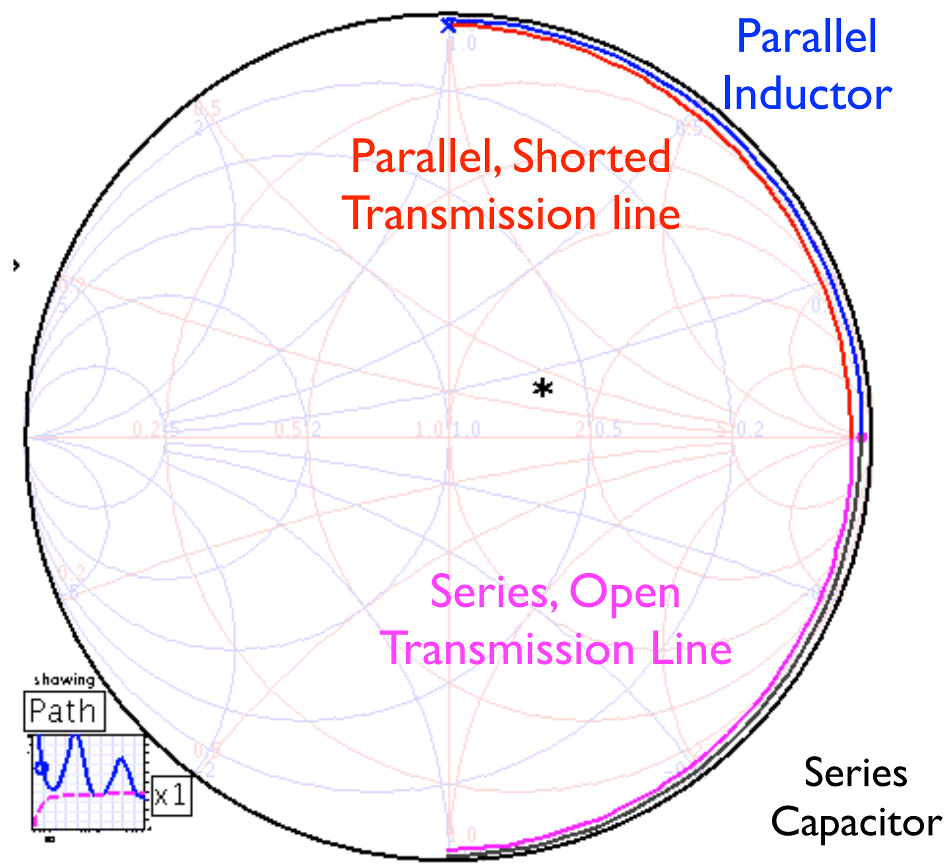


Lesson 11
Parallel Stubs as Reactances

Shorted Tlines increase inductance as they get longer...

Open lines increase capacitance as they grow

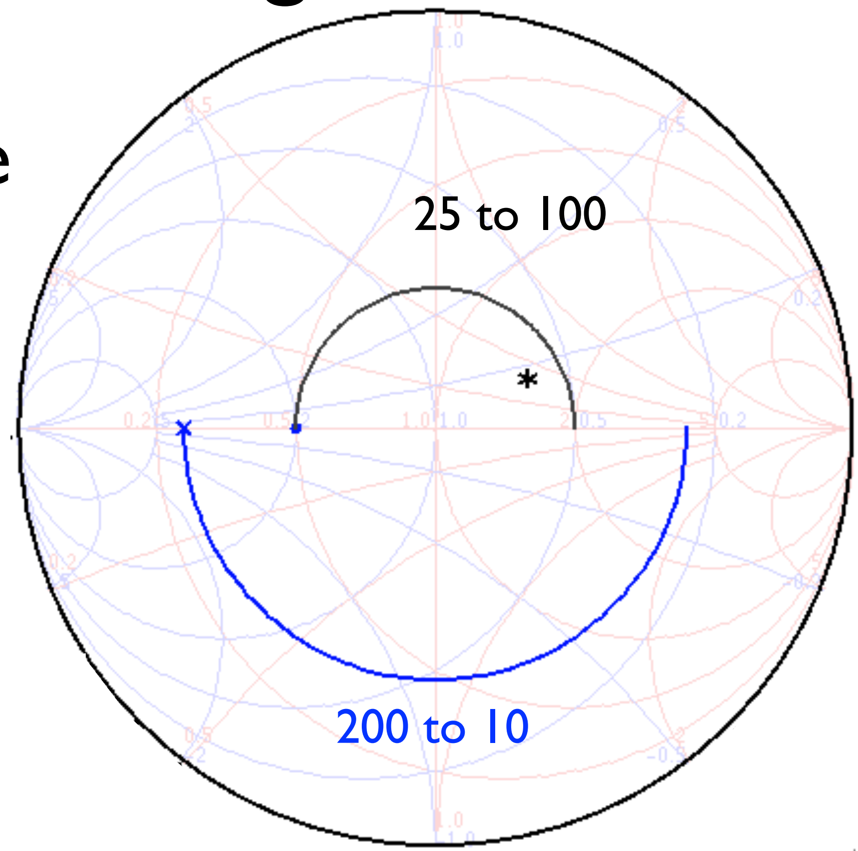
(but only up to a point)



Lesson III
1/4 WaveLengths

Transmission lines which are 1/4 wave lengths long are 'special'.

They 'invert' the impedance,
(but only at a
single frequency)

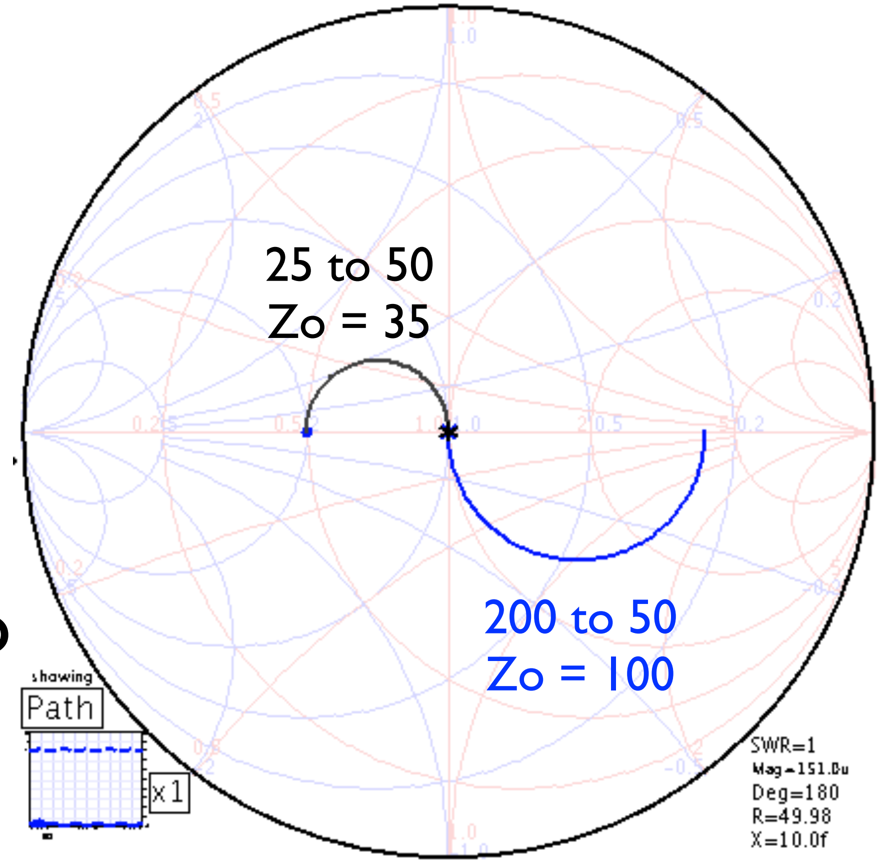


Lesson III (cont)
1/4 WaveLengths

Impedance isn't really 'inverted'.

The real formula is:

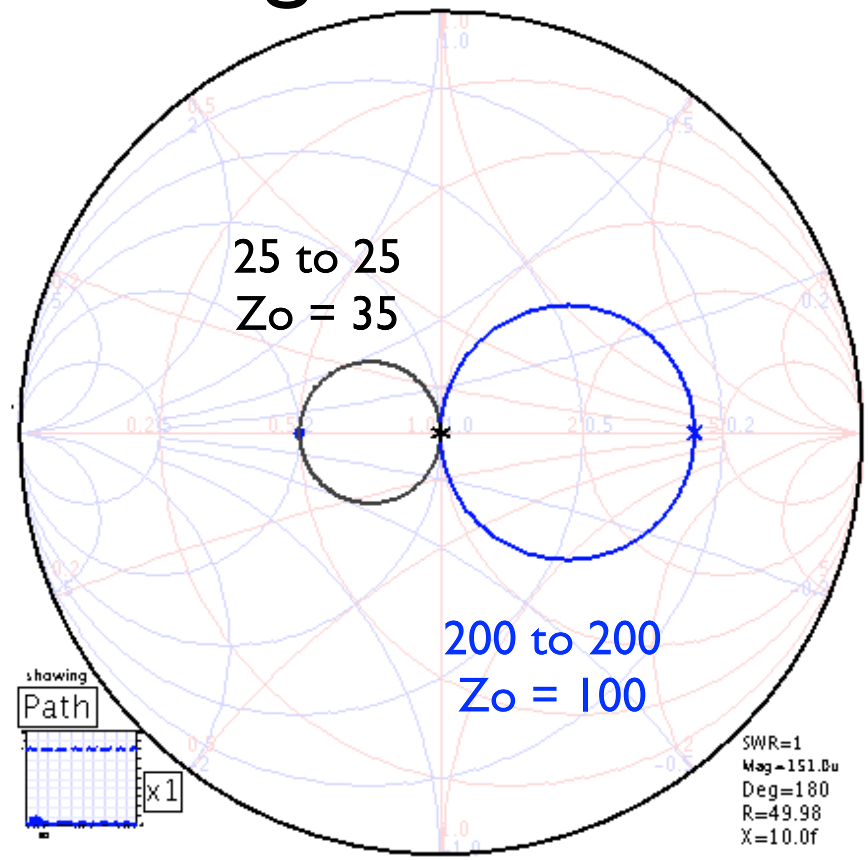
Zin Zout = Zo Zo



Lesson IV
half WaveLengths

Half wave lines act just like two 1/4 wave lines in series....

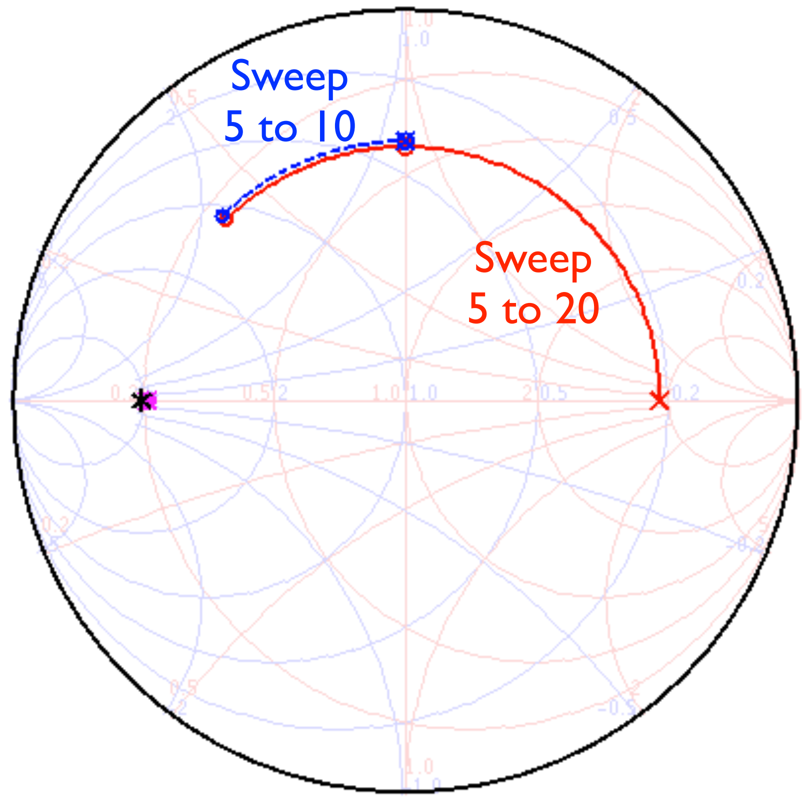
Often described as having ‘no effect’ but only if the frequency is constant.



Observation

Change in Frequency = Change in length

For transmission lines:
Increasing the frequency of analysis is (much) the same as increasing the length of a transmission line.

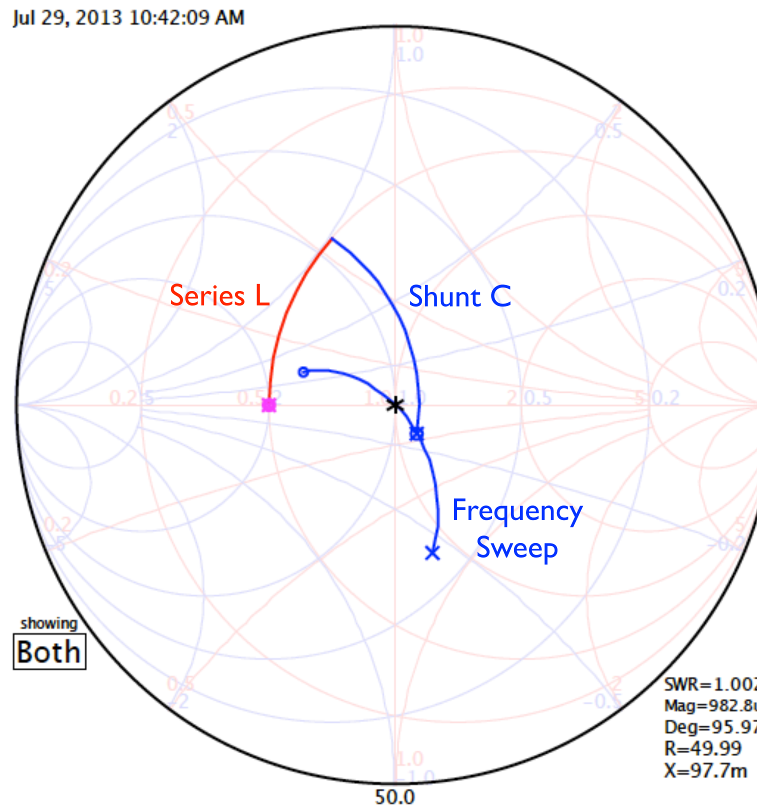


Observation

Sweeps

Smith chart can show how impedance changes as frequency changes.

For example, here is a the familiar 'path' of a matching L network and a frequency 'sweep' of the impedance.



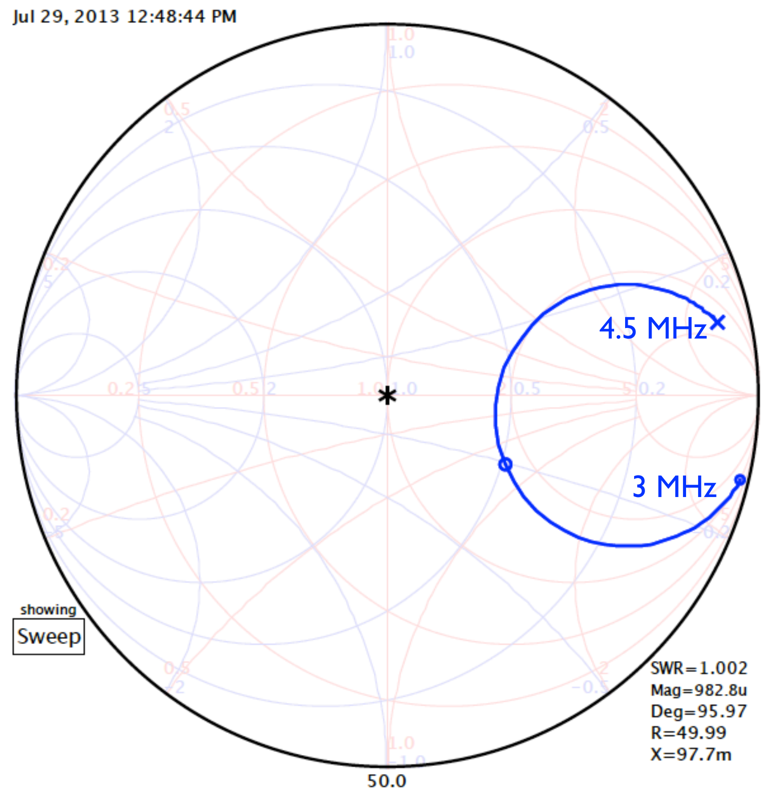
Observations

Sweeps (cont)

Smith charts are often used in describing antenna impedances.

Here is the impedance of a dipole for 80m.

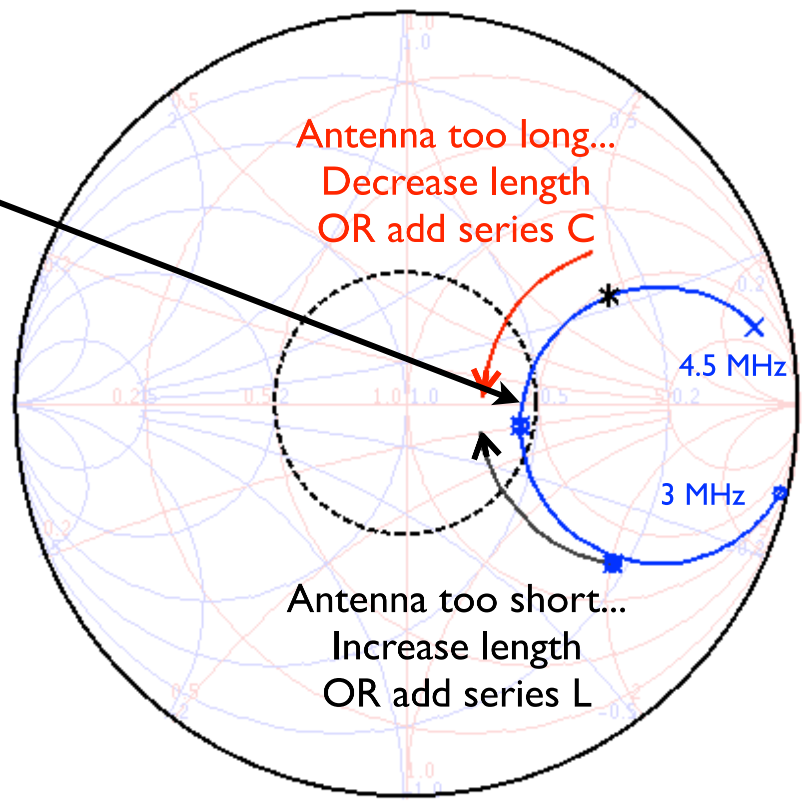
Sweep from 3.0 to 4.5 MHz.



Observations
(half wave dipole)

“Resonance” is when ‘reactance’ is zero..

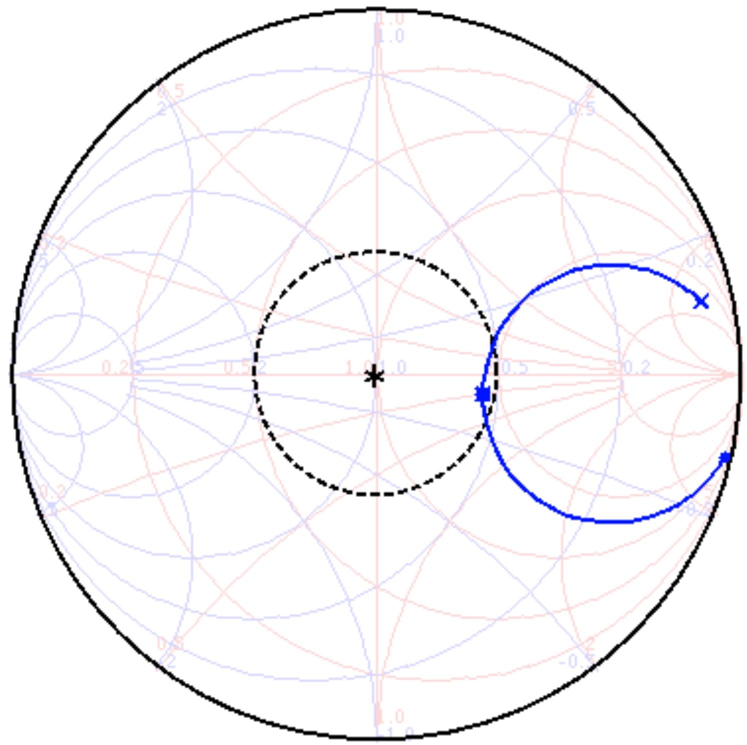
we can change resonance with capacitors and inductors.



Observations

Smith chart can show SWR circles as well. Here's an SWR=2 circle.

Unrolling the circle results in the well known SWR chart...



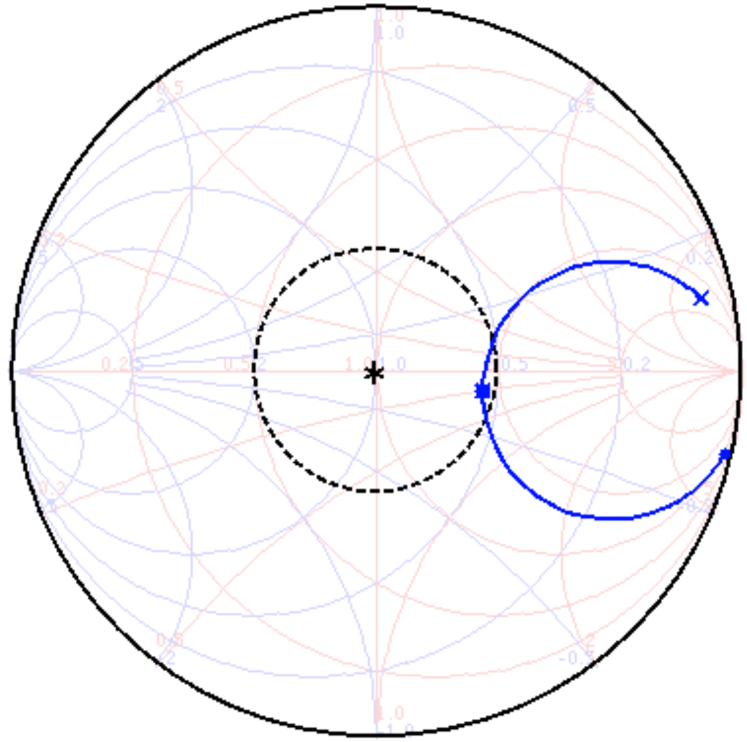
Observations

Here is the resulting
SWR chart.

Application 1
Impedance Transforms

Many methods. All have the goal of moving the impedance to the center of the chart.

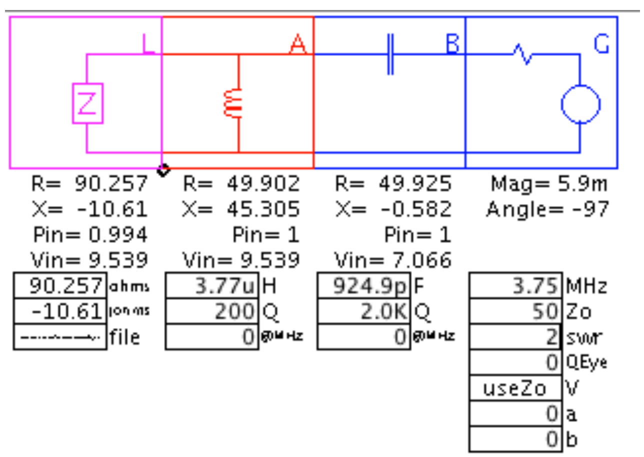
Classic LC
1/4 wave
1/12 wave
coax + reactance
1/4 resonant

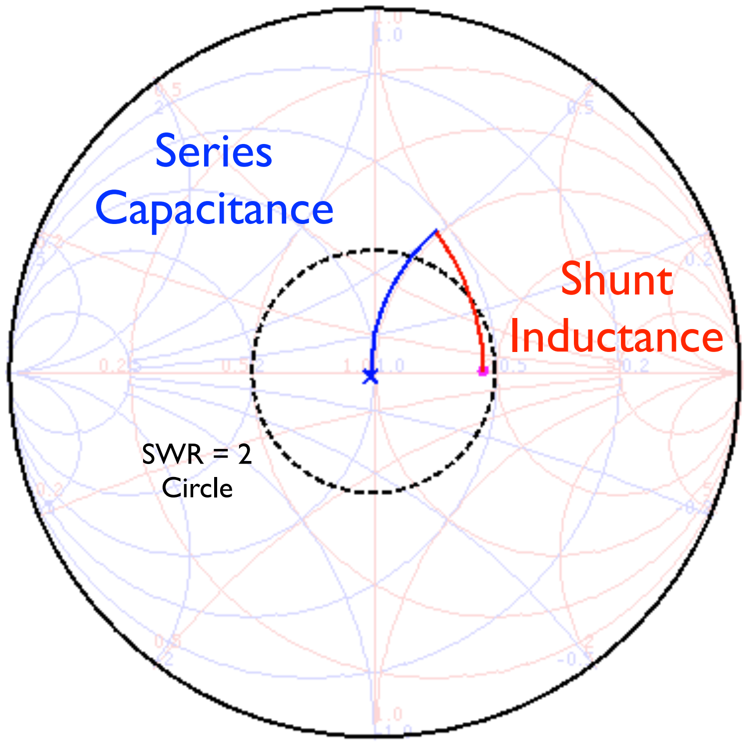


Application 1

Classic LC

Use L to move to R=50 circle. Use C to move center.



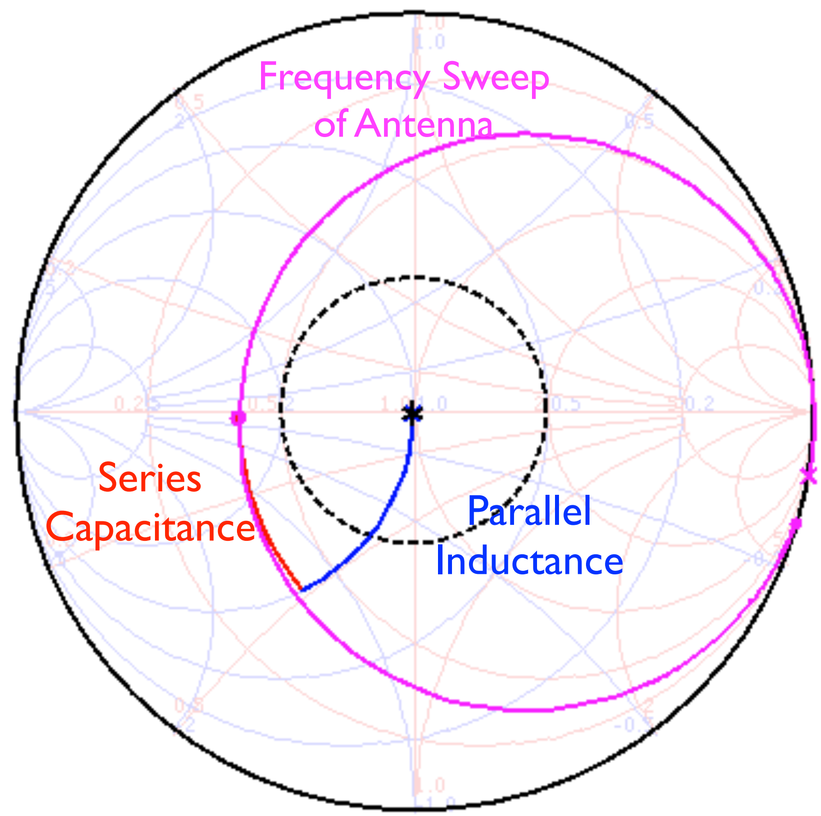


Observations

Impedances lower than 50

Most antennas have an impedance > 50 ohms but many do not. Here is a sweep of a 10m vertical with 4 horizontal radials.

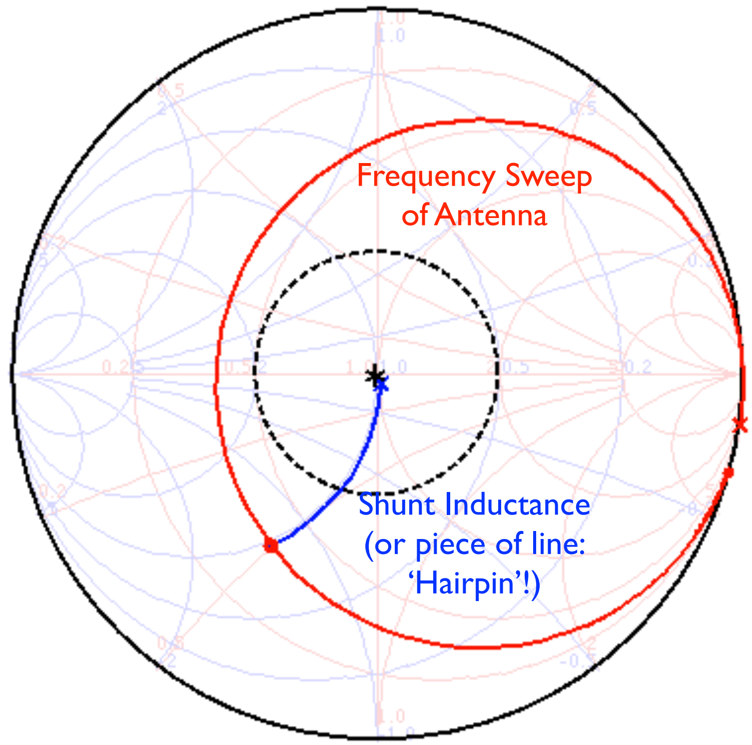
We can match it with an LC....



Lesson V

Parasitic Capacitor

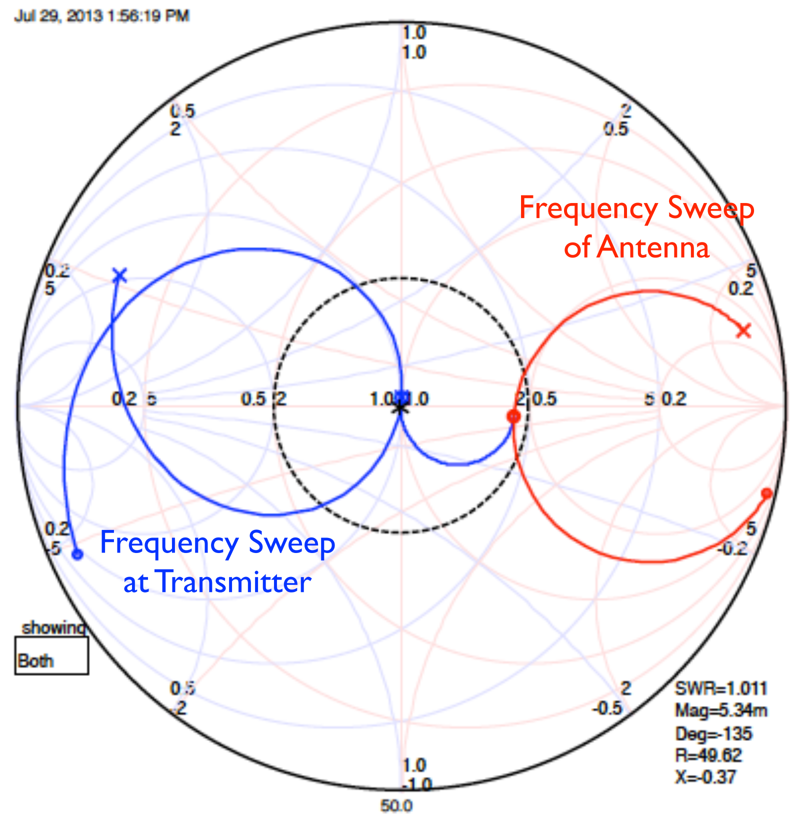
However, if we remember that an antenna is capacitive below resonance, we can implement the capacitor by shortening the antenna!



Application 1
1/4 wave section

Here we use a 1/4 wave section to match our dipole to 50 ohms at a given frequency.

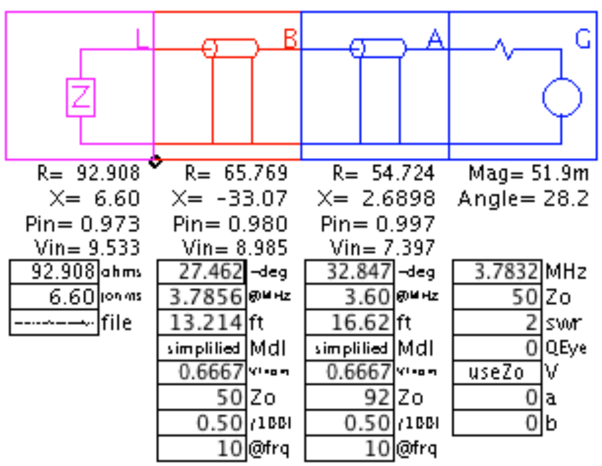
Here, a 67 ohm line.

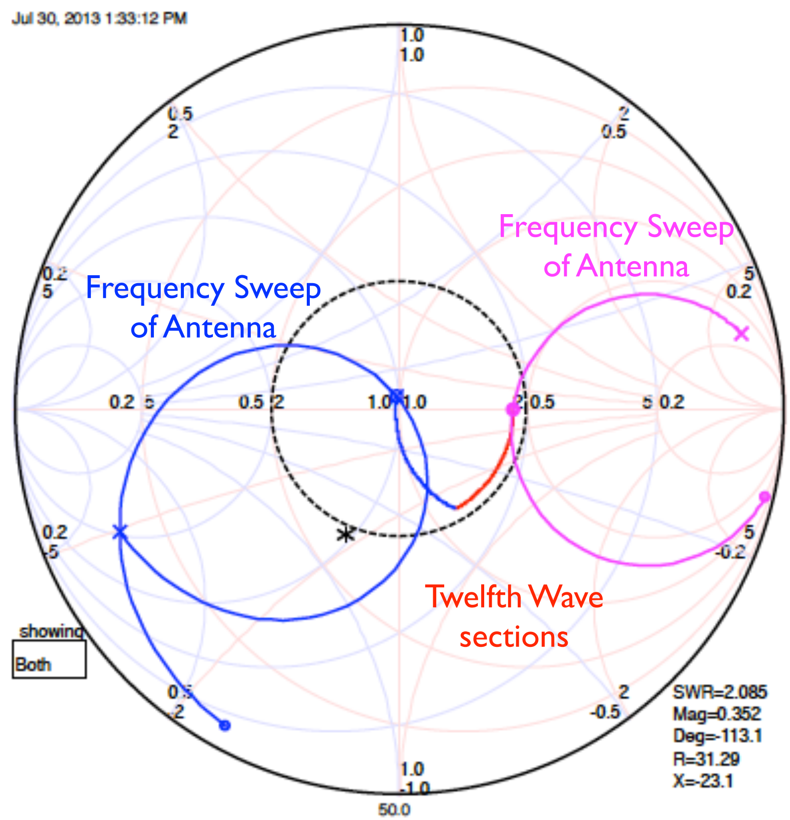


Application 1

1/12th wave

Add 1/12th wave of 50, 1/12th wave of 92...

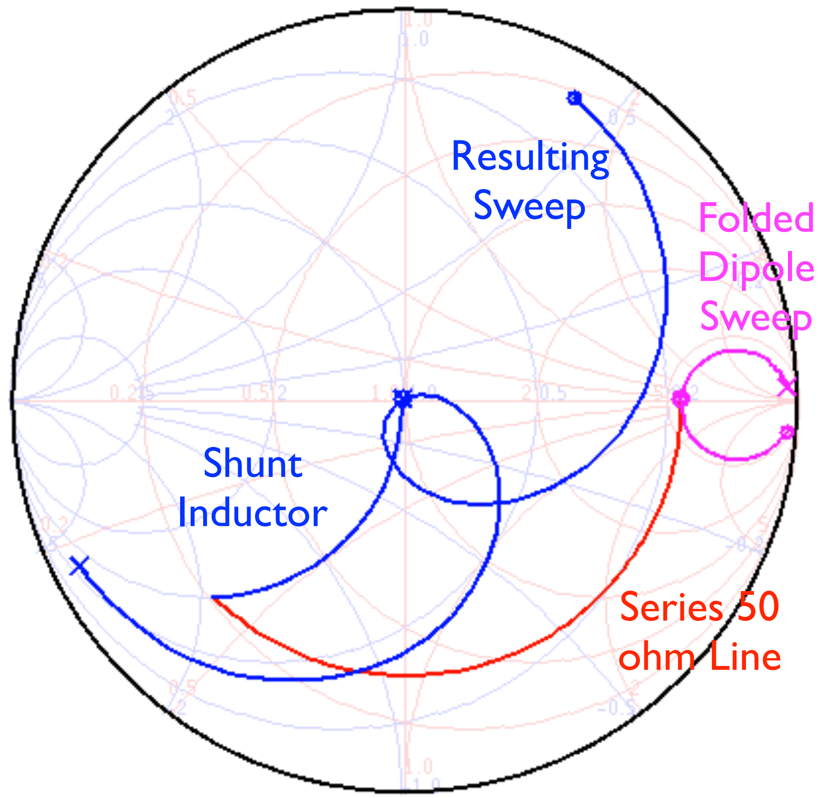




Application 1
coax and reactance

Use coax to rotate impedance to blue conductance circle and then add reactance.

Here, an inductor is used.



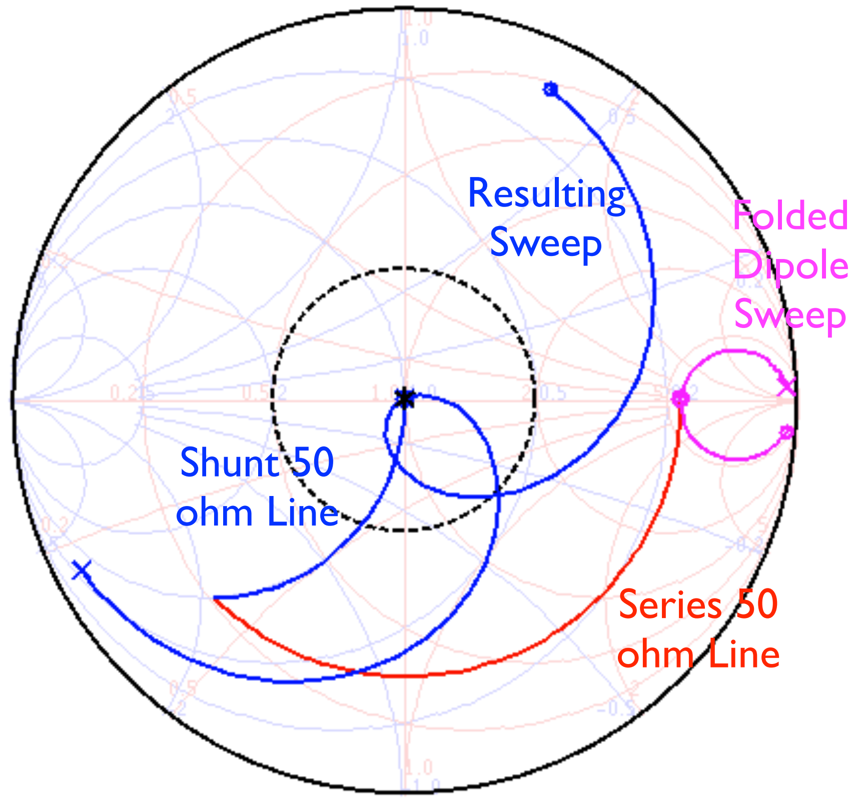
Application 1

quarter wave resonant

Use coax to rotate impedance AND a piece of coax for the reactance.

The total length of coax is often close to "1/4 wave".

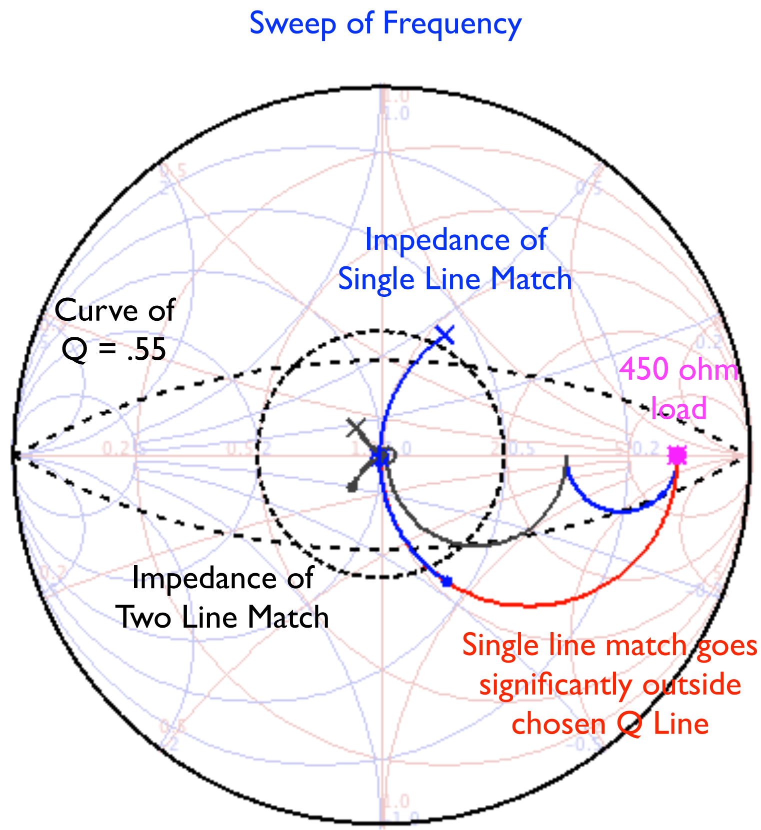
(BTW this is how most jpoles work)



Application II
"Q eye"

"Q" contours are curves of constant Q. Keeping the Q low increases the Bandwidth of a match.

Here 450 is match to 50 ohms. One using 1/4 wave of 146 ohm line. The other using 257 & 87.

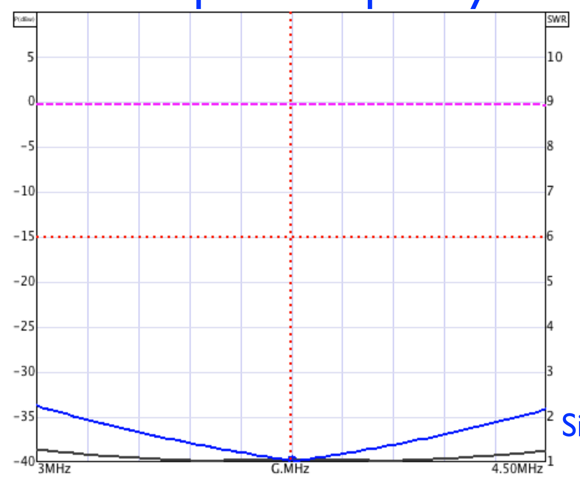


Application II

"Q eye"

Here is the resulting SWR chart. Notice two line match is significantly better.

Sweep of Frequency



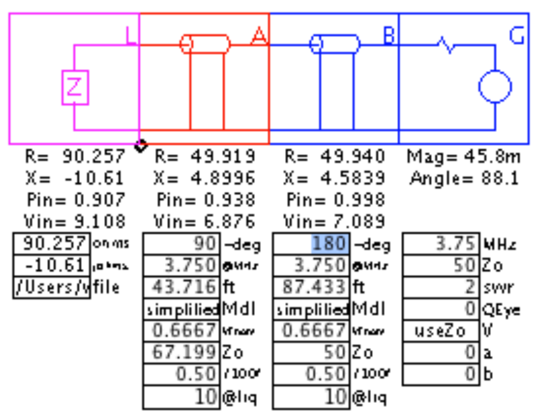
BLACK
Impedance of
Two Line Match

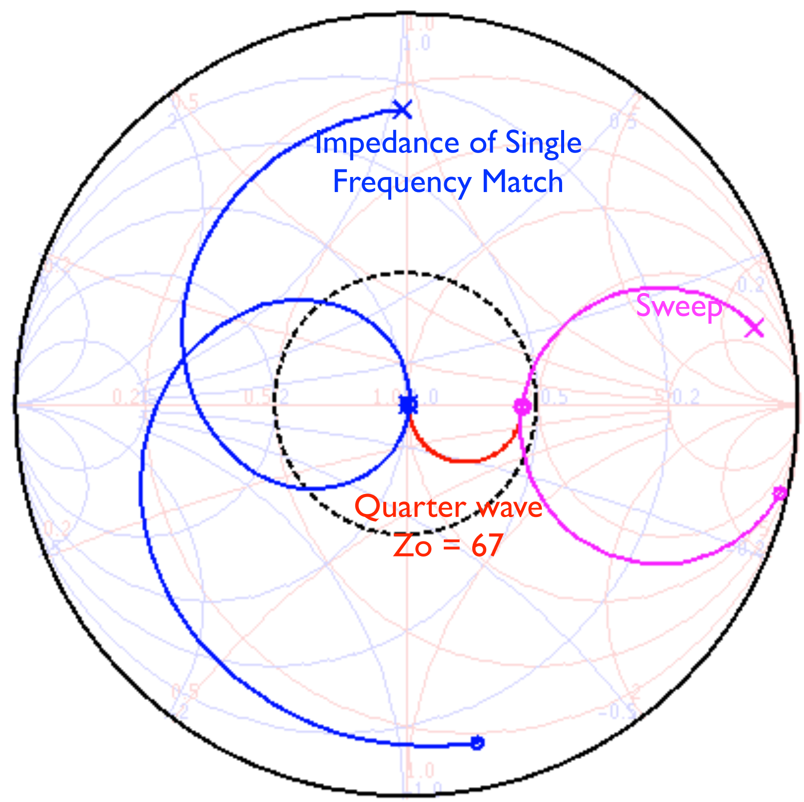
BLUE
Impedance of
Single Line Match

Lesson VI
Broadbanding

Optimizing the match at a single frequency can be suboptimal across a band.

For example, usually, folks will match the antenna to 50 ohms and then attach the feedline:

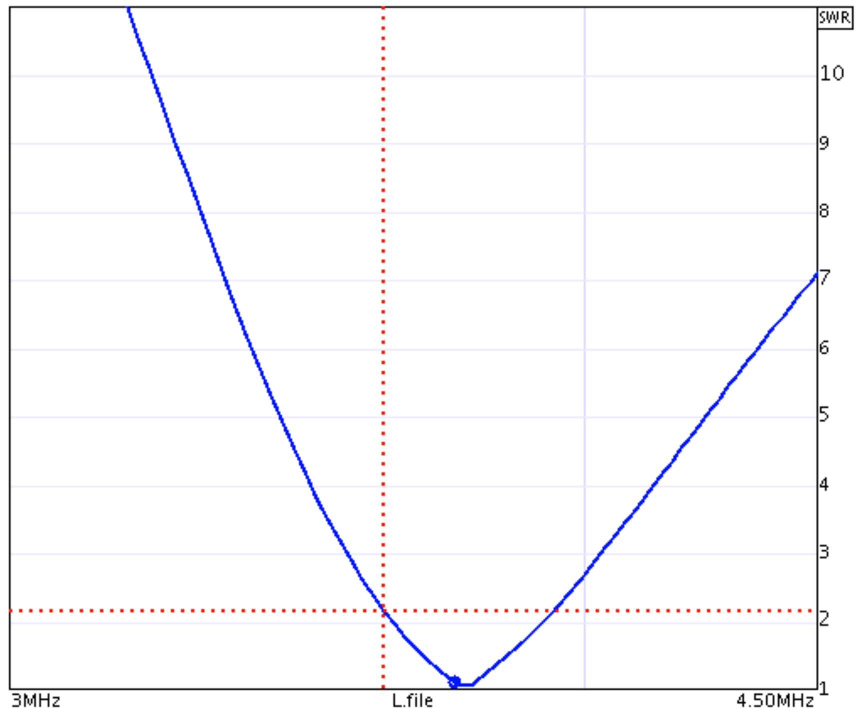




Lesson VI

Broadbanding

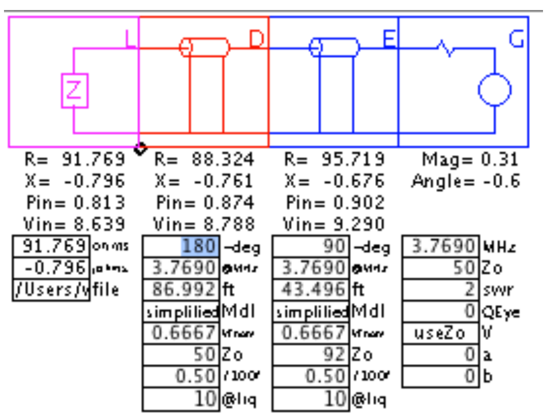
Here is the resulting SWR

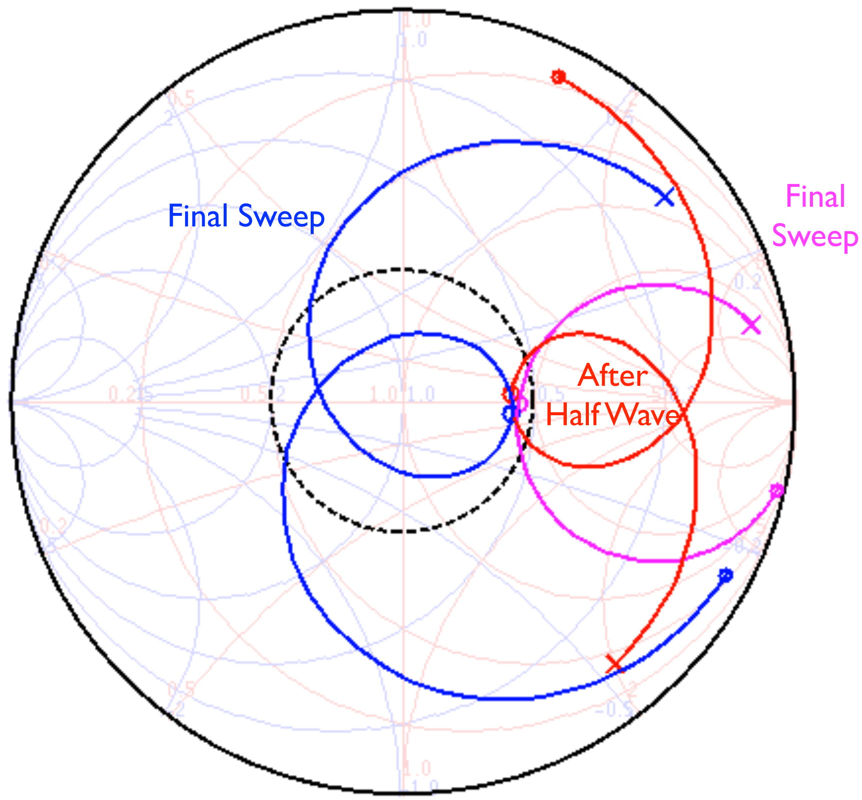


Lesson VI

Broadbanding

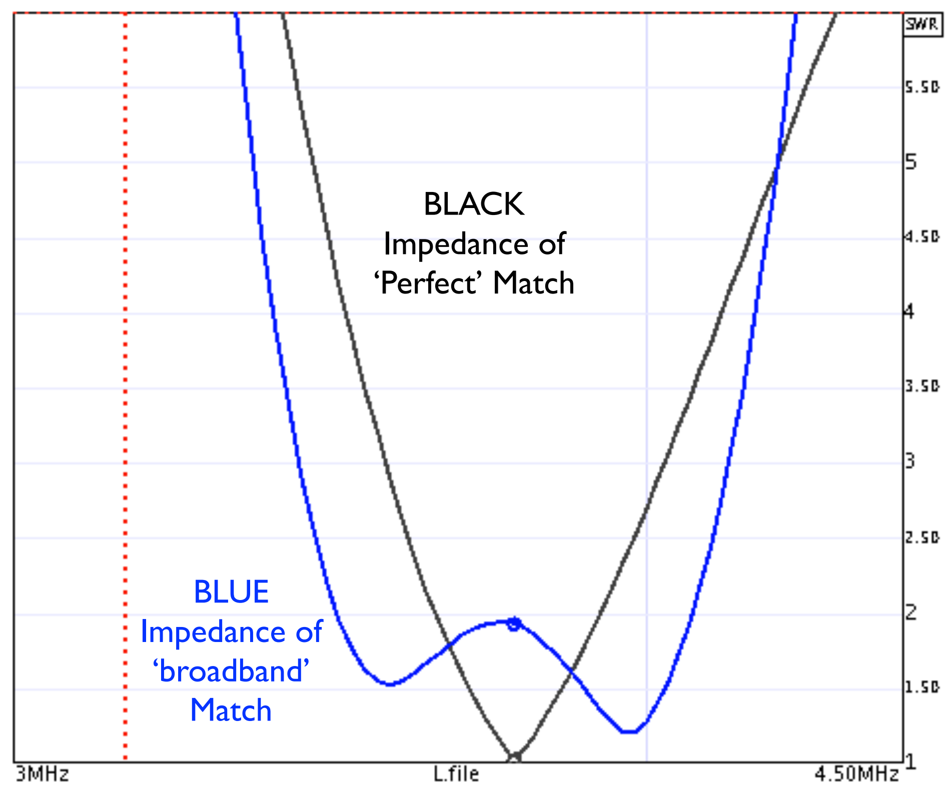
BUT: if you move the 'matching' to other end of the half wave feed line you can get:





Application III
Broadbanding for 80m band

Here are the two curves compared across the 80m band

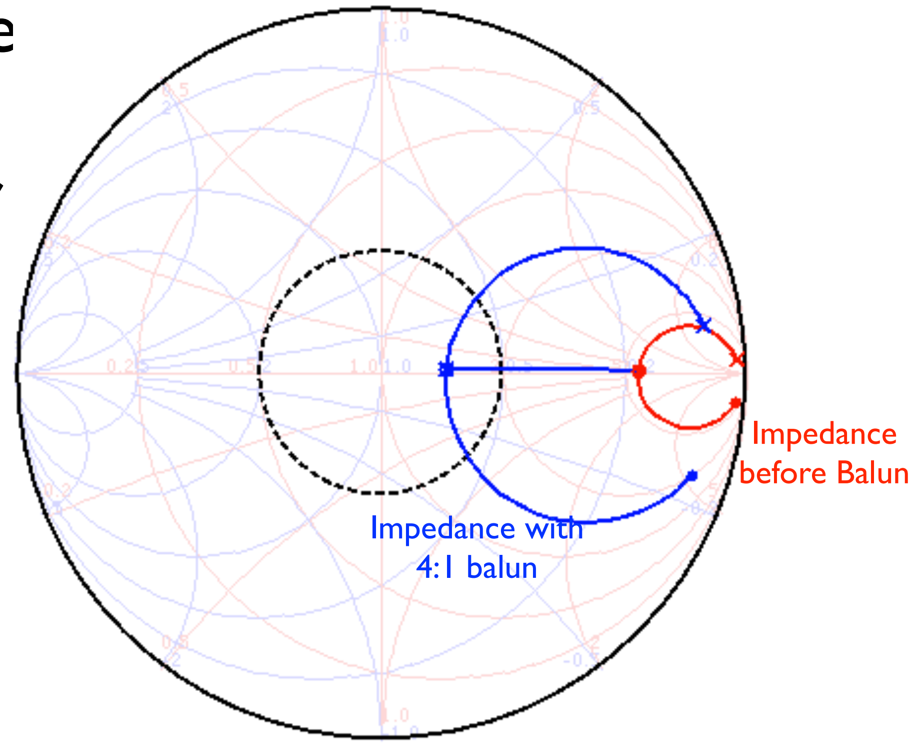


Application IV

Broadbanding the 20m folded dipole

For folded dipoles the 'classic' solution is to use a 4:1 transformer (balun) at the feed point.

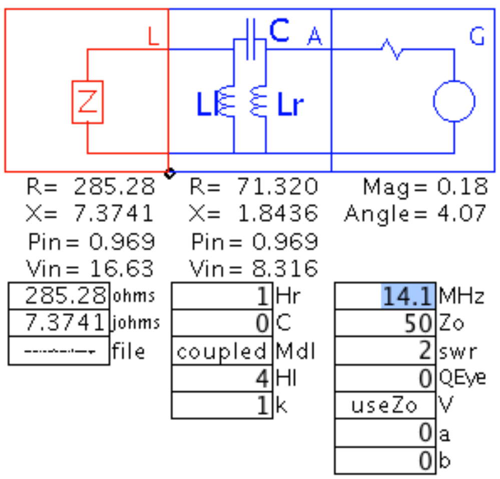
Here is the Smith chart for the result:

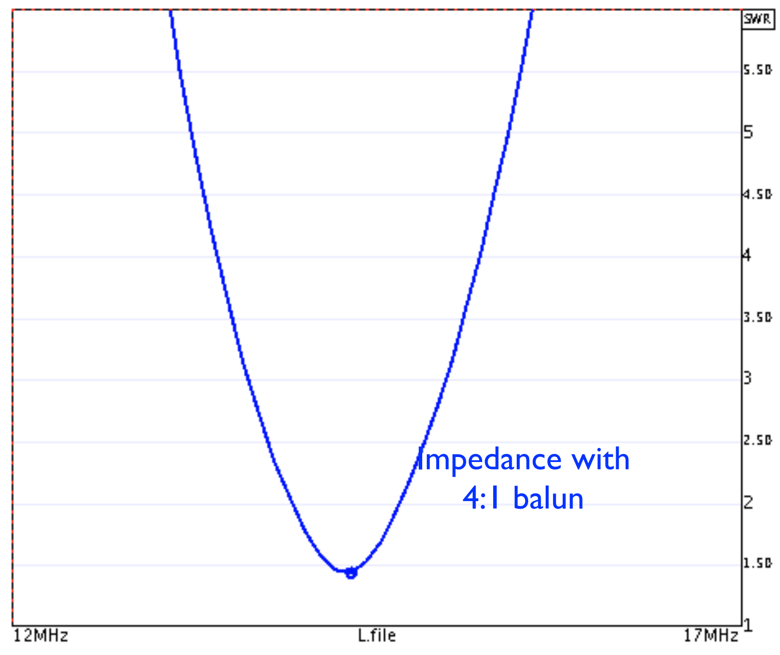


Application IV

Broadbanding the 20m folded dipole

And here is the circuit and SWR chart:



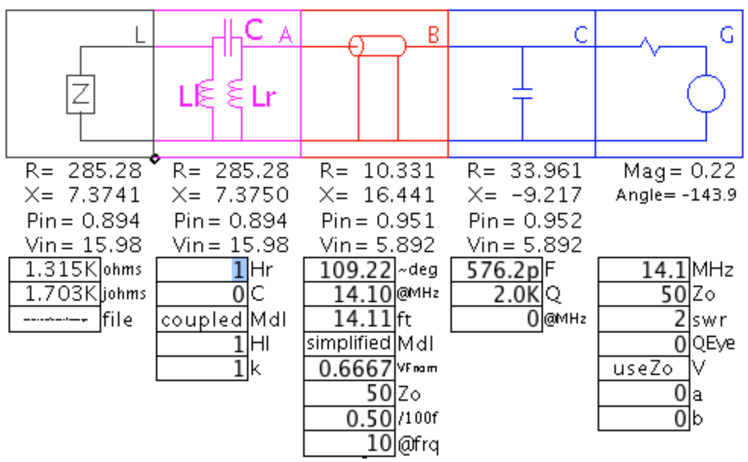


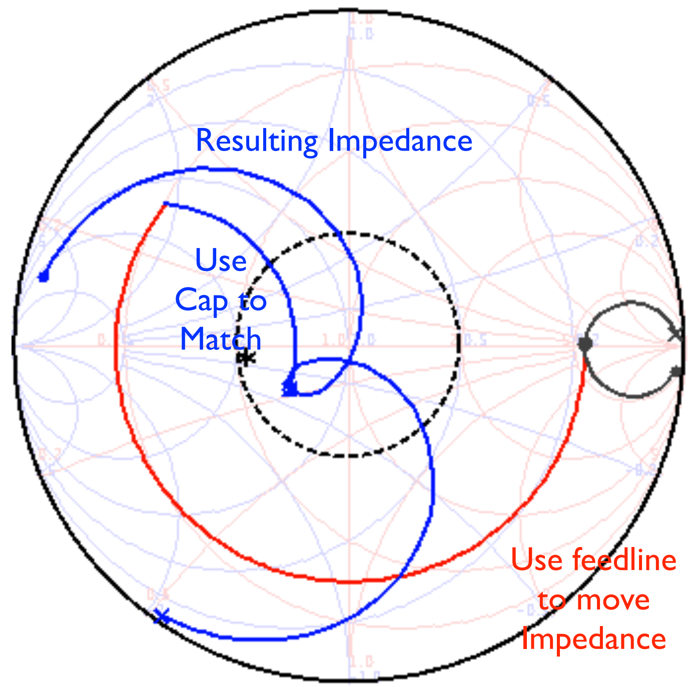
Note balun modeled as perfect transformer

Application IV

Broadbanding the 20m folded dipole

But 1/1 baluns are much easier to build AND we can match the impedance more easily if we use the feed line to our advantage.

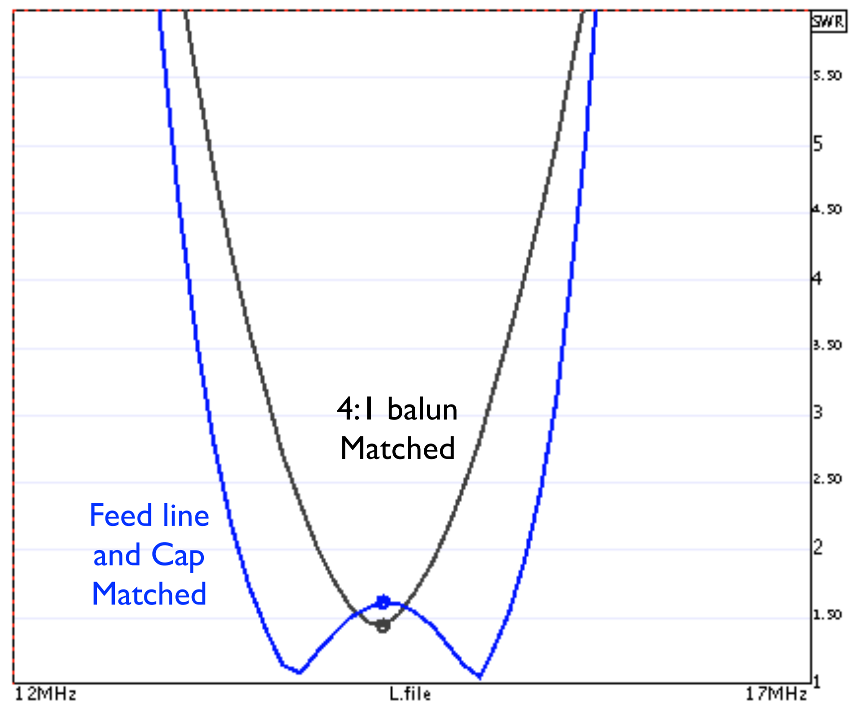




Application IV

Broadbanding the 20m folded dipole

Here is a comparison of the resulting SWRs:



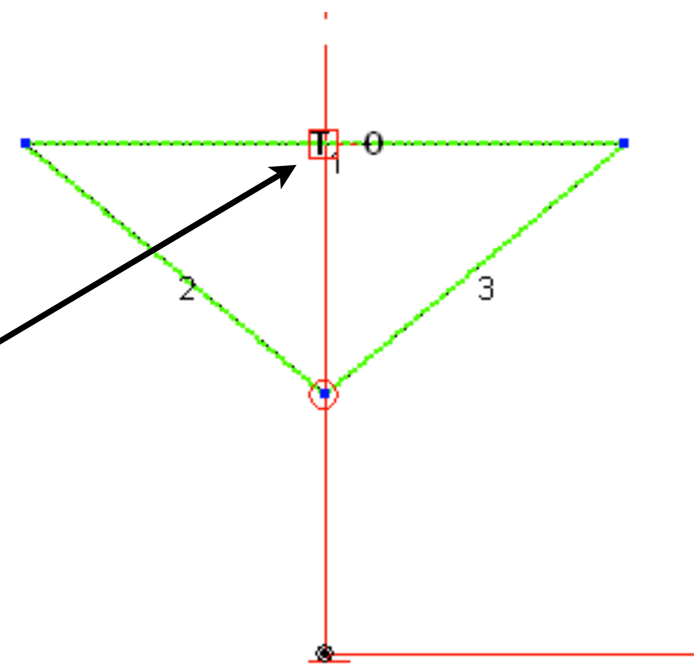
Application V

The 40/80m delta/delta (NI6T)

Dual band delta antenna.
Sides are 76 feet long,
top wire 118 feet.

60 foot, 450 ohm, open
stub in middle of top wire.

(shown as ‘load’ box in
this EZNEC plot)



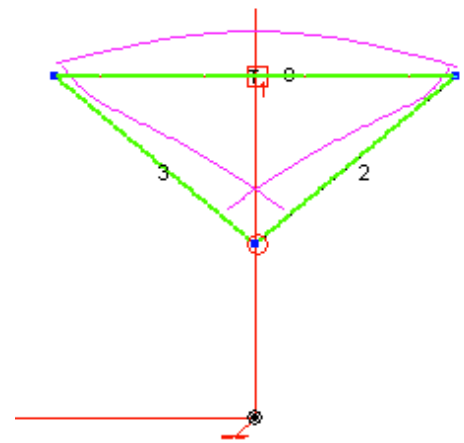
Application V

The 40/80m delta/delta (NI6T)

On 80m, the 60 foot stub 1/4 wave which means it is effectively a ‘short’.

Thus, on 40m the loop is a one wavelength loop.

(Here is the EZNEC current plot)

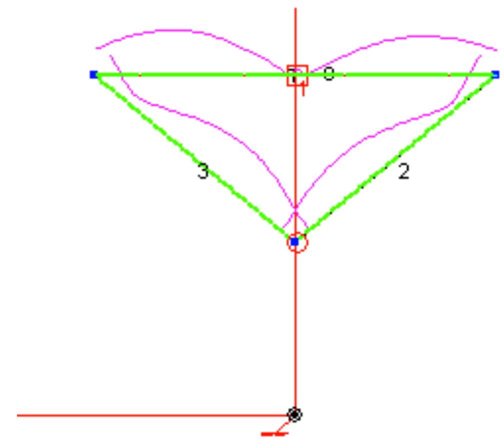


Application V
The 40/80m delta/delta (NI6T)

On 40m, the 60 foot stub is 1/2 a wave which means it is an ‘open’.

Thus, the antenna is a two wavelength partially folded dipole. It is relatively high impedance.

Here is the EZNEC current plot.

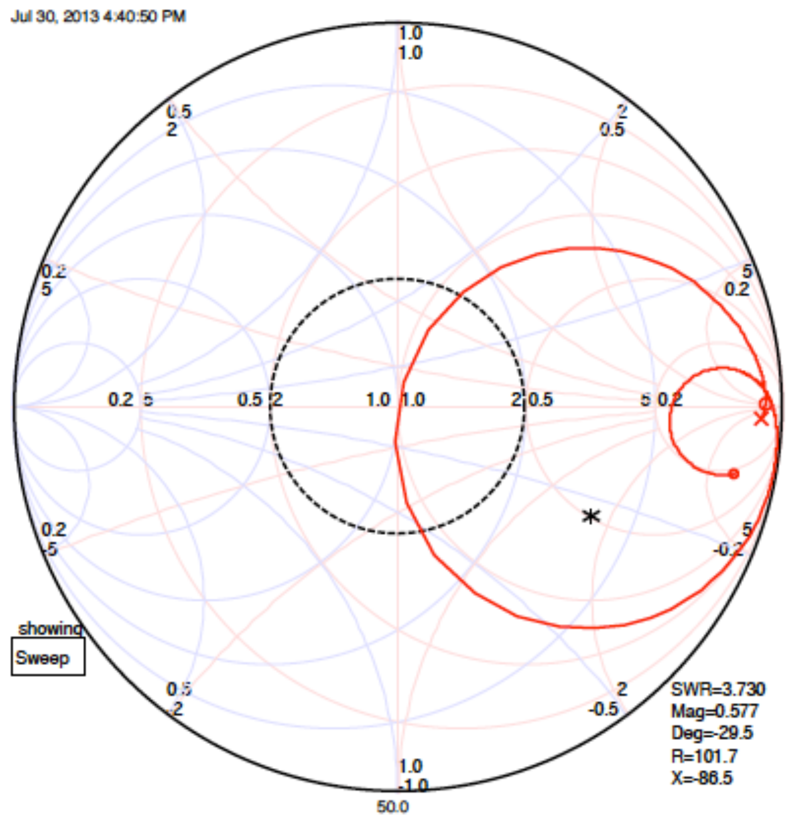


Application V
The 40/80m delta/delta (NI6T)

Sweep of impedance from 3.4 to 7.4
(from EZNEC)

3.75 MHz: 300 + 21j

7.20 MHz: 1.5K + 925j

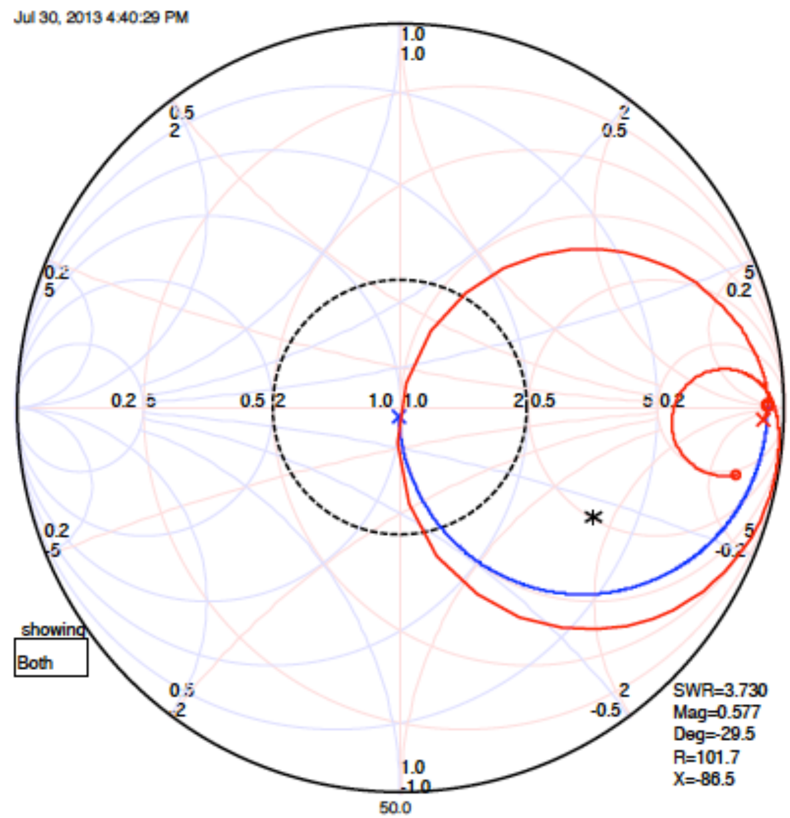


Application V

The 40/80m delta/delta (NI6T)

Tune 40m first.

1/4 wave,
300 ohm line.

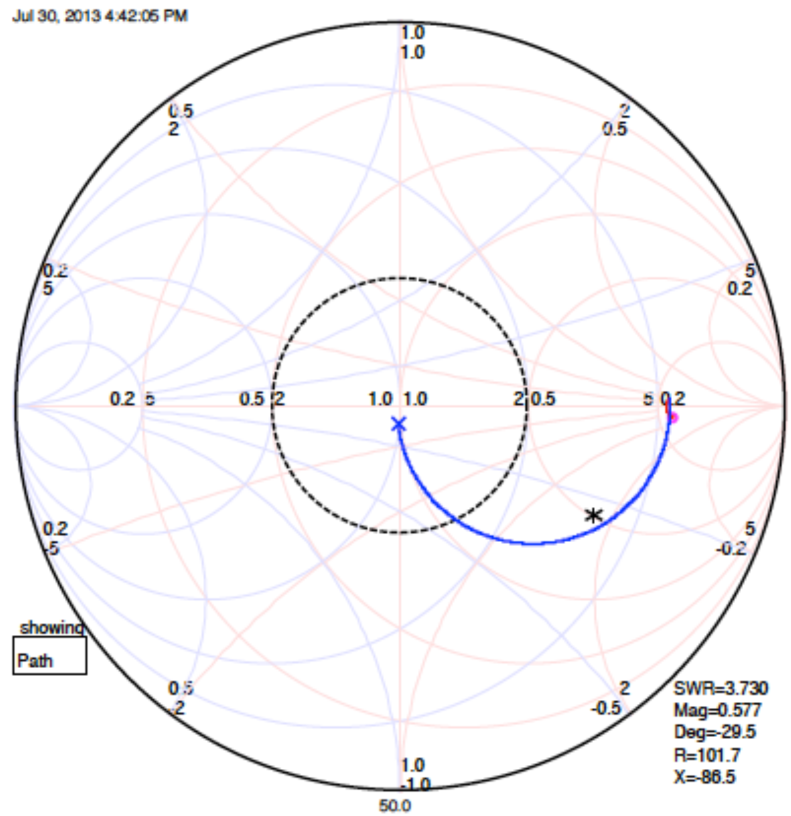


Application V
The 40/80m delta/delta (NI6T)

Then tune 80m

1/4 wave,
100 ohm line

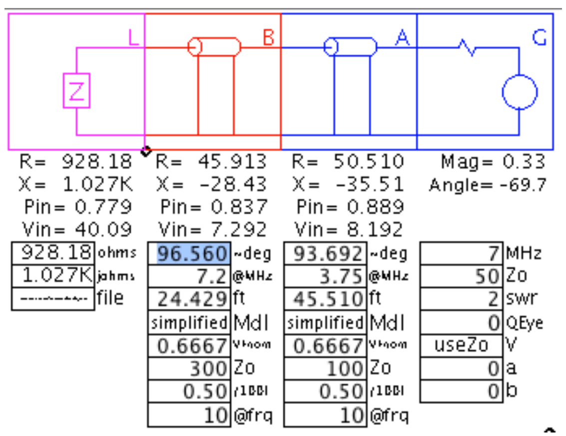
NOTICE: 300 ohm line has no impact because impedance starts close to 300 ohms.

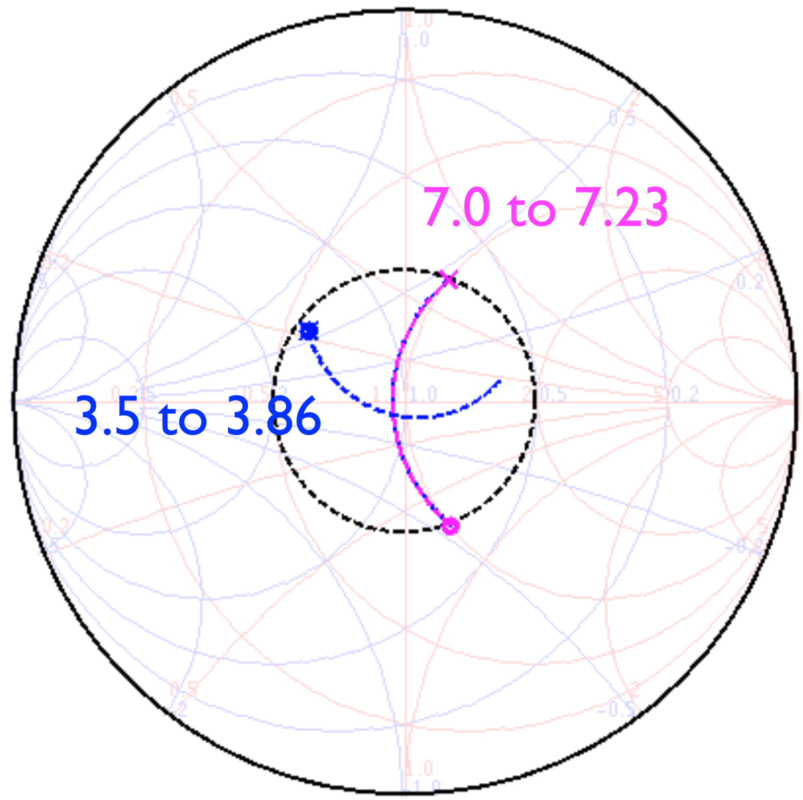


Application V

The 40/80m delta/delta (NI6T)

Lots of tradeoffs to be made but here are two sweeps.



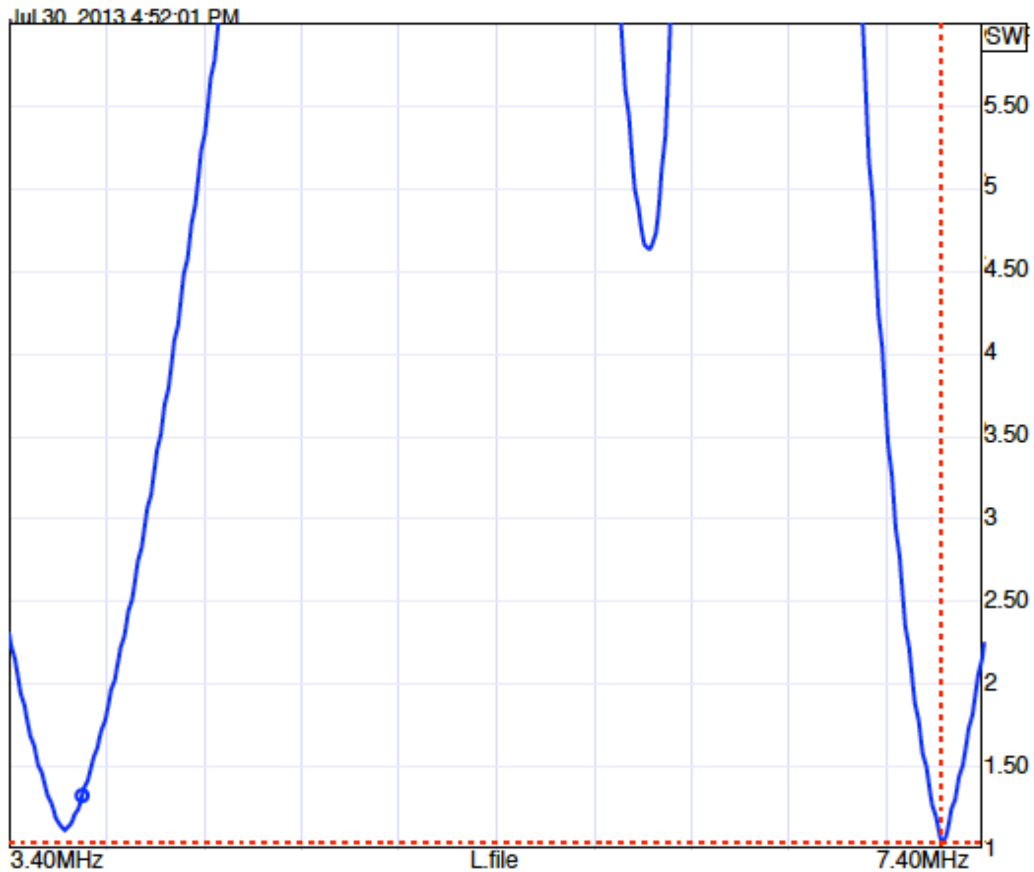


Application V

The 40/80m delta/delta (NI6T)

Resulting
SWR chart

400 KHz 3.7
200 KHz 7.2



Application V

The 40/80m delta/delta (NI6T)

This antenna uses several techniques. In each case a piece of transmission line acts one way on 40 and a completely different way on 80m.

a) the 60 foot stub acts like a switch;
it is a short on 80m and an open on 40

b) the 1/4 wave matching section for 40m
has a Zo which 'circles' the impedance
on 80m; essentially, no effect on 80.

c) the 80m 1/4 wave matching section is
1/2 wavelength on 40m; essentially
no effect on 40!

Wrap Up

Smith chart provides a ‘two dimensional’ view of impedances; a picture is worth 1000 words!

Smith chart lends insight to how impedances transform with a change in circuits or parameters.

Modern Smith chart software removes the drudgery of performing the complex arithmetic and frees the designer to see the forest and not just trees.