Adaptation d'impédance et mesure de signaux RF

Impedance Matching and RF Signal Measurement

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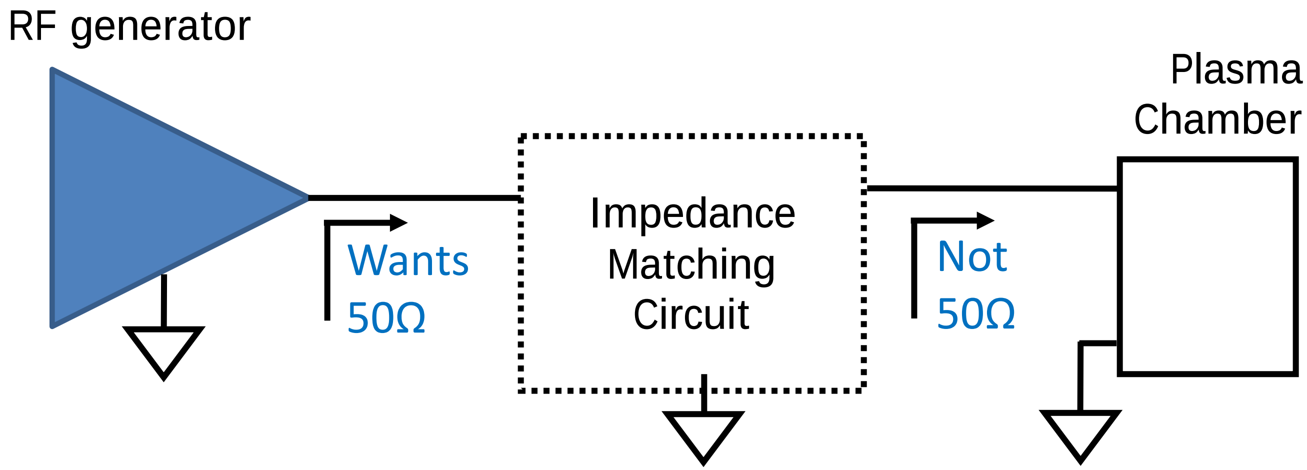
Why do I need impedance matching?



- RF generators/amplifiers need to « see » their own characteristic impedance to :
  - Enable maximum power transfer (efficiently use amplifier)
  - Minimize back-reflected power (possibly damage amplifier)

- Plasma reactors are far from 50Ω
  - CCPs appear as large capacitors in series with small resistance
  - ICPs look like inductors

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Outline

- Impedance Matching
  - Smith Chart
  - Using Smith Chart to understand matchboxes

- Practical Matchbox
  - Identifying components
  - Changing matchbox performance

- RF Signal Measurement
  - Useful measurements
  - How to interpret

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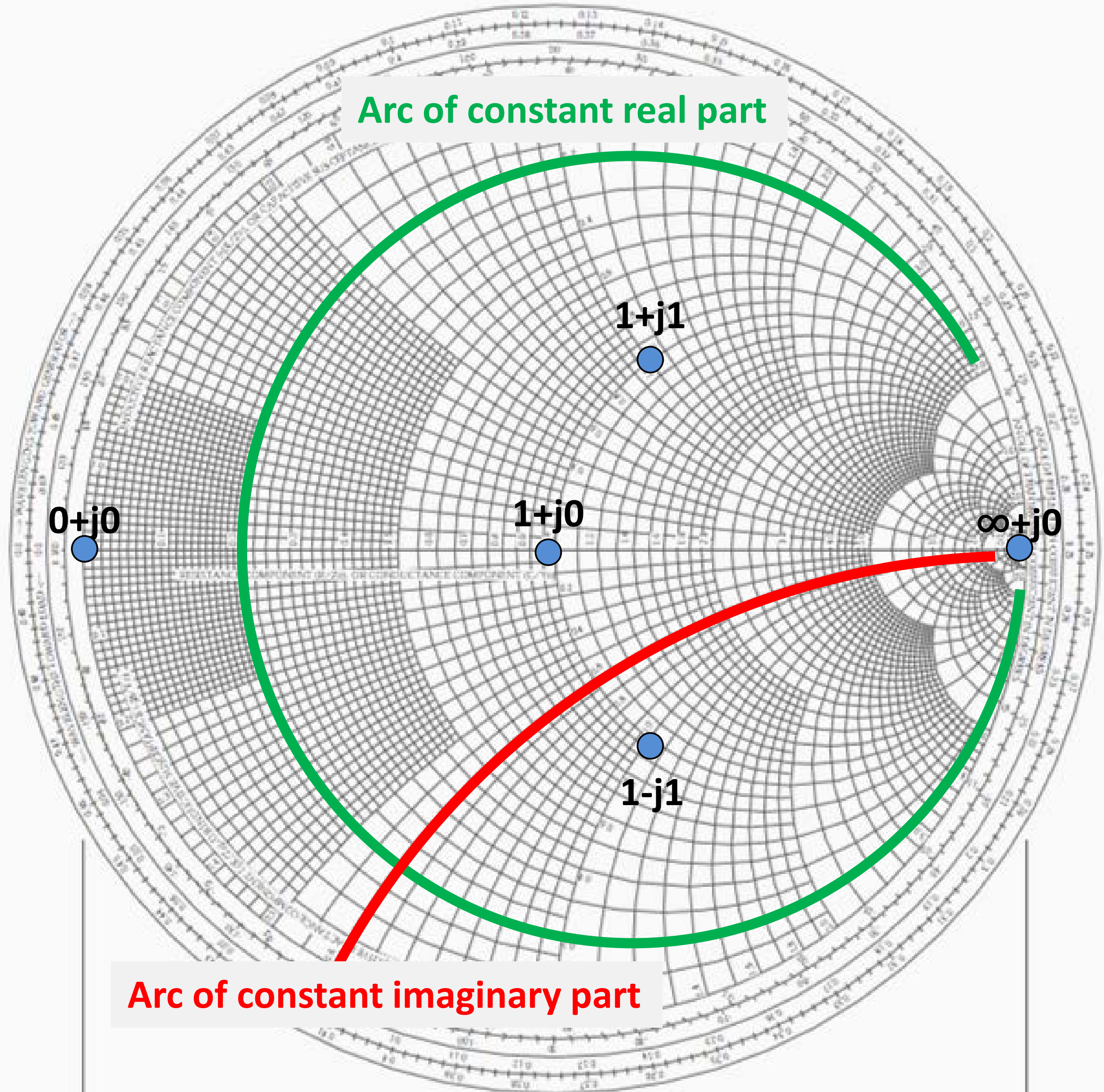
The Smith Chart

Maps imaginary numbers onto a series of circles.

For us, these are electrical impedances and admittances.

Normalized to the characteristic impedance Z_0 (normally 50 or 100 ohm), $z=Z/Z_0$

Handy property: inverting number ($y=1/z$) is just a reflection through the origin.



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The Smith Chart

Each component has a frequency dependent impedance and admittance.

$Z=1/j\omega C$

$Y=j\omega C$

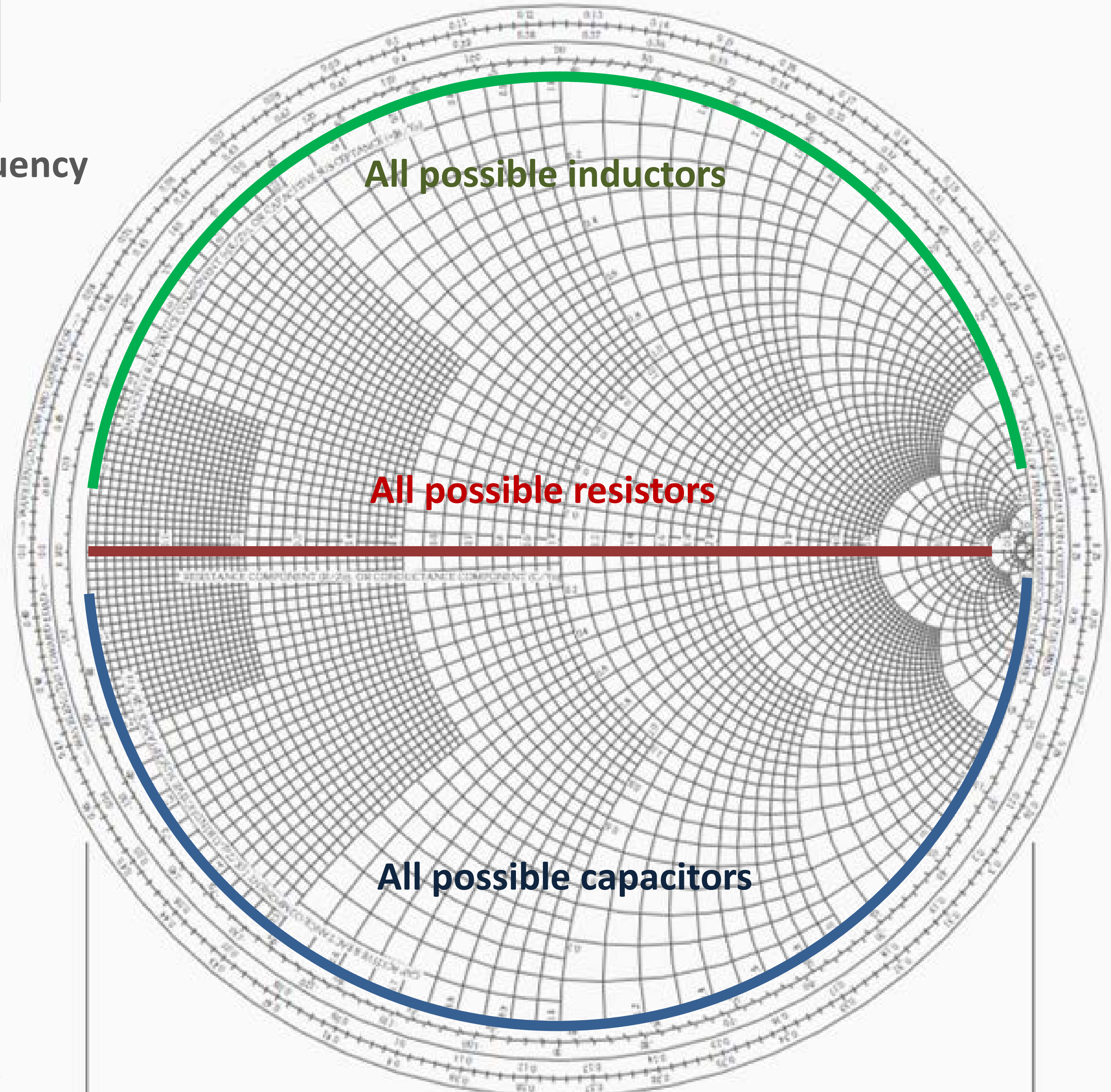
$Z=j\omega L$

$Y=1/j\omega L$

$Z=R$

$Y=1/R$

Can also map combinations of components



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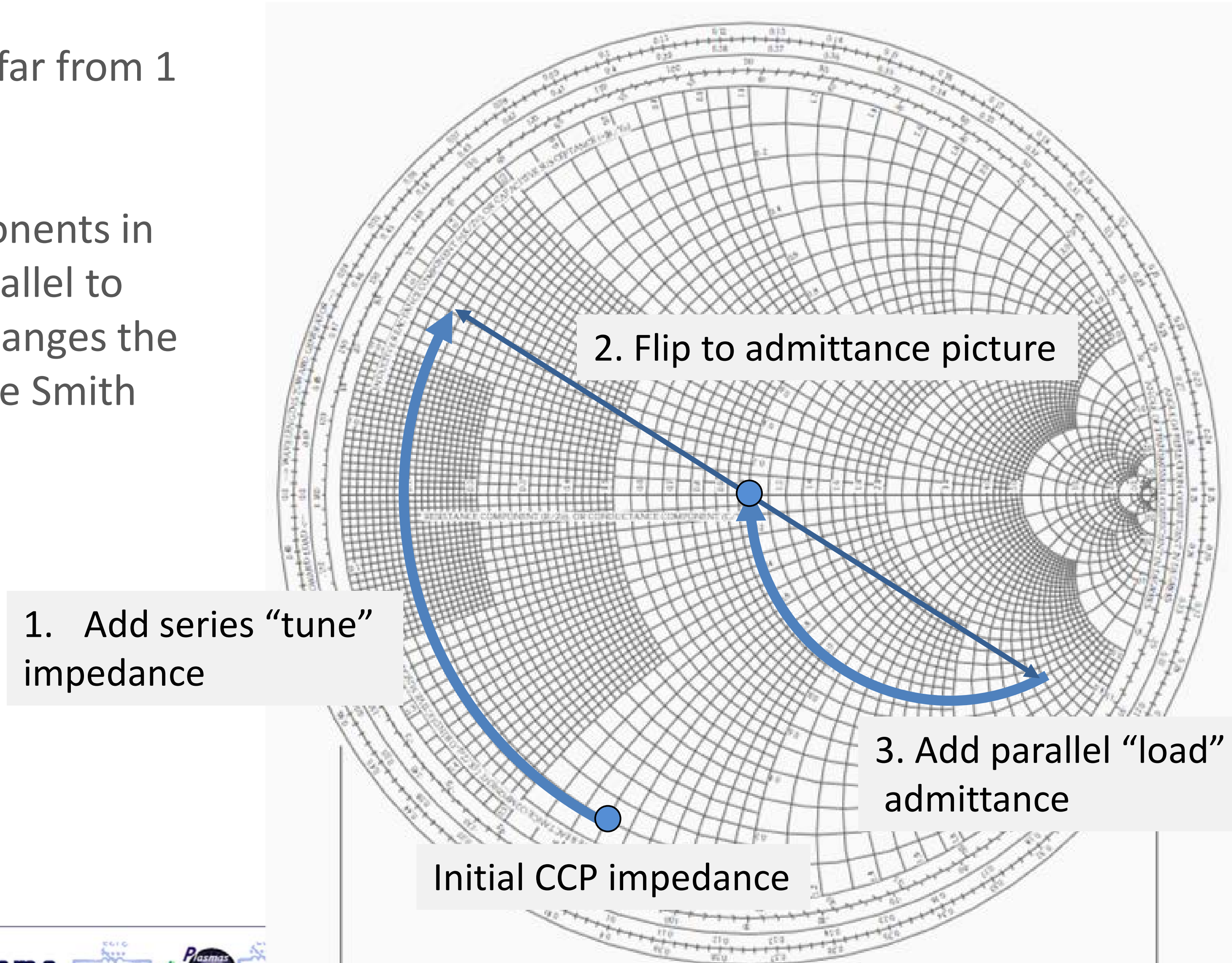
Adjusting reactor impedance

Initial reactor impedance is far from 1 (the origin)

Adding components in series and parallel to the reactor changes the position on the Smith chart.



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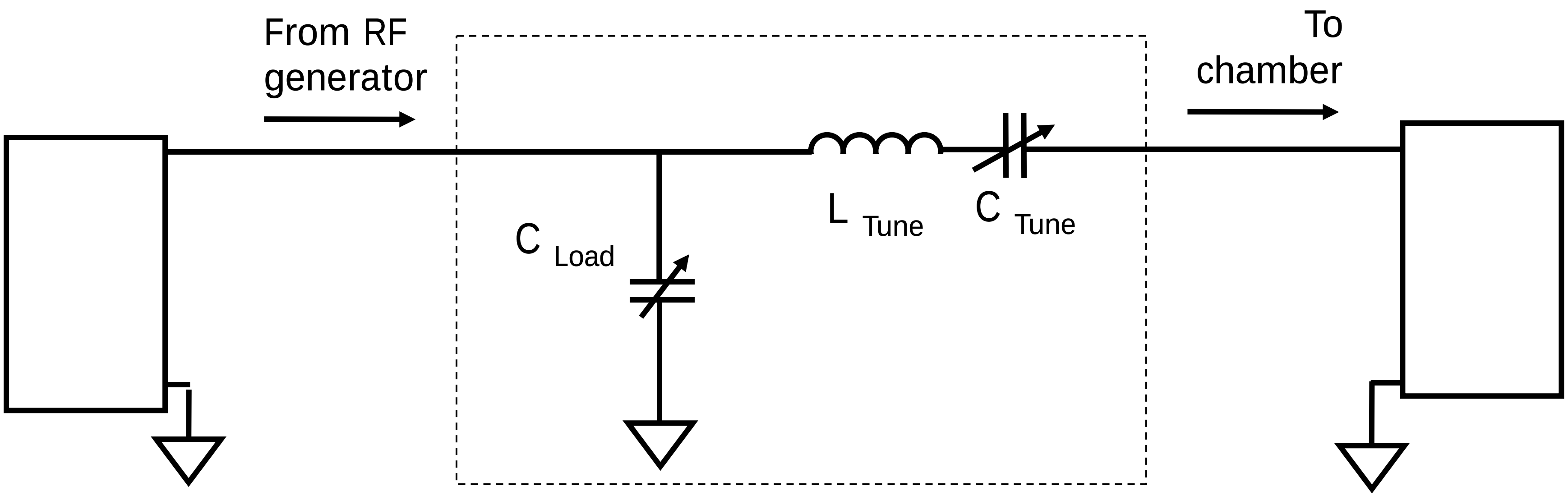
Circuit for Frequency Matching

- Tune circuit is typically an inductor with a variable capacitor
- Load circuit is a varicap (with fixed capacitors in parallel)
- It is harder to fabricate a variable inductor.



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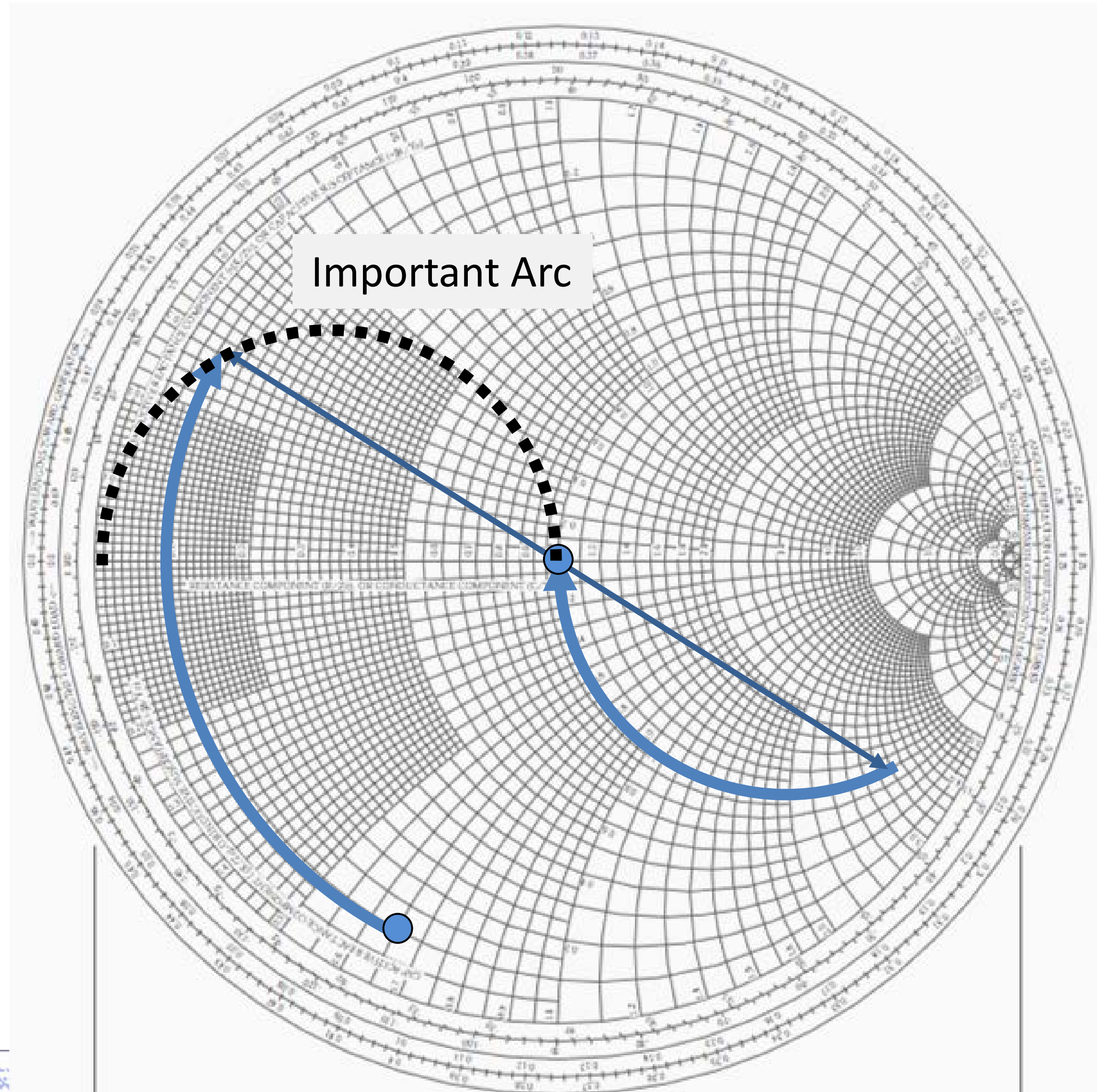
Adjusting reactor impedance

There is an important arc on the Smith chart: normalized impedances that, when flipped into admittances, have a real part (conductance) of unity and a negative imaginary part (susceptance).

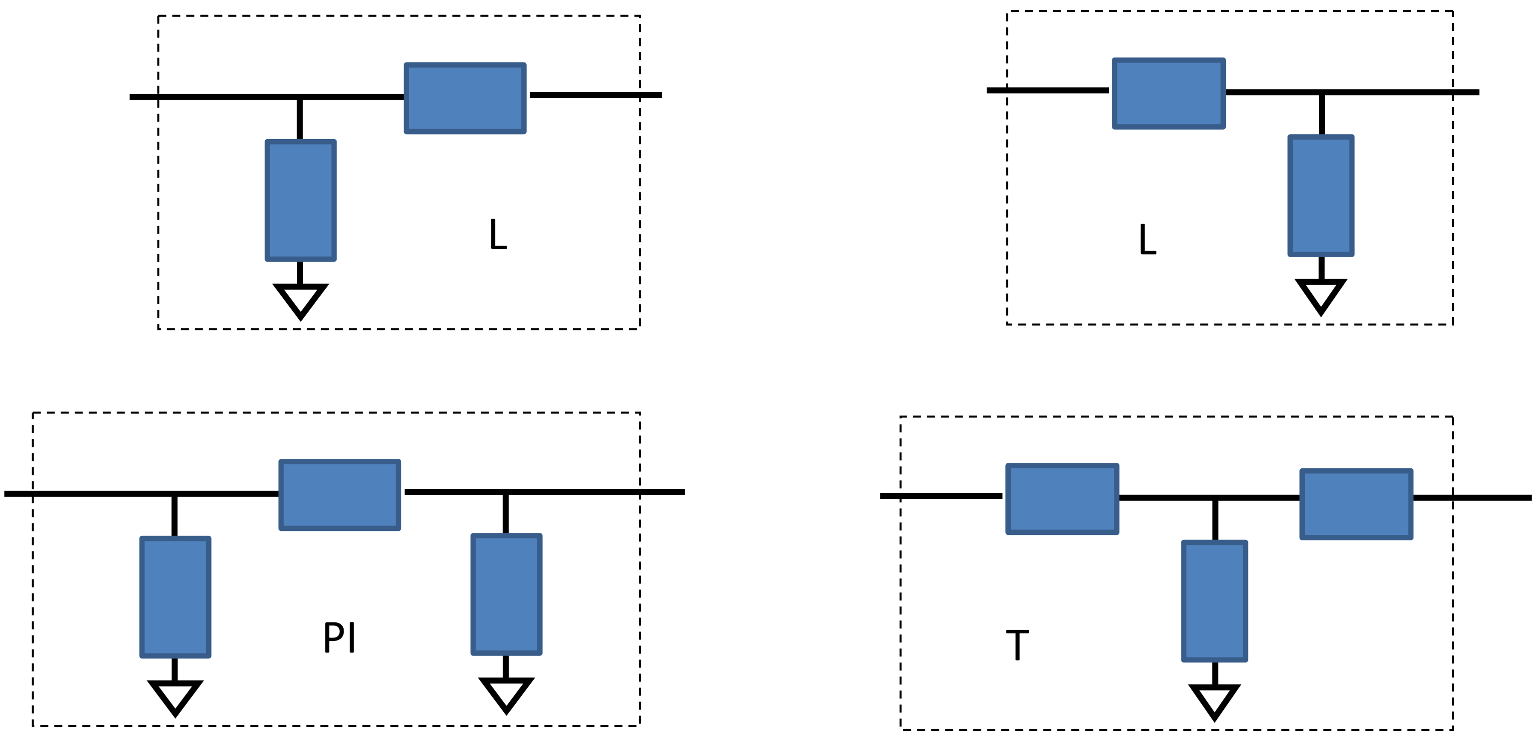
1/z=1-jb

If adjusting tune circuit cannot get reactor onto this arc, it cannot be matched.



Different Layouts

- So far, I have shown the L (or gamma) configuration
- Could also be used backwards for high resistance loads
- Only one solution for matching (so bandwidth is predetermined)
- Pi or T configurations give greater design control over bandwidth



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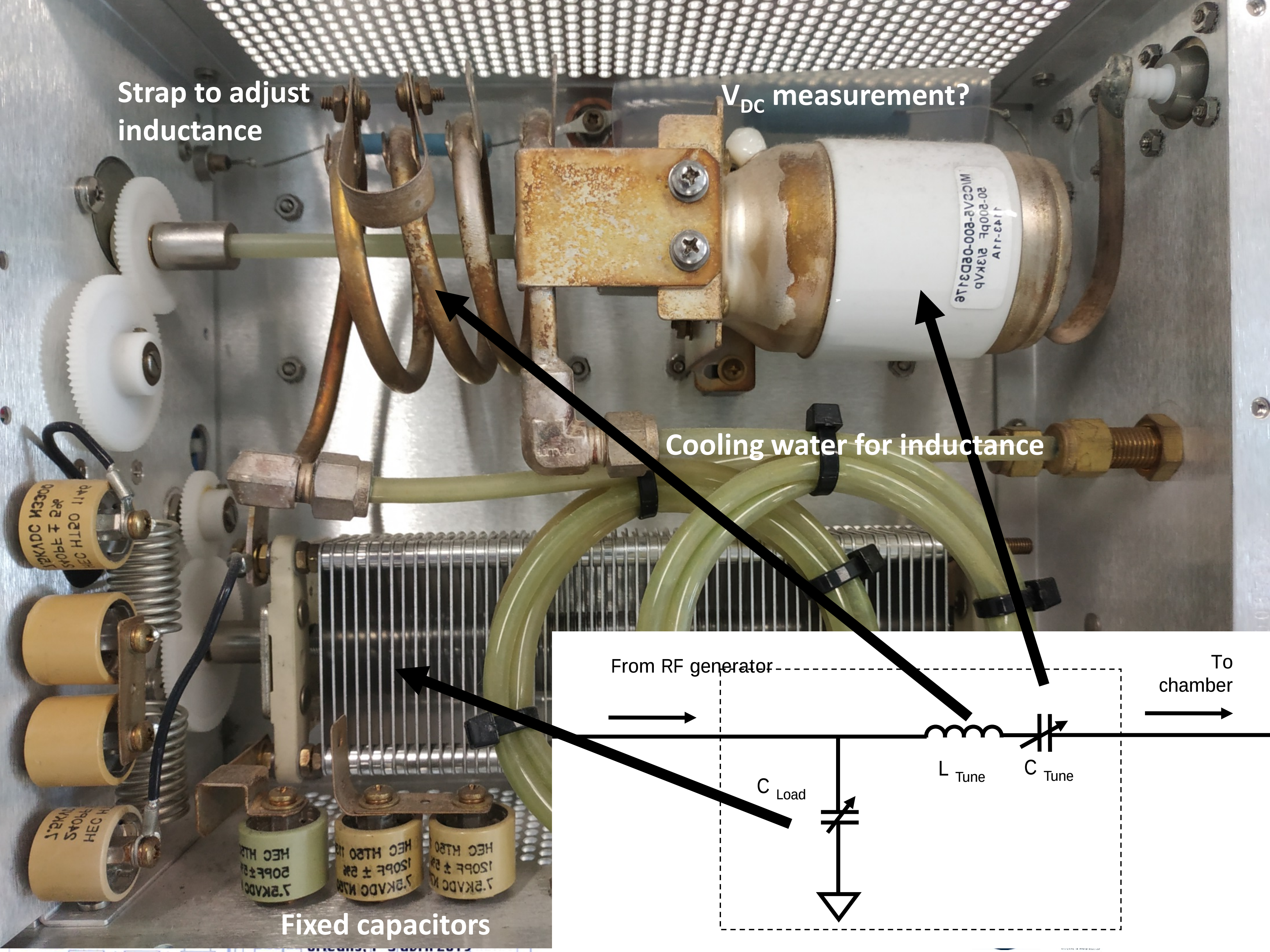
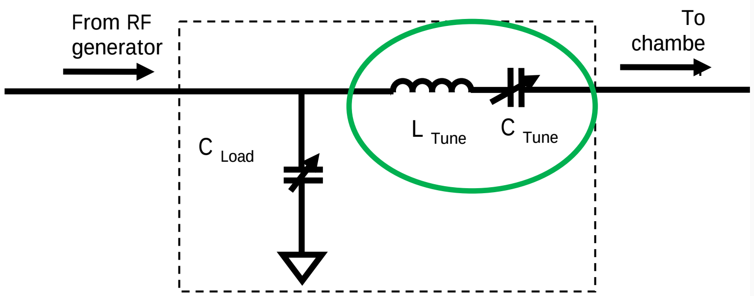

Strap to adjust inductance
V_DC measurement?
Cooling water for inductance
Fixed capacitors
From RF generator
To chamber
L Tune
C Tune
C Load

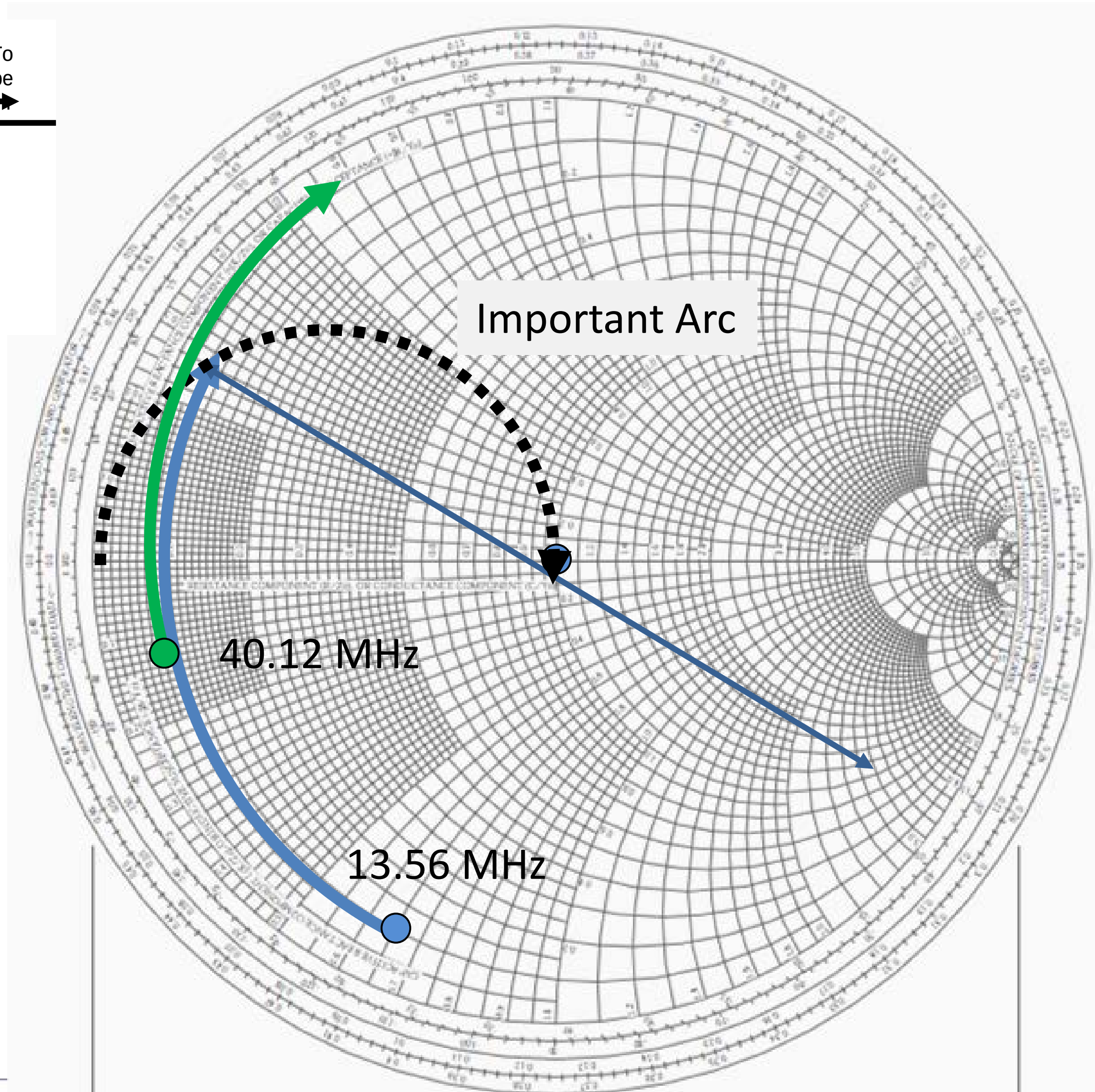
Modifying components - Tune



At higher frequencies, system reactance will get less negative.

Z=jwL in Tune will get bigger, may make matching impossible

Will want to reduce value of L (strapping)



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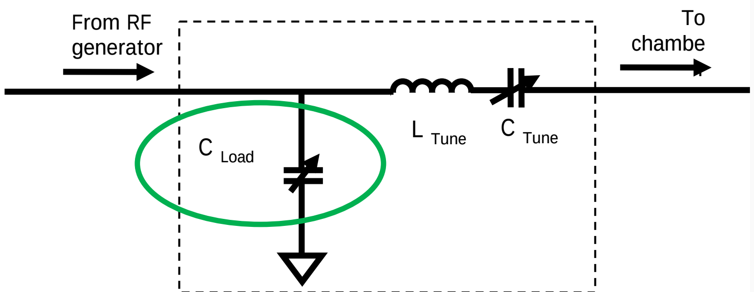
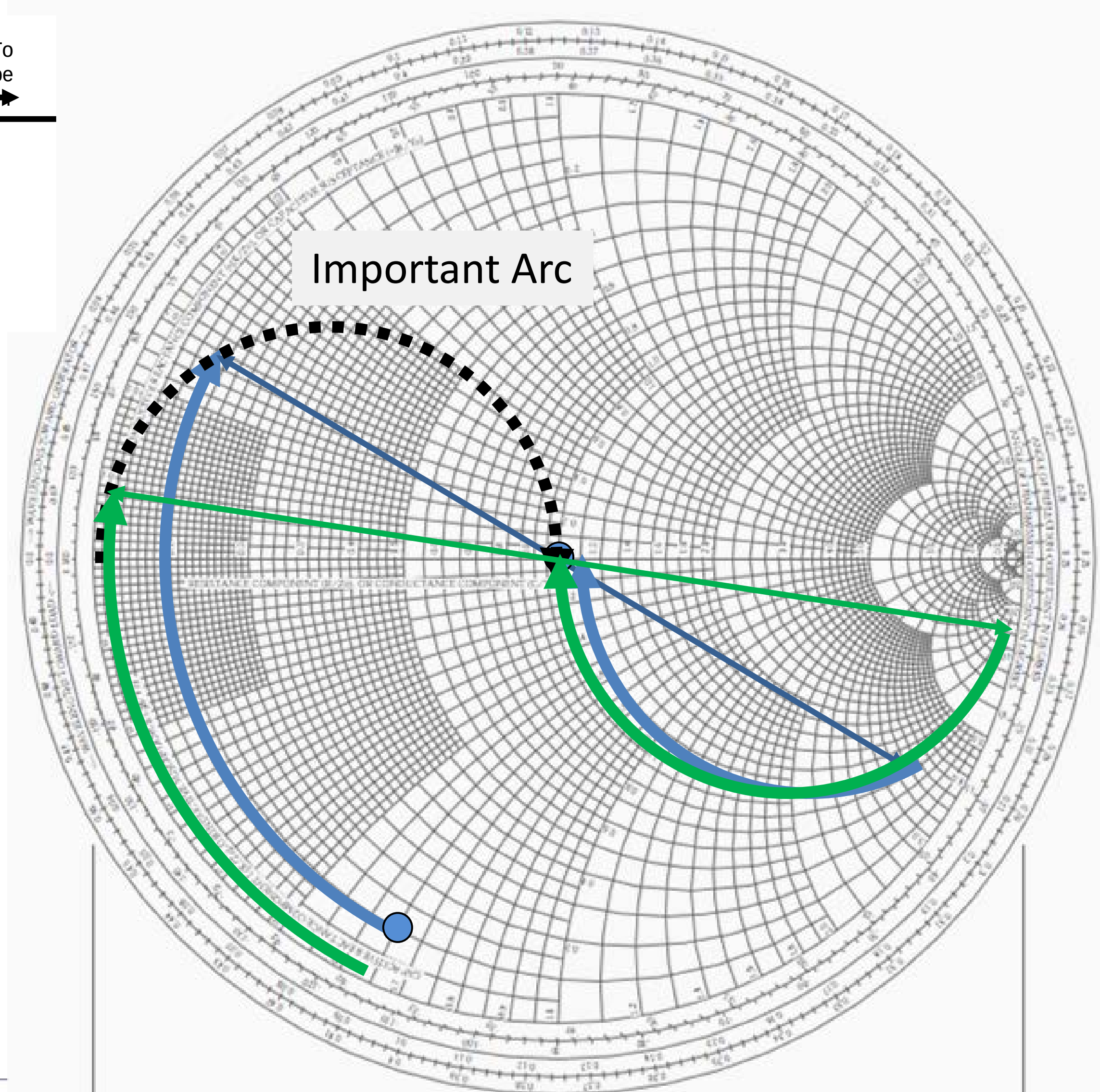
Modifying components - Load



Less resistive reactors will require a higher Y=jB in the load branch to get to the origin

Y=jwC, so a larger value of C

We can add in those fixed capacitors



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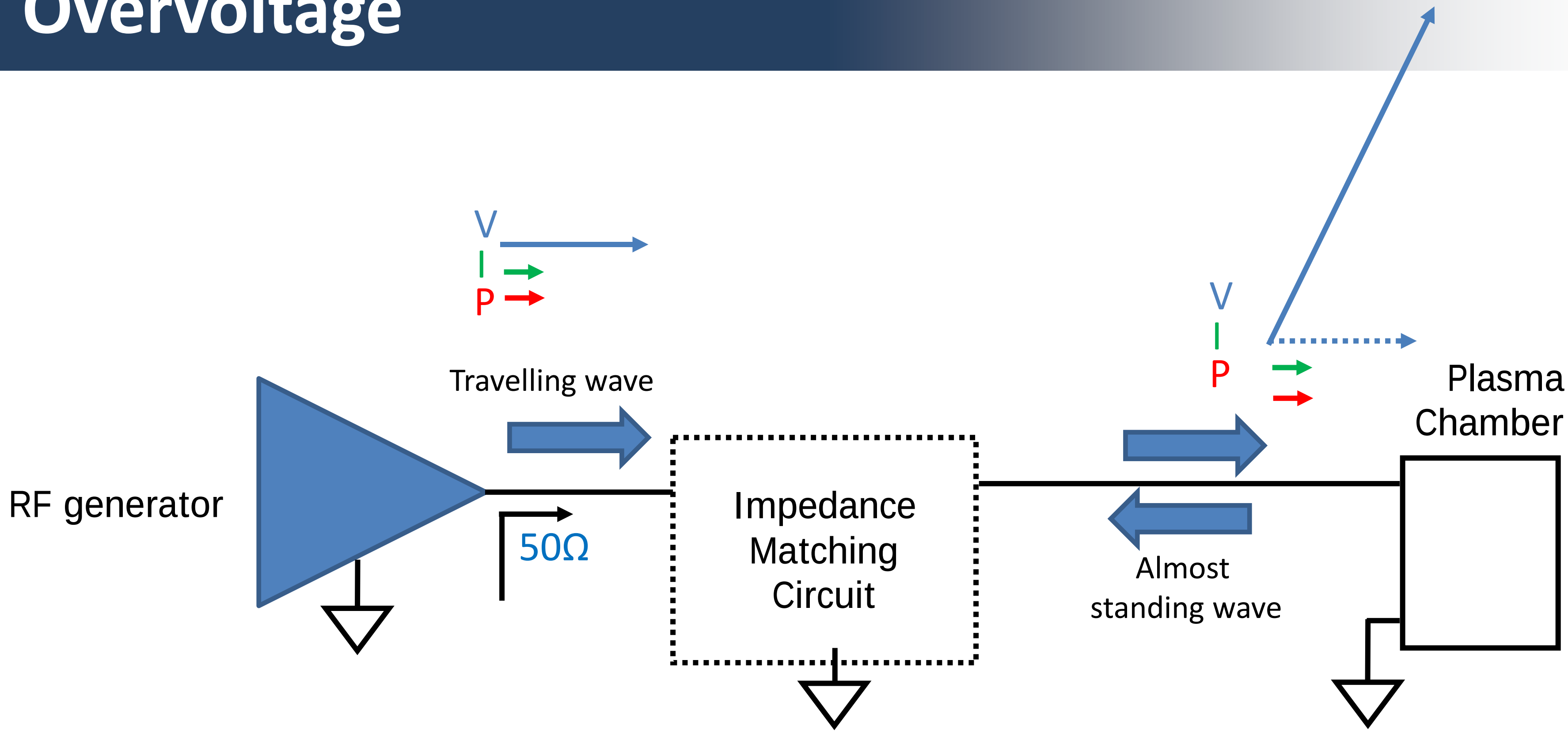
Why is this one a vacuum capacitor?
And this one can be air?

Overvoltage



On amplifier side, voltage and current are in phase and give a certain power

On chamber side, they are almost out of phase – much higher voltage for similar power

Due to counterpropagating waves after matchbox

Magnitude of voltage on plasma side is much larger than on generator side

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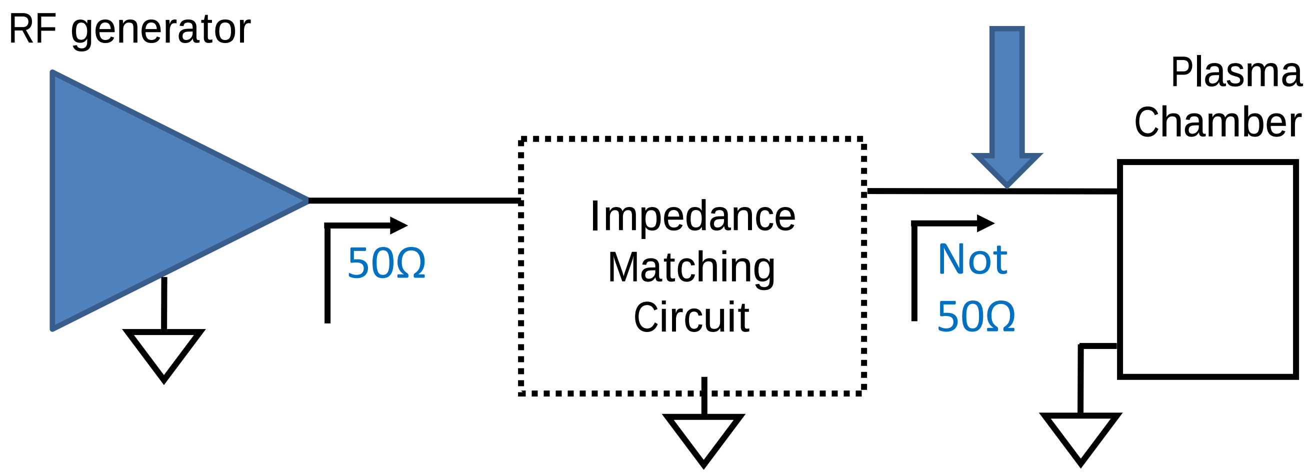
RF Signal Measurement



Information at input of matchbox typically provided by amplifier/power source (coupled power).

Accurate, but incorrect

Does not account for losses in the matchbox/cables/feedthroughs.

Measurement close to plasma can be more valuable

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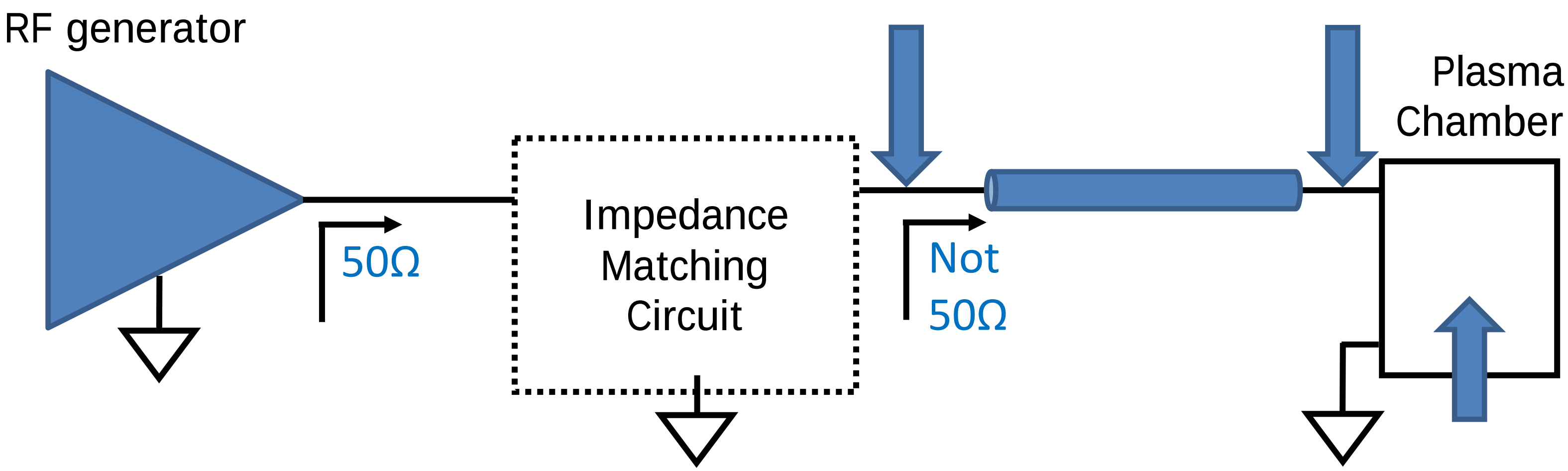
RF Signal Measurement



If cable is low-loss, power measurements can be the same everywhere on reactor side

On reactor side, a large standing wave is present.

Values of current and voltage can depend strongly on position.

Closer to the electrode is better.

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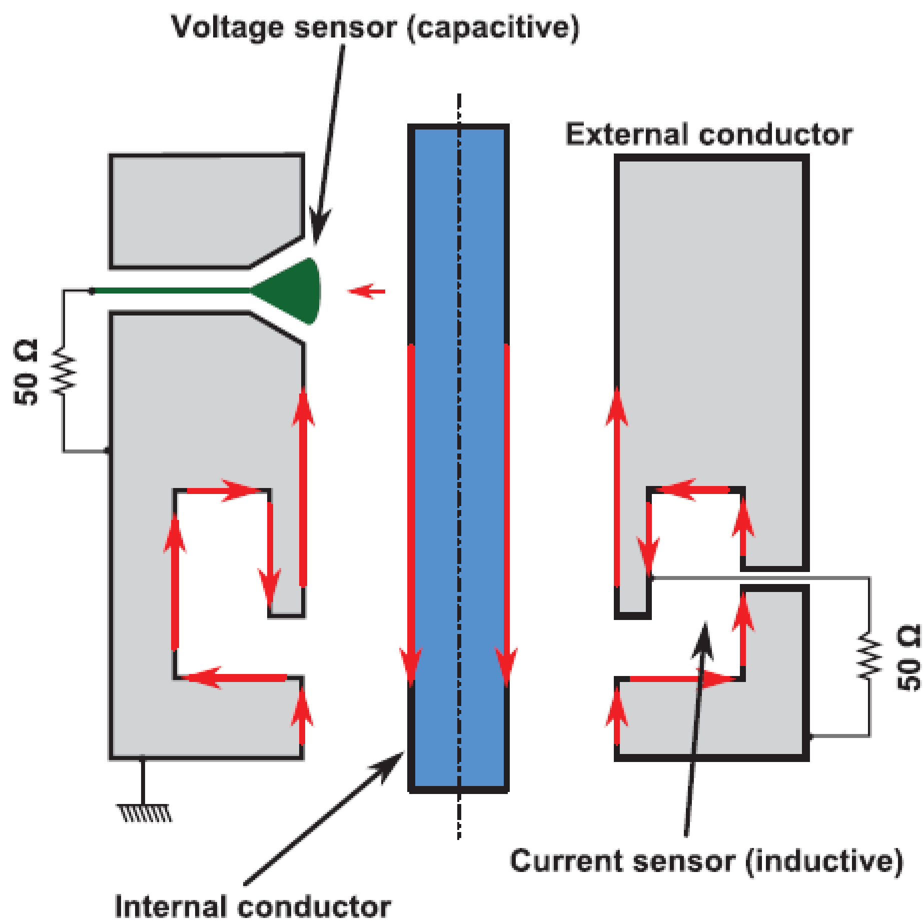
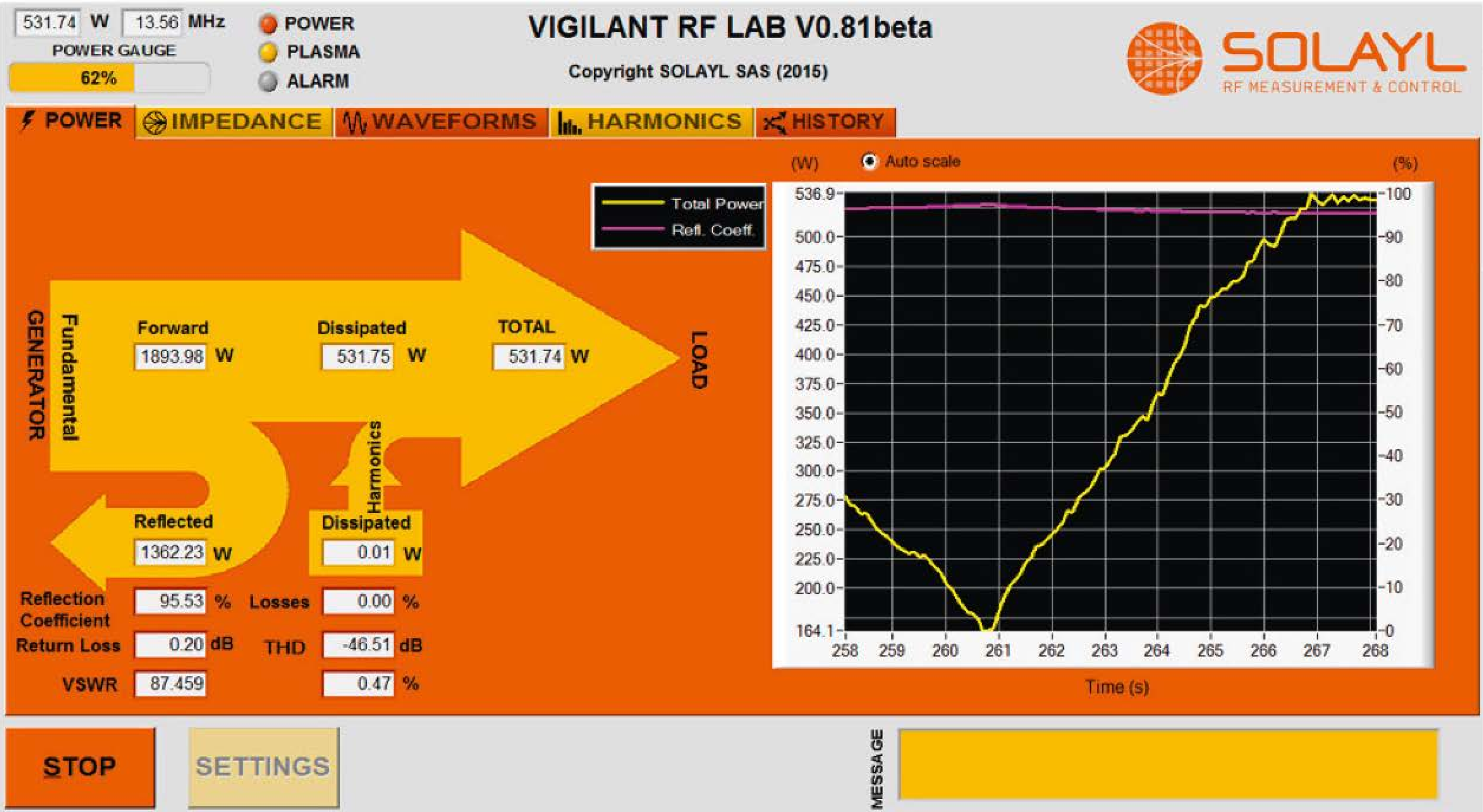
SOLAYL Probe

Shape of external conductor results in capacitive and inductive pickups.

Generates two signals proportional to the derivative of the current and voltage.



Data provided by SOLAYL Vigilant



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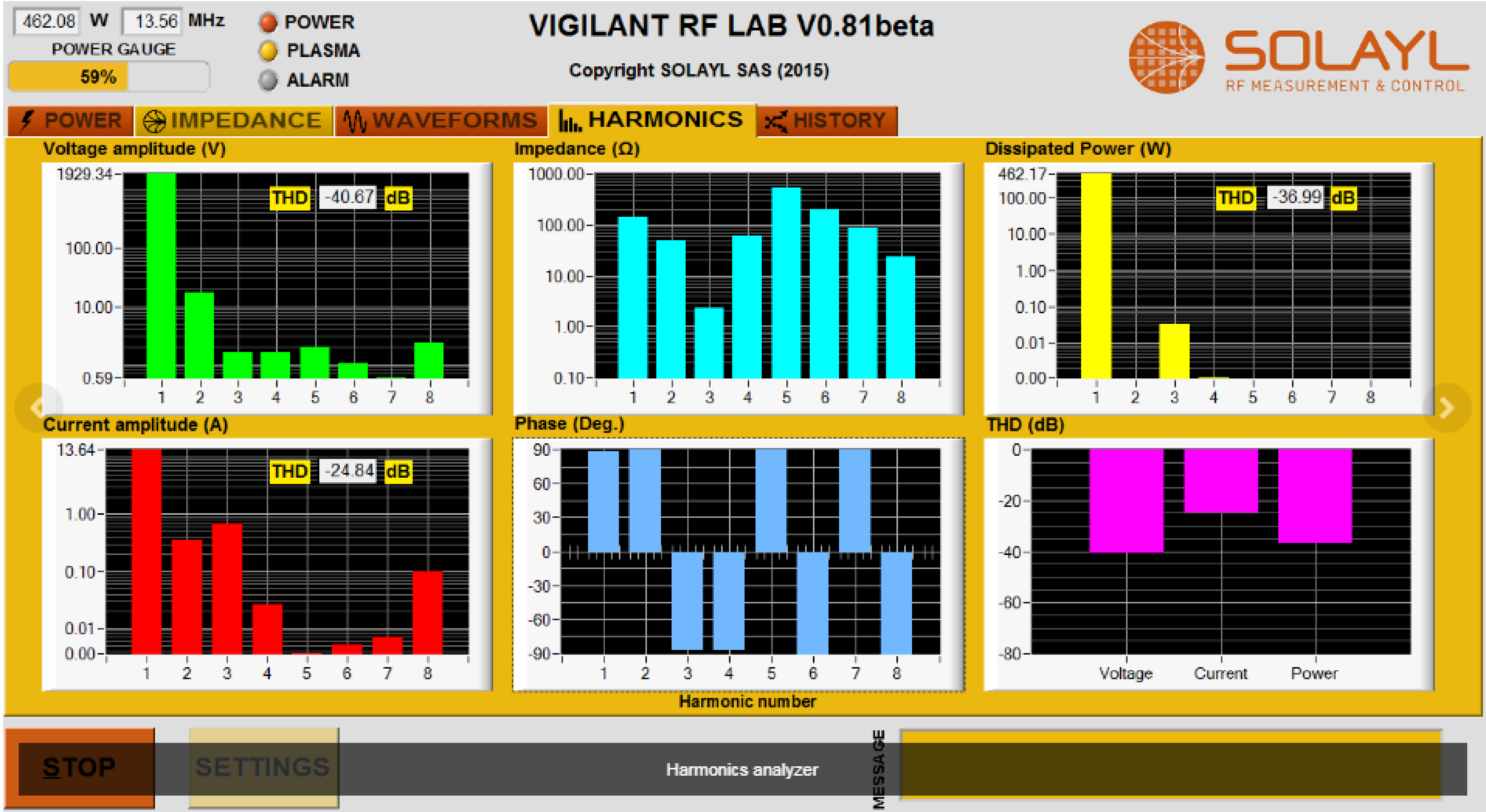

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Conclusion

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  - Smith Chart helps to understand matchboxes
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