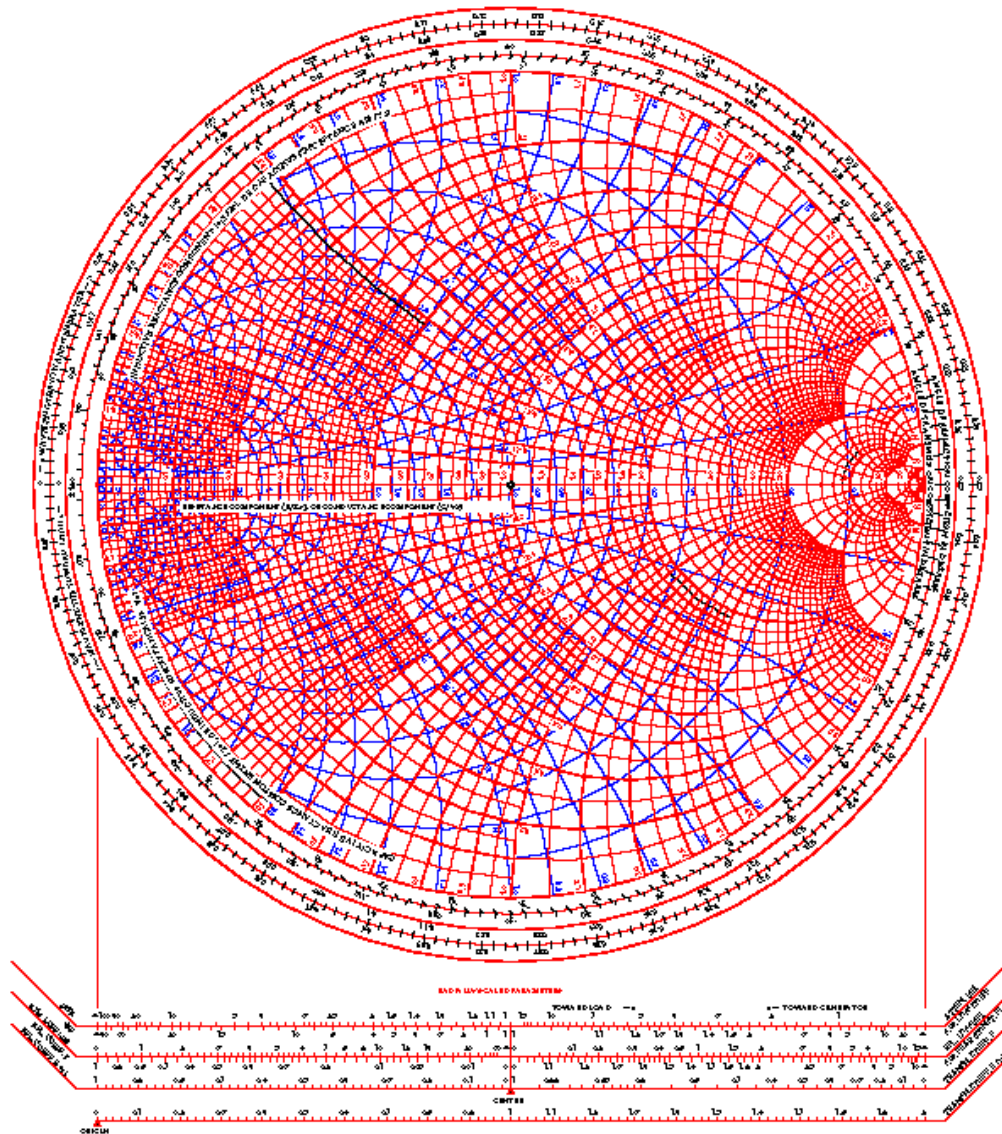


I will assume that everyone realizes that to get optimum power transfer between a source and a load, one must have the impedance of the load matched to that of the source. If these impedances are not matched, we can match them by adding components between the source and load. Rf plasma systems must follow this impedance match requirement. How this is done, can be determined with what is known as a Smith Chart.

NAME	TITLE	DWG. NO.
SMITH CHART FORM ZY-01-N	COLOR BY J. COLEMAN, UNIVERSITY OF FLORIDA, 1997	DATE

NORMALIZED IMPEDANCE AND ADMITTANCE COORDINATES



Smith charts are based on the reflection coefficient of a line and load. In general this reflection coefficient is complex in nature.

$$\Gamma_0 = \frac{Z_L - Z_0}{Z_L + Z_0}$$

where  $Z_0$  is the characteristic impedance of the line and  $Z_L$  is the impedance of the load. The magnitude of  $\Gamma_0$  runs between  $\pm 1$  and it is in the complex plane. Typically we describe  $\Gamma_0 = |\Gamma_0| \angle \text{phase angle}$ . We can change the phase angle by adding additional lengths of line, finding that the phase of the reflected signal changes by  $2\beta d$ , where  $d$  is the line length and  $\beta = \frac{2\pi}{\lambda}$ . (This should make sense as the wave has to travel down the line and then back the other way to be truly reflected.) Any change in the line length simply corresponds to phase change on the circles of radius  $|\Gamma_0|$  in the complex plane.

Now it also turns out that the reflection coefficient is related to the impedance. A little bit of math shows that

$$\begin{aligned} z_{in} &= \frac{Z_{in}}{Z_0} = r + ix \\ &= \frac{1 - \Gamma_r^2 - \Gamma_i^2}{(1 - \Gamma_r)^2 + \Gamma_i^2} + i \frac{2\Gamma_i}{(1 - \Gamma_r)^2 + \Gamma_i^2} \end{aligned}$$

This results in circles that are off set from the origin and shrinking in size. In a similar manner we can determine the admittance,  $y_{in} = g + iby$ , which is simply the inverse of the impedance. This gives us a second set of offset circles which are in a mirror image position to those found for impedance.

How do these circles help us to understand the tuning of an rf plasma system?

First we have a characteristic impedance for the plasma-antenna and an impedance for the power supply. (Note that the impedance of the plasma-antenna is set in part by the plasma. Since the plasma can and does change, the impedance of the plasma-antenna changes.)

We can change our location on the Smith chart by adding complex impedance components. These can be capacitor, inductors, line or tuning stubs. (We will not consider lines or tuning stubs here.) If we were to add a capacitor in parallel, also known as a shunt capacitor, then we find that

$$\frac{1}{z_{new}} = \frac{1}{z_{old}} + \frac{i}{c\omega}$$

This change is somewhat hard to plot. On the other hand if we were to look on the admittance part of the chart we find that

$$b_{new} = b_{old} + c\omega Z_0$$

which is easy to plot, we simply follow the complex part of the admittance curve – subtracting the capacitor's admittance. Likewise for a capacitor in series the change can be determined adding to the complex part of the impedance curve. This is because

$$x_{new} = x_{old} - \frac{1}{c\omega Z_0}$$

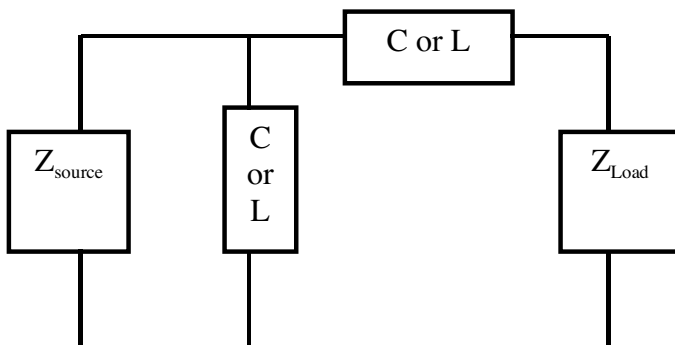
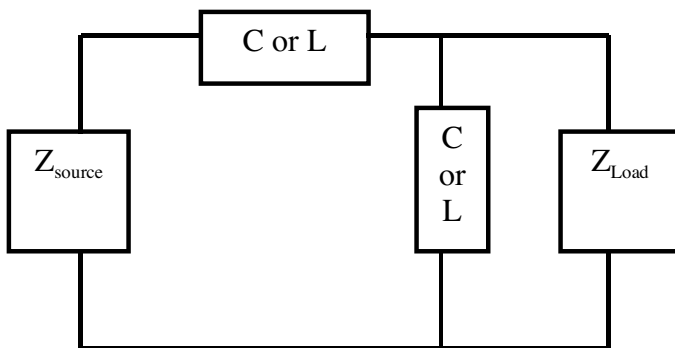
In a similar manner, we find for a series inductor that

$$x_{new} = x_{old} + \frac{L\omega}{Z_0}$$

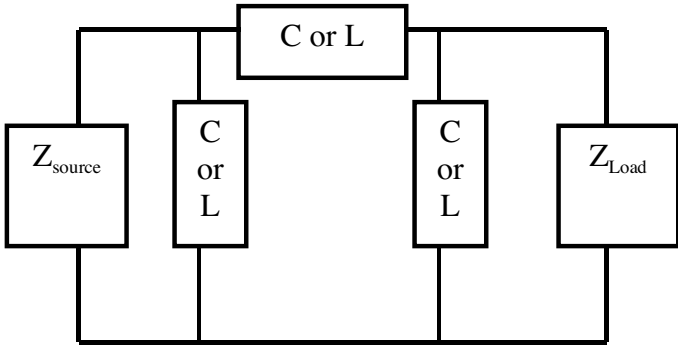
and for a shunt inductor

$$b_{new} = b_{old} - \frac{Z_0}{L\omega}$$

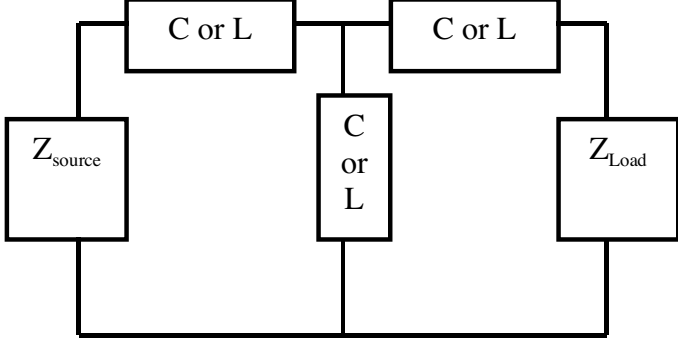
From experience and from looking at a Smith chart for a little while, it is possible to see that any point on the Smith chart can be reached from any other point provided proper inductor/capacitor network is used. The simplest network is known as an 'L' network. It comes in eight configurations.



This is typically what is used to match most rf plasma antenna to the power sources. A second, less commonly used network is the 'pi' network. It looks like



Finally there is the 'T' network which looks like.



These later two networks can have high Q factors, which has some advantages for some applications but they are typically not as useful for plasma systems.