

Simple Network Synthesis and the Smith Plot

Introduction

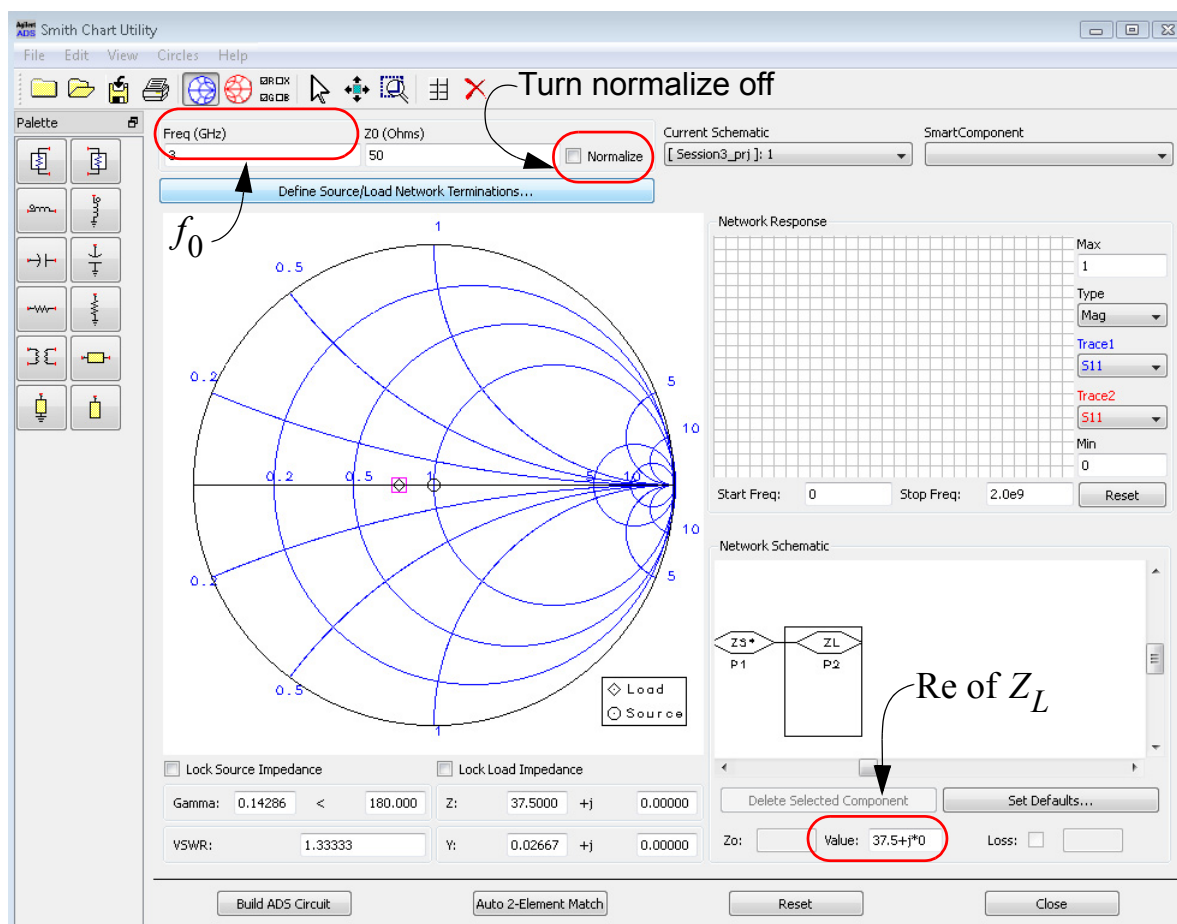
This third session will look at simple network synthesis using the Smith chart, via the Smith chart utility and the use of the *Smith* plot type in ADS plot windows.

Simple Network Synthesis

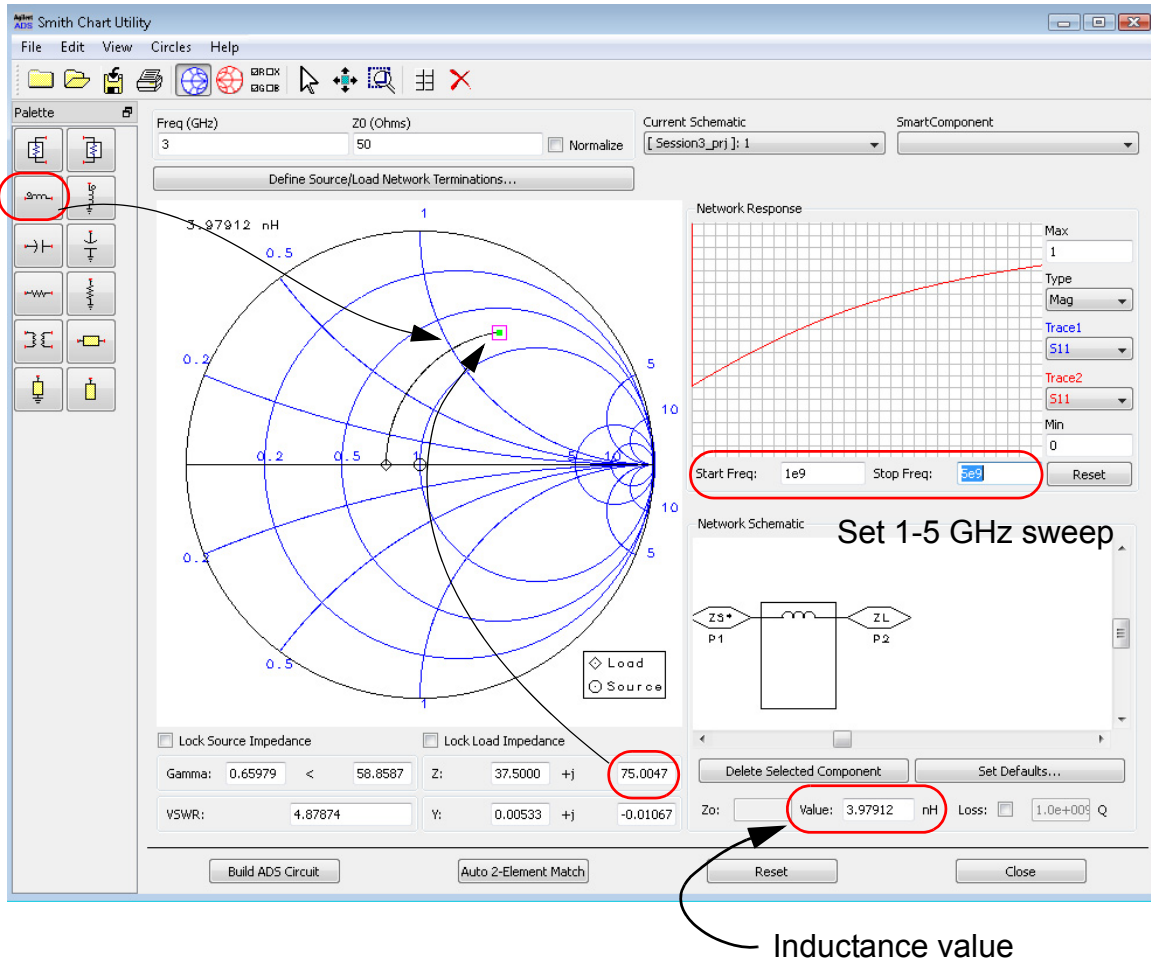
- The Smith chart utility in ADS can be used to synthesize matching networks
- Matching networks is a subject unto itself
- Motivation at this point comes from the desire to synthesize a network of elements that result in a particular Z_L at some center frequency f_0

Example: $Z_L = 37.5 + j75$ Ohms

- We open up the Smith chart utility in ADS and set the operating frequency to 3 GHz
- The normalizing impedance can be left at 50 ohms
- We are going to synthesize Z_L starting from a 37.5 ohm resistor as the load impedance in the Smith chart utility



- We now place a series or shunt element in front of the resistive part of the load so that we can create a combined impedance of $37.5 + j75$
 - What should this be?
 - With the 37.5 resistive portion already in place, the most direct approach is to place down a series inductor
- Select a series inductor from the parts palette and click the mouse in the Smith chart at a location in the top half of the Gamma plane

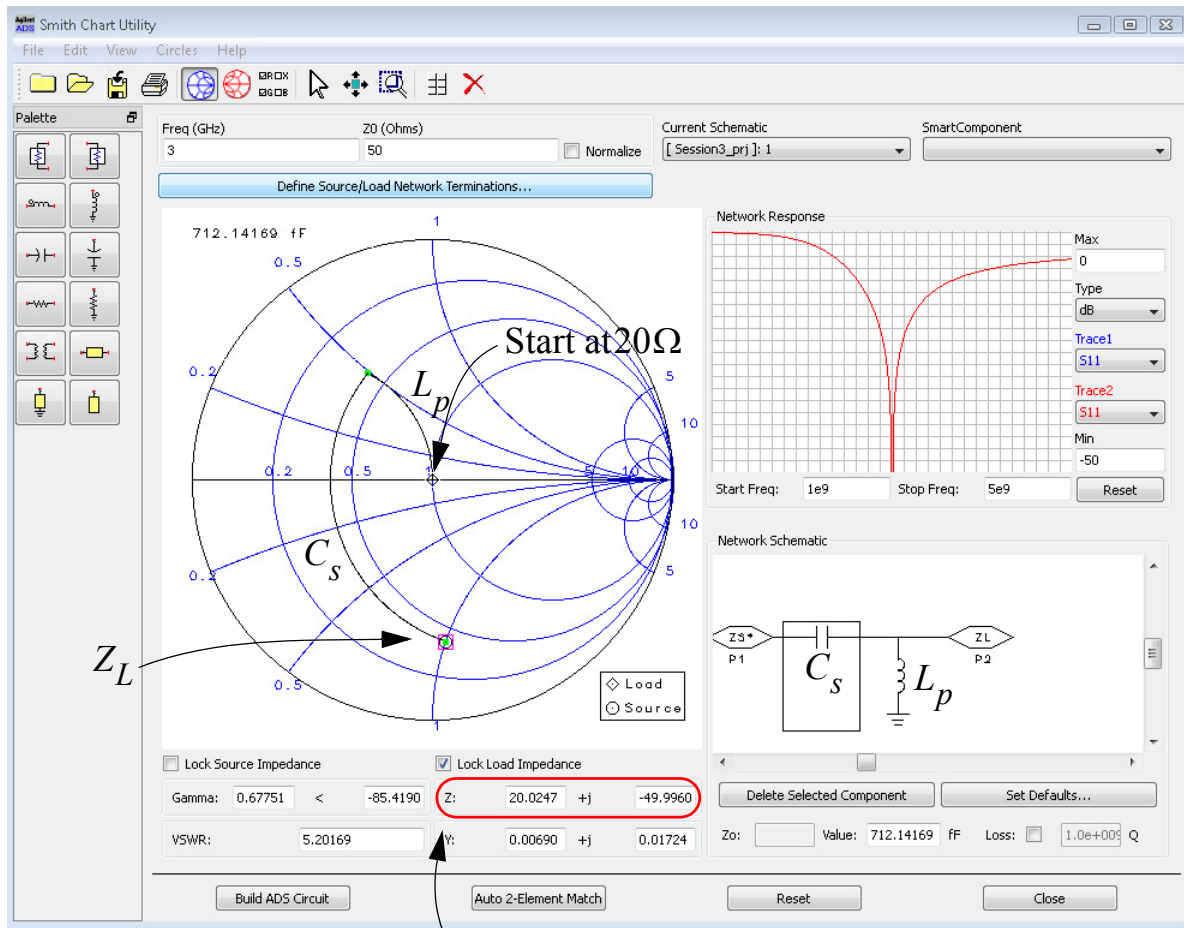


- As you drag the mouse you can watch the value of the load impedance change
 - The real part should stay fixed at 37.4, while the reactive part changes
 - Release the mouse at some point, then you can fine tune the reactive part to exactly 75 by entering it into reactance field for load impedance, then Lock Load Impedance and hit the tab key
 - The green-dot location on the Smith chart should adjust accordingly

- The inductance value can be read from the lower right as 3.98 nh, or is displayed in the upper left of the Smith chart when the element is selected
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- We can arrive at the desired Z_L by many different ways if we choose to introduce more components, say shunt elements too
 - More elements may be dictated by the actual physics of the circuit, i.e. bond wires and pad capacitances
 - In a matching network the number elements increases complexity and space, but also impacts the bandwidth of the match — narrow vs. wide
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Example: $Z_L = 20 - j50$

- We will work this example using two elements beyond a resistor
- We will also make use of the source impedance to set a reference point for the synthesis that we can view on the Smith chart, and also allow return loss of the complex conjugate match to be displayed versus frequency (more on this when matching circuits are discussed)
- In the Smith chart utility we set the source impedance to $20 - j50$ and set the load resistance to 50 ohms
- Next we add a shunt inductor, adjusting the real part of the load impedance to 20 ohms
- Next we add a series capacitor to bring the reactance to $-j50$



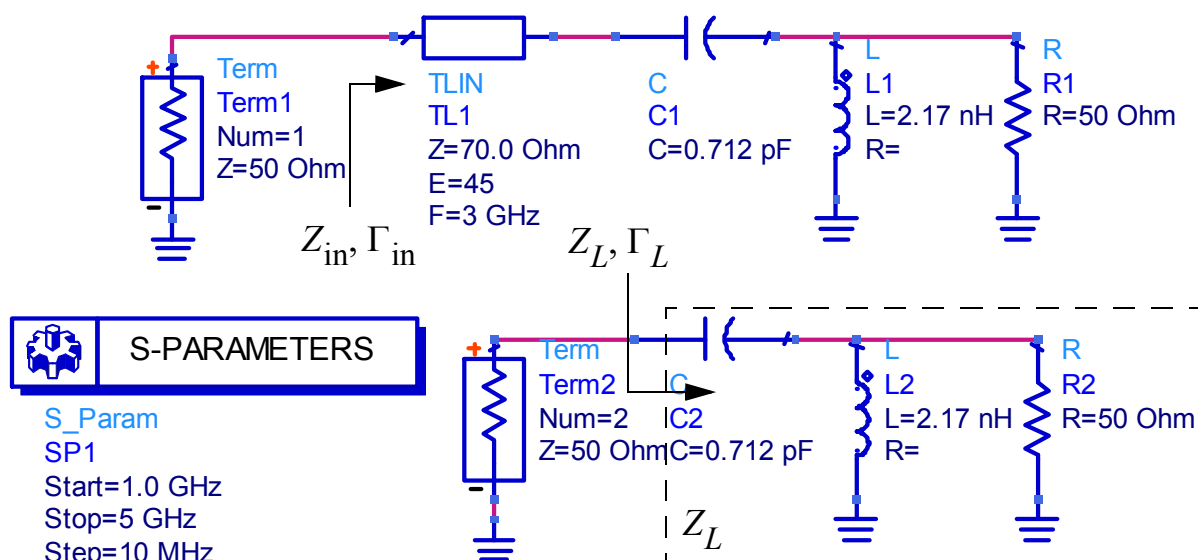
Final synthesized impedance

- The element values are:

$$\begin{aligned} L_p &= 2.168 \text{ nh} \\ C_s &= 0.712 \text{ pf} \end{aligned} \quad (3.1)$$

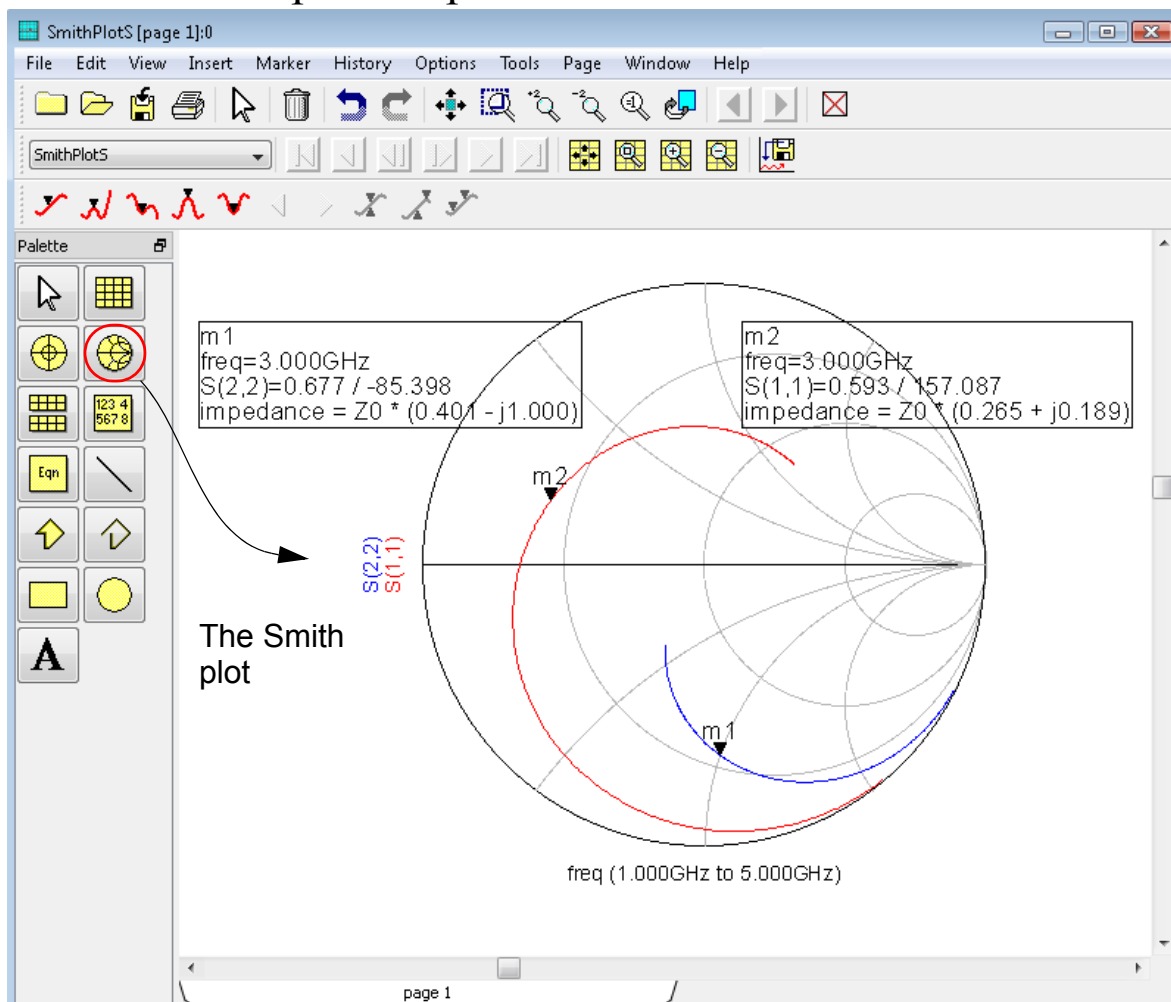
The Smith Plot for Measurements

- When the need arises to look at input impedances and/or reflection coefficients as complex quantities, the Smith chart can be very helpful
- When frequency is swept, as in S-parameters simulations, we get a locus of points in the Smith chart to consider
 - The markers can be useful then for evaluating impedance and reflection values at a particular frequency of interest
- Consider the load synthesized in the previous section, only suppose we place a 50 ohm line in from of this load
- We wish to consider Z_L and Γ_L when f sweeps from 1 to 5 GHz
- We also wish to consider Z_{in} and Γ_{in} at the transmission line input
- The ADS schematic is the following:



- Two circuits have been modeled, one with a series $Z_0 = 75\Omega$ line of length $\lambda/8$ (45°) at 3 GHz in front of the synthesized Z_L and the other just the synthesized load
- Now we simulate the circuits and when the plot window opens we place a Smith plot
 - We will plot S_{11} for both of the one-port networks ($S(1,1)$ and $S(2,2)$)
 - We make use of the fact that $S_{ii} = \Gamma_i$, that is here

$$\Gamma_{in} = S(1,1) \quad \Gamma_L = S(2,2) \quad (3.2)$$
- In the Smith plot we place markers on each trace at 3 GHz



- From the marker values for Γ_L or $S(2,2)$, we see that

$$\begin{aligned} Z_L &= Z_0(0.401 - j1.00) \\ &= 50(0.401 - j1.00) \\ &= 20 - j50 \end{aligned} \quad (3.3)$$

which is the expected value

- The locus of points for Γ_{in} or $S(1,1)$ is different, but we expect that since we are now looking through a 45° section of 70 ohm transmission line
- The reflection coefficients at the two locations should have the same magnitude?
 - Not in this case, since we have the port impedances set to 50 ohms and the T-line section has $Z_0 = 70$ ohms
 - We can run the simulation again, but now with the port impedances changed to 70 ohms

