Tutorial: Fundamental Concept of Microwave Circuit and Basic Operations on ADS

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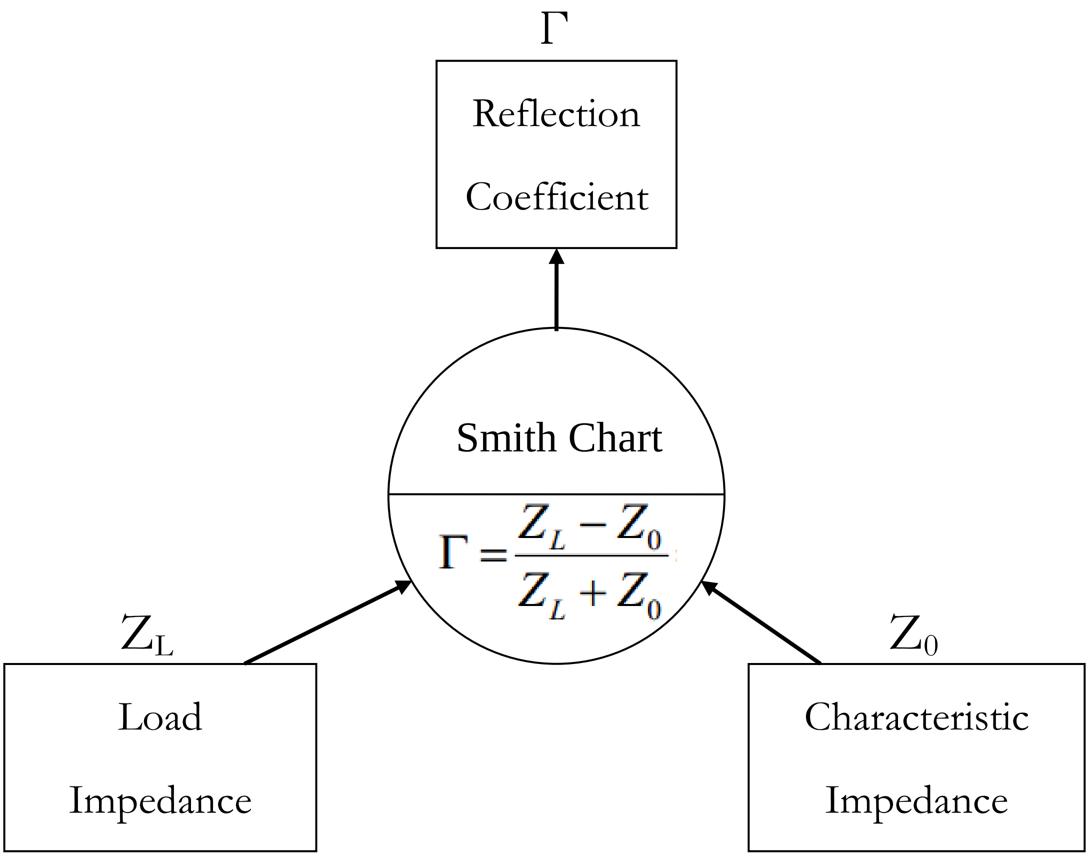
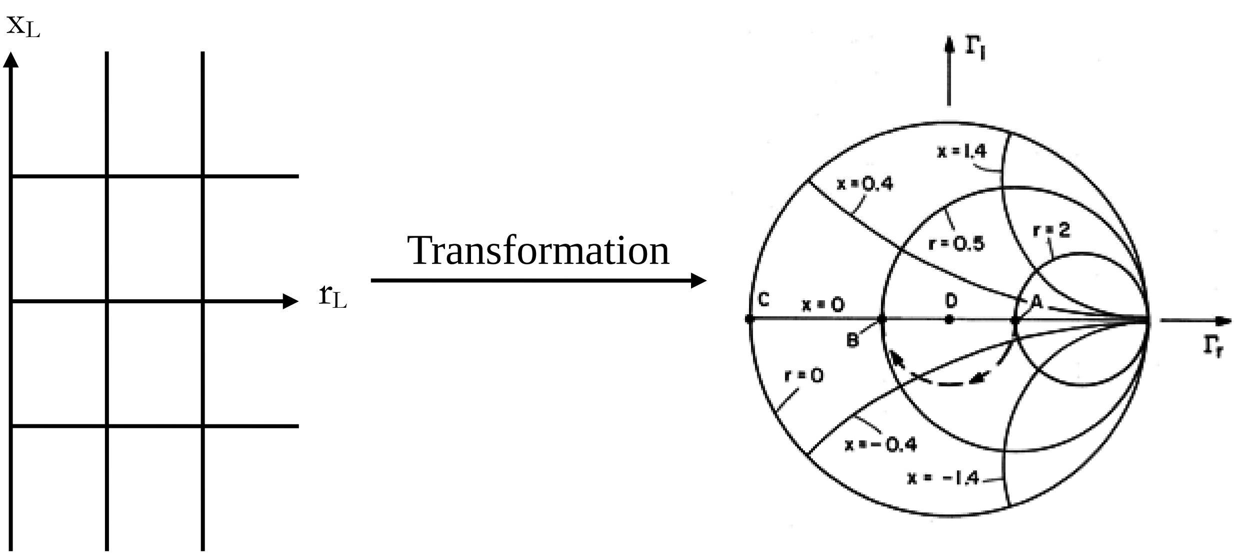
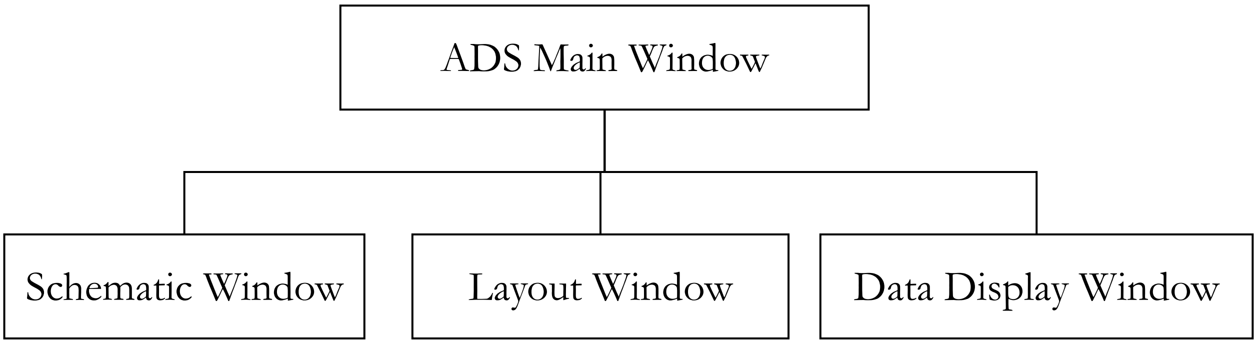
If you have any questions, please contact Ke Zeng (kzeng2@buffalo.edu)

PART 1: Fundamental Concept of Microwave Circuit





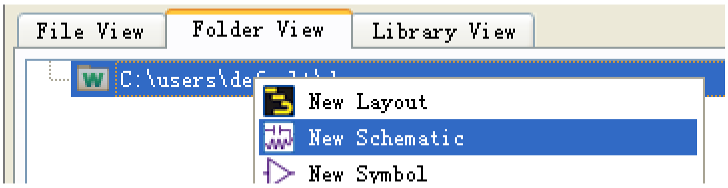
PART 2: Basic Operations on ADS



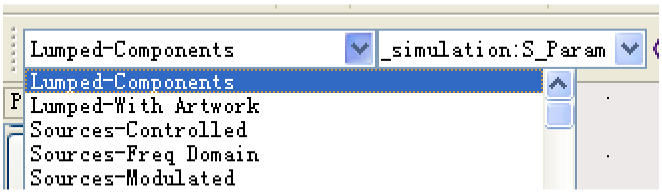
Schematic Window	Layout Window	Data Display Window
Abstract circuit representation with no dimension	**Physical layout of circuit with 2 or 3-dimensional element**	**Measurement result of circuit (Reflection Coefficient, Smith Chart, Radiation pattern)**

Demo #1: Single resistor, Short and open circuit

1. Open ADS, create a workspace for your design.
2. Right click on your workspace, choose 'New Schematic' to create a new schematic.

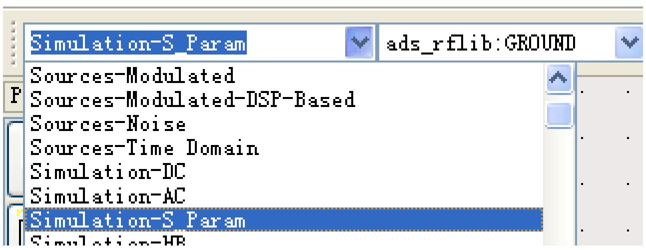


3. Now we want to create a circuit with a single resistor. Choose your component library from various libraries for different application, here we choose 'Lumped-Components'.



Find 'R' for resistance on the left side palette, click on it and put it in the schematic field. Any kind circuit should be grounded, so click 'Insert' on menu bar and choose 'GROUND' to place a ground in schematic.

4. Circuit is complete now. To add measurement terminal, choose your component library as 'Simulation-S_Param'. Or you can type 'term' in the text field on the right side of component library label and press 'Enter' key.

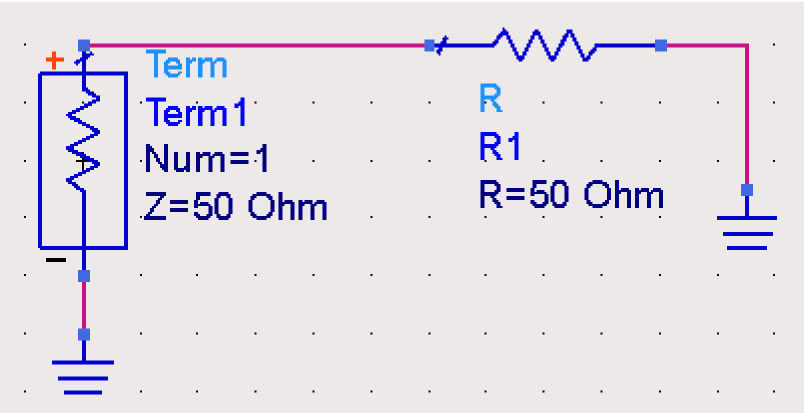


In the 'Palette' section, select 'Term' component, place it in schematic.

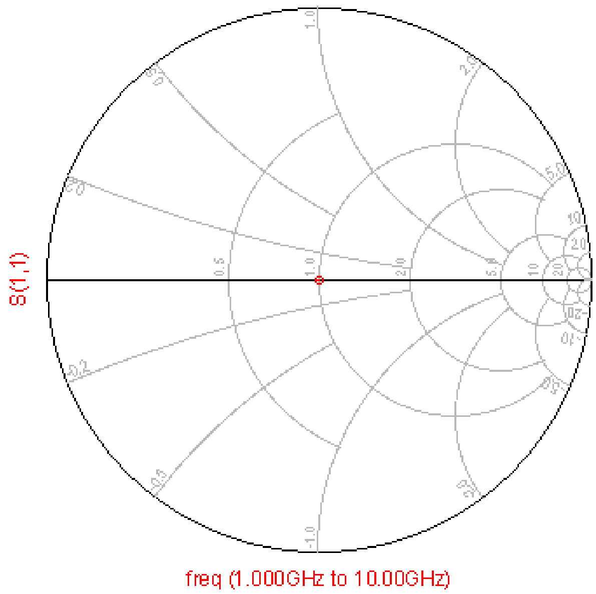
5. Connecting circuit and measurement terminal using wire. 'Insert' → 'Wire' or click on the wire icon

on top panel. Note that only the tiny red box on the component can connect to wires.

6. Measurement terminal has two connecting ports, the '+' port is where the signal goes out. And the '-' port should be grounded so that measurement device and circuit have the same reference ground voltage. So add a ground to schematic and connect it to terminal too. After this, we will see:

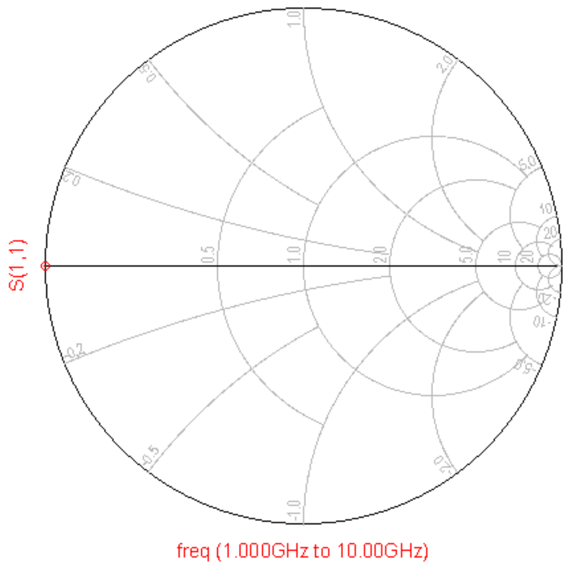


7. After setting up the measurement device, you also have to set up the measurement configuration. Select 'S P' in palette section, place it somewhere in schematic. Specify the start and stop frequency, as well as step between each frequency point. For now, we use the default setting.
8. Run the simulation and measurement by click on the gear icon. After this, a data process window will pop up. When it is finished, the data display window will show up automatically.
9. In data display window, choose 'Smith Chart' in palette, place one in the middle. You will see a window asking you for the detailed configuration of plot. Choose 'S(1,1)' on the left side box add it to the right side, click 'OK'.



We can see the load 50ohm resistor is matched to the input as we expected in the center. Center of the smith chart is the matching point where no reflection will occur.

10. Now you can try change the value of resistor to 0 to create a short circuit. Run the simulation again, the result will be:

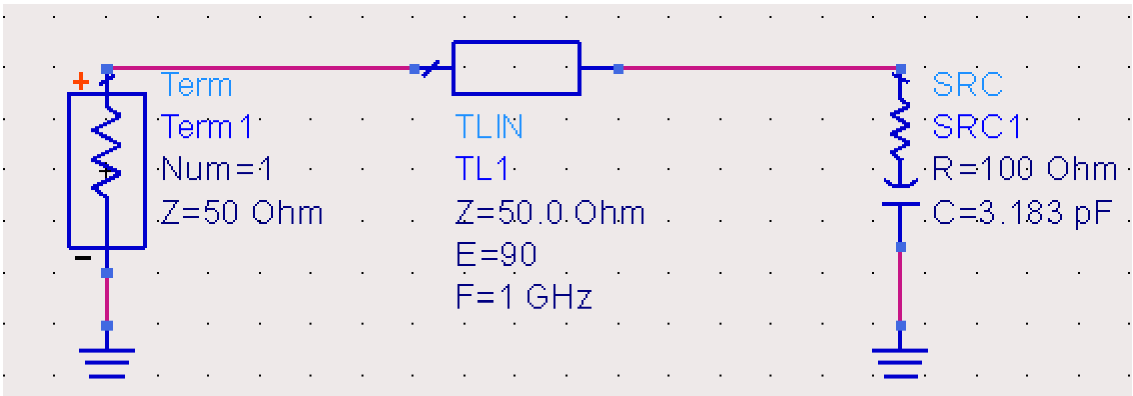


This shows that short circuit is at the very left side of smith chart.

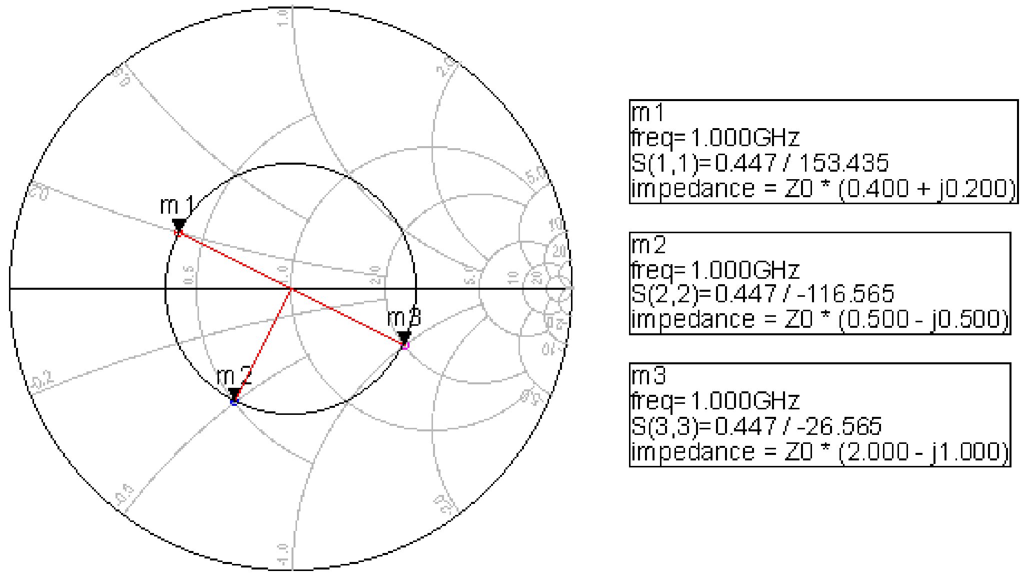
11. Change value of resistor to 1Tohm to make the circuit open, the load point will shift to the very right side of the smith chart.

Demo #2: Unmatched load and the influence of Ideal TL(Transmission Line)

1. In a new schematic, add a lumped component SRC(series resistor capacitor), set R=100 ohm, C= 3.183pF.
2. Add terminal to measure it just like in demo#1, but this time set start and stop frequency both at 1GHz since it is our design frequency now. You will see load at 2-j1.
3. Select 'TLIN' component from library 'TLines-Ideal', TLIN represent ideal transmission line. Use the default settings, the characteristic impedance of it is 50ohm, its electrical length is 90degrees and its working frequency 1GHz. Connect it between terminal and SRC load.



4. Now measure the system again with this length of TL. You will see load impedance goes to 0.4+j0.2, this is the point if you rotate 2-j1 around center for 180 degrees clockwise.
5. Change the electrical length of TLIN to 45 degrees, measure again you will see 0.5-j0.5 which is the point if you rotate 2-j1 around center for 90 degrees clockwise. These three points look like so together:

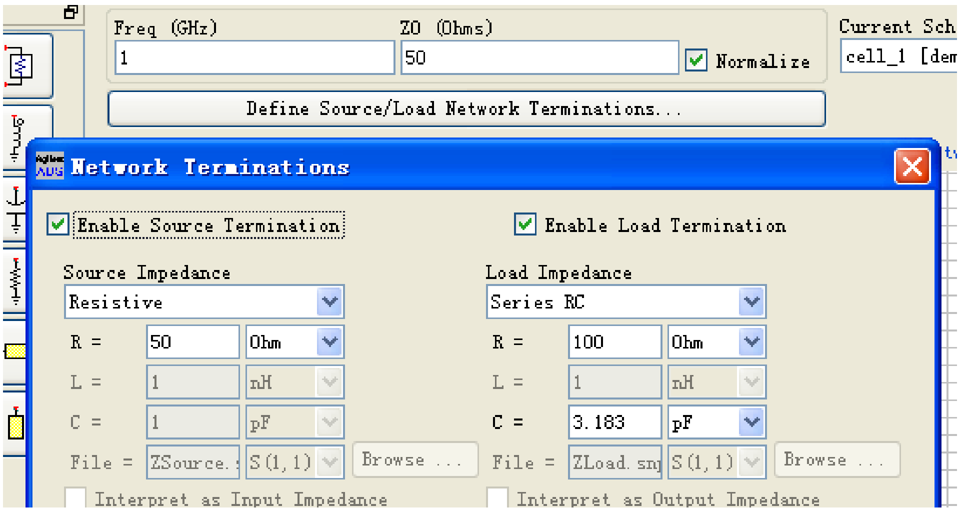


freq (1.000GHz to 1.000GHz)

This demo shows us that adding a length of TL from the load is equivalent to rotating the load impedance point around center of smith chart clockwise. Moreover, θ degrees of electrical length corresponding to 2θ degrees of rotating.

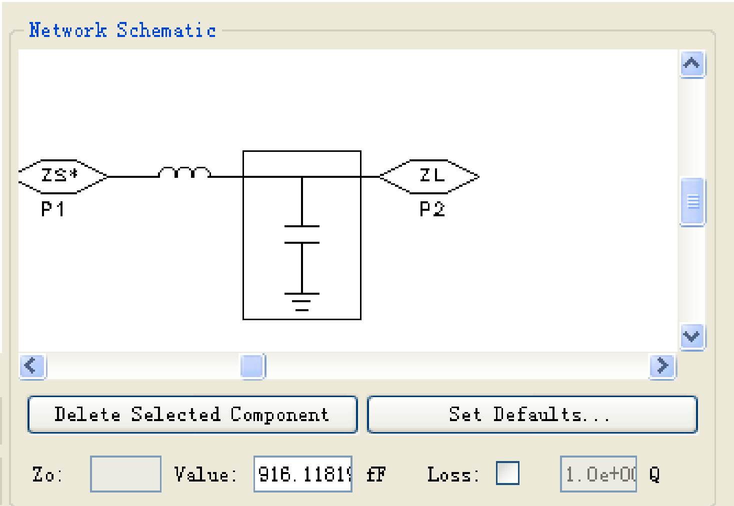
Demo #4: Impedance match by LC circuit(ADS aid matching)

1. Now suppose we have a SRC load same as above which is a 2-j1 load. We can match this load to the center of smith chart by a LC network. Use smith chart tool to determine the exact component and values of the LC network.
2. In the schematic window, click 'Tools'→ 'Smith Chart'.
3. Set up the design frequency and characteristic impedance as 1GHz and 50 ohm. Then click 'Define Source/Load Netwrok Terminations', Fill in source and load impedance then enable them. Press 'OK' to go back to smith chart, you will see the load point as a tiny square and source point in the center.

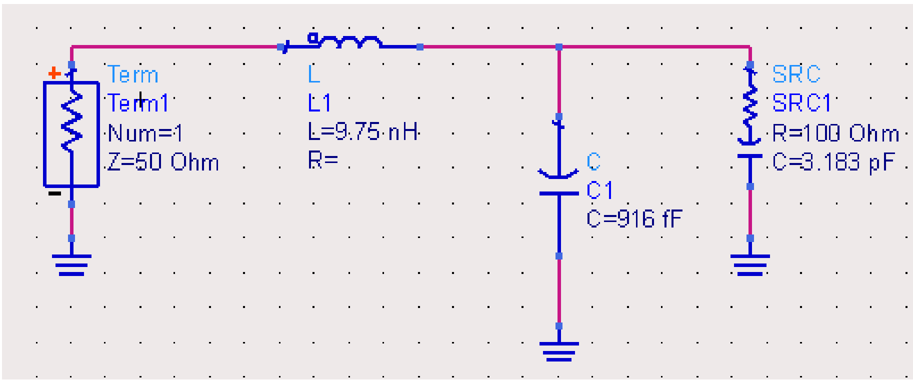


4. Choose 'Shunt Capacitor' in the left side palette. Move your mouse on to the smith chart, you will see a circle as the effect of the capacitor, and you can specify the destination of the curve. Make sure the end of the curve is located on the 50ohm resistance circle.
5. Next step, use 'Series Inductor' to go back to the center of the chart. Now matching network is

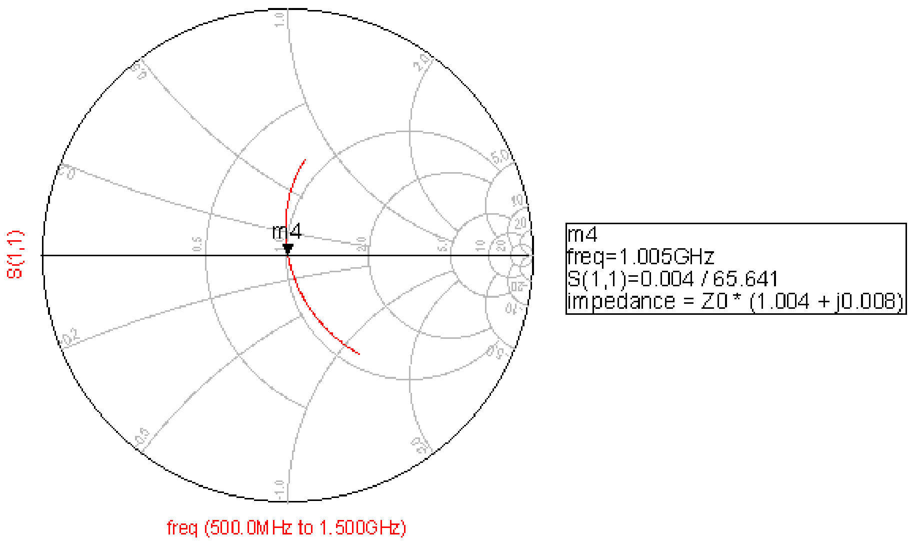
done, you can see it at right side 'Network Schematic'.



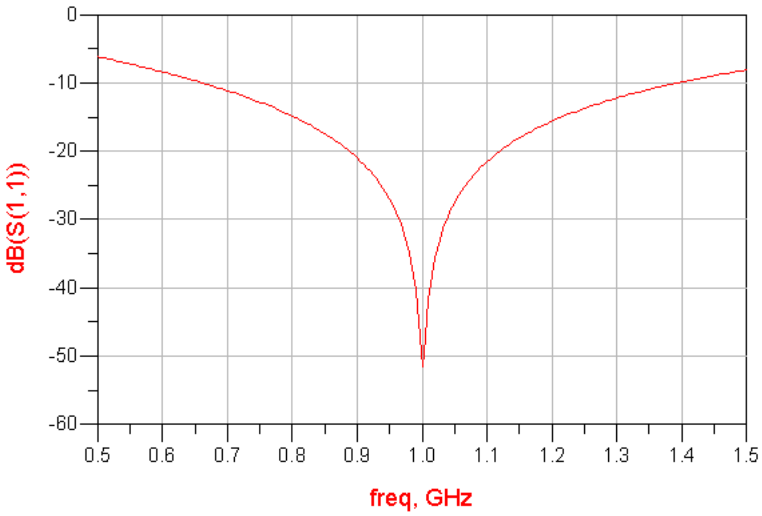
6. Click on each of the matching network component, read off the values of the component as C=916 fF, L=9.75 nH. Close the Smith Chart tool.
7. In the schematic window, build a corresponding matching network like so:



8. Run simulation at 1GHz, you will find the load has been matched to 50 ohm.
9. Now, change the frequency plan starting from 0.5G to 1.5GHz with 201 sample points between. Simulate again, you will see:



Only 1GHz frequency is matched, other frequencies are not. This happens because when we were designing the matching network, we specified design frequency as 1GHz. It is also obvious from the plot:

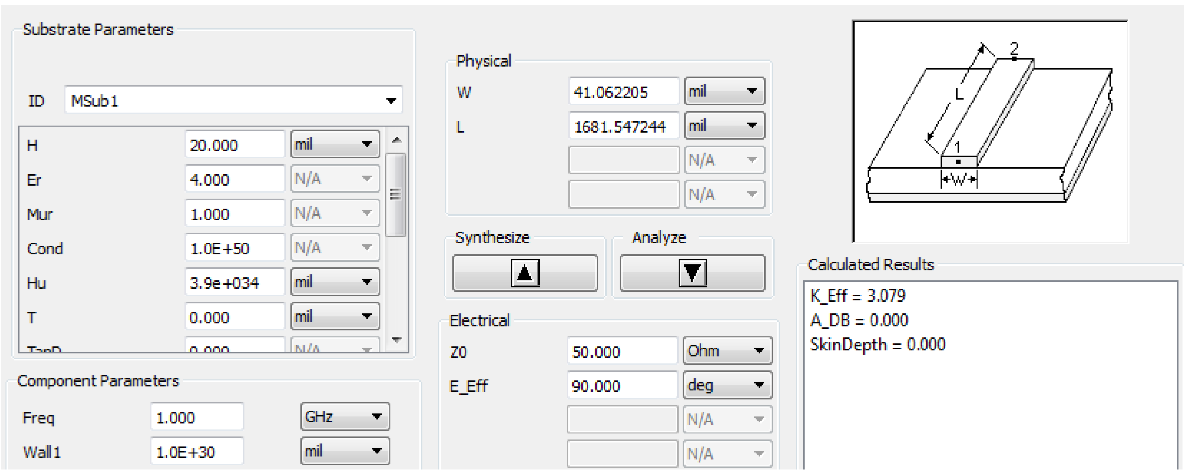


To match load for boarder frequency range, more sophisticated matching network needs to be implemented.

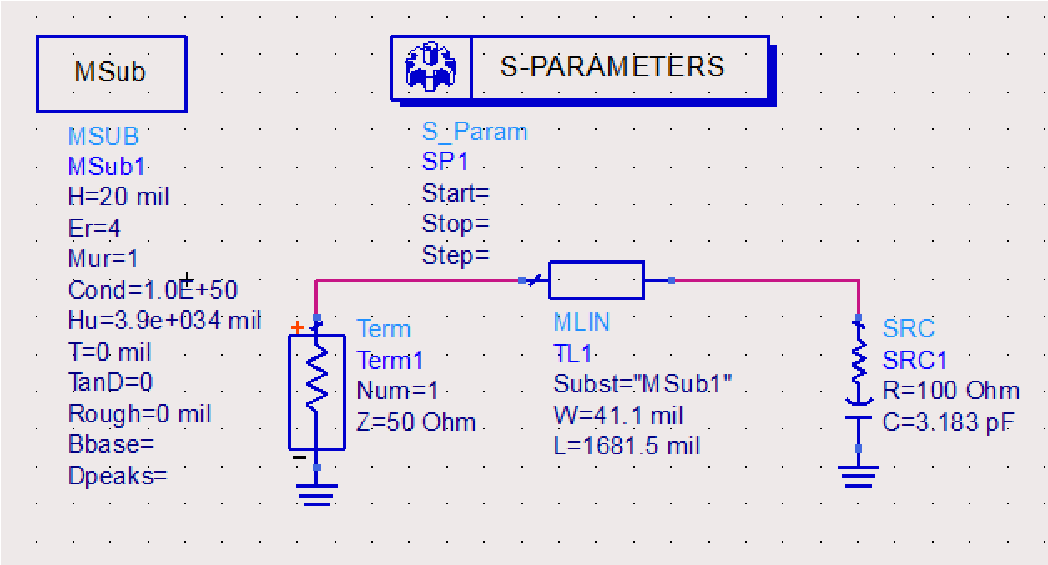
Demo #4: Impedance match by microstrip line(LineCalc)

In demo #2, we explored the role of transmission line when it comes to changing the load impedance. However, that is an ideal transmission line. Now we will try to use <u>microstrip line to imitate exactly the behavior of ideal transmission line in schematic simulation environment.</u>

1. Build the same circuit as demo #2 excluding ideal TL.
2. Add a micro-stripline from 'TLines-Microstrip' library or type 'MLIN' in the field right to library dropdown box and press Enter. Use this micro-stripline to replace ideal TL before.
3. Connect everything. Since we are designing microstrip line circuit now, we have to specify the substrate property. To do that, add 'MSUB' into schematic, it is a simulation condition.
4. In MSUB parameters, 'H' is substrate thickness and we set it to 20mil, 'Er' permittivity to 4. You can set these values according to your substrate. Make sure all the substrate values are the ones you wanted.
5. To find the width and length of micro-stripline that is equivalent to ideal TL, select MLIN in your schematic and then click 'Tool'→ 'LineCalc'→ 'Send Selected Component to LineCalc'.
6. The LineCalc tool will pop up, check all the values in substrate parameters section make sure they are all the same as you specified. Set frequency in component parameters to your design frequency then enter electrical length and Z_0 press 'synthesize' in the middle which is pointing up. It will convert the values below to above. You get W=41.1 mil and L=1681.5mil.



7. Go back to schematic, change the W and L values for MLIN. Add 'S P' simulation condition to schematic, run simulation.



8. You will see exactly the same result as demo #2 when E=90 for TLIN. This means <u>MLIN can be used to change the load impedance and when properly placed it can also be used to match the load.</u>