ADS Session

4

S-Parameter Files, List Plots, and Parameter Sweeps

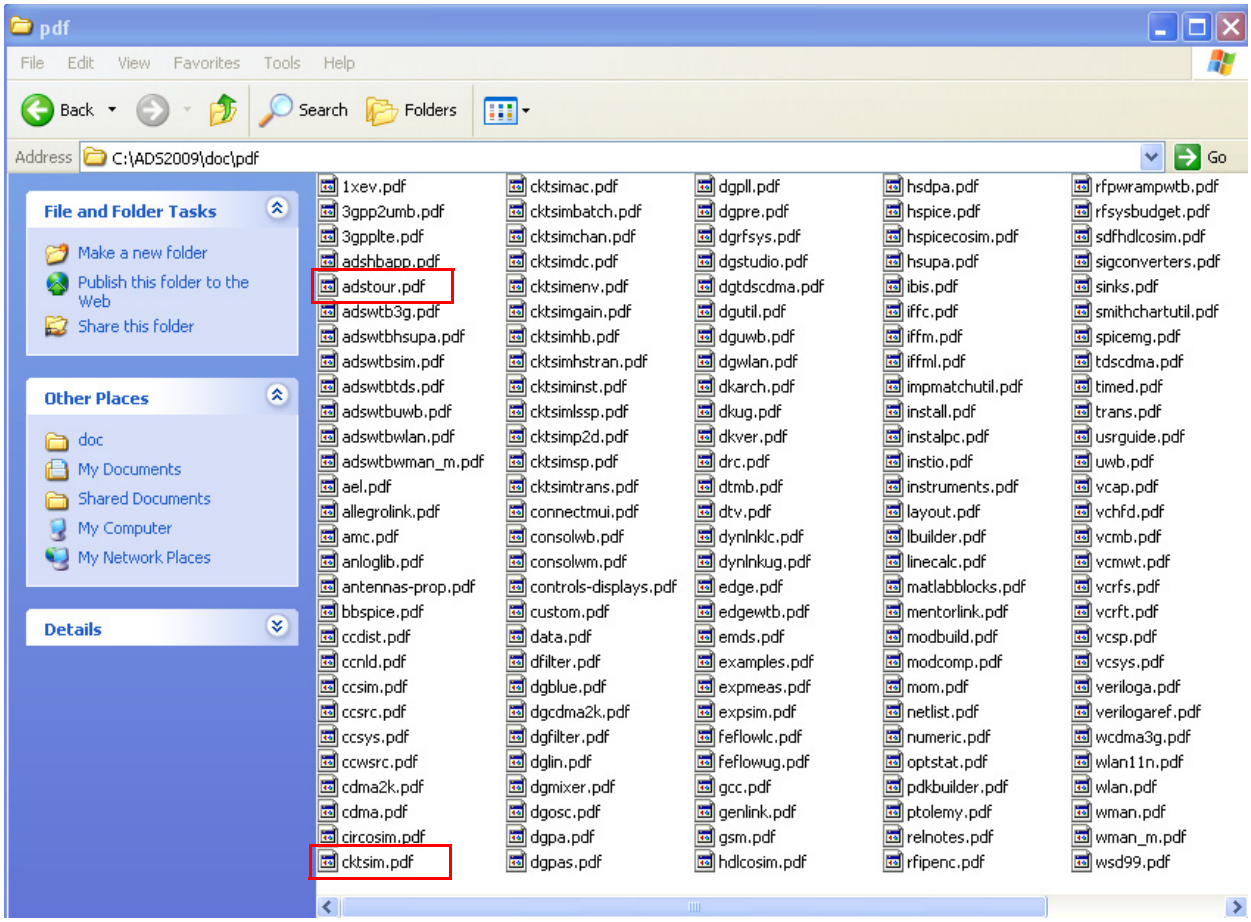
Introduction

The primary focus of this session is on working with S-parameter files of type `*.SnP`. This format was developed for one of the first PC-based microwave CAD programs, *Touchstone*™. Along the way we will investigate the use of *List Plots* to display simulation results in tabular form. In the final section a filter/an amplifier cascade is simulated using commercial-off-the-shelve (COTS) S-parameter files downloaded from vendor Web Sites. This practical application is also coupled with the first use of *parameter sweeps*, a very powerful ADS capability. Parameter sweeping is available for use in (all?) ADS controllers.

Agilent ADS Documentation/Tutorials

Beyond the HTML help system available within ADS, there is a complete set of PDF-based documents contained within the ADS2009 install folder. This folder resides as the root level on PC installs. A screen capture showing the file names in the folder is shown below.

- Note that the file `cktsim.pdf` contains detailed information on the `.SnP` file format



- The document `adstour.pdf` gives a nice overview of ADS projects and gives a brief description of each of the ADS controllers

Working with `.SnP` Files

- For linear circuit analysis, in particular AC and S-parameter modeling, the ability to import data sets of measured impedance, admittance, or S-parameters is very powerful
  - `filename.SnP` specifically refers to an S-parameter data file by virtue of the fact that `S` denotes S-parameters; `n` denotes the number of ports, and `P` denotes port

- The ADS document `cktsim.pdf` explains that 1–99 port networks can be handled using `.SnP` files
  - This is also an excellent resource for understanding the various format available
- In most cases you will not be involved with constructing these files
- The format for one and two-port networks is slightly different from the three and four case, and then different again for $n \geq 5$
- The files are composed of three entry types:
  - Option line: line begins with #
  - Data line
  - Comment line: line begins with !
- Here we will consider the format of just 1–4 port networks
- On the option line you specify the actual S-parameter format to be one of three modes:
  - `RI` = real and imaginary
  - `MA` = magnitude and angle in degrees
  - `DB` = magnitude in dB and angle in degrees

S-Parameter 1-Port MA, RI, and DB File Formats:

```
# frequency_unit S MA R impedance
freq magS11 angS11
# frequency_unit S RI R impedance
freq reS11 imS11
# frequency_unit S DB R impedance
freq dbS11 angS11
```

S-Parameter 2-Port MA, RI, and DB File Formats:

```
# frequency_unit S MA R impedance
freq magS11 angS11 magS21 angS21 magS12 angS12 magS22 angS22
# frequency_unit S RI R impedance
freq reS11 imS11 reS21 imS21 reS12 imS12 reS22 imS22
# frequency_unit S DB R impedance
freq dbS11 angS11 dbS21 angS21 dbS12 angS12 dbS22 angS22
S-Parameter 3-Port MA, RI, and DB File Formats
# frequency_unit S MA R impedance
freq magS11 angS11 magS12 angS12 magS13 angS13 ! 1st row
     magS21 angS21 magS22 angS22 magS23 angS23 ! 2nd row
     magS31 angS31 magS32 angS32 magS33 angS33 ! 3rd row
# frequency_unit S RI R impedance
freq reS11 imS11 reS12 imS12 reS13 imS13 ! 1st row
     reS21 imS21 reS22 imS22 reS23 imS23 ! 2nd row
     reS31 imS31 reS32 imS32 reS33 imS33 ! 3rd row
# frequency_unit S DB R impedance
freq dbS11 angS11 dbS12 angS12 dbS13 angS13 ! 1st row
     dbS21 angS21 dbS22 angS22 dbS23 angS23 ! 2nd row
     dbS31 angS31 dbS32 angS32 dbS33 angS33 ! 3rd row
```

S-Parameter 4-Port MA, RI, and DB File Formats:

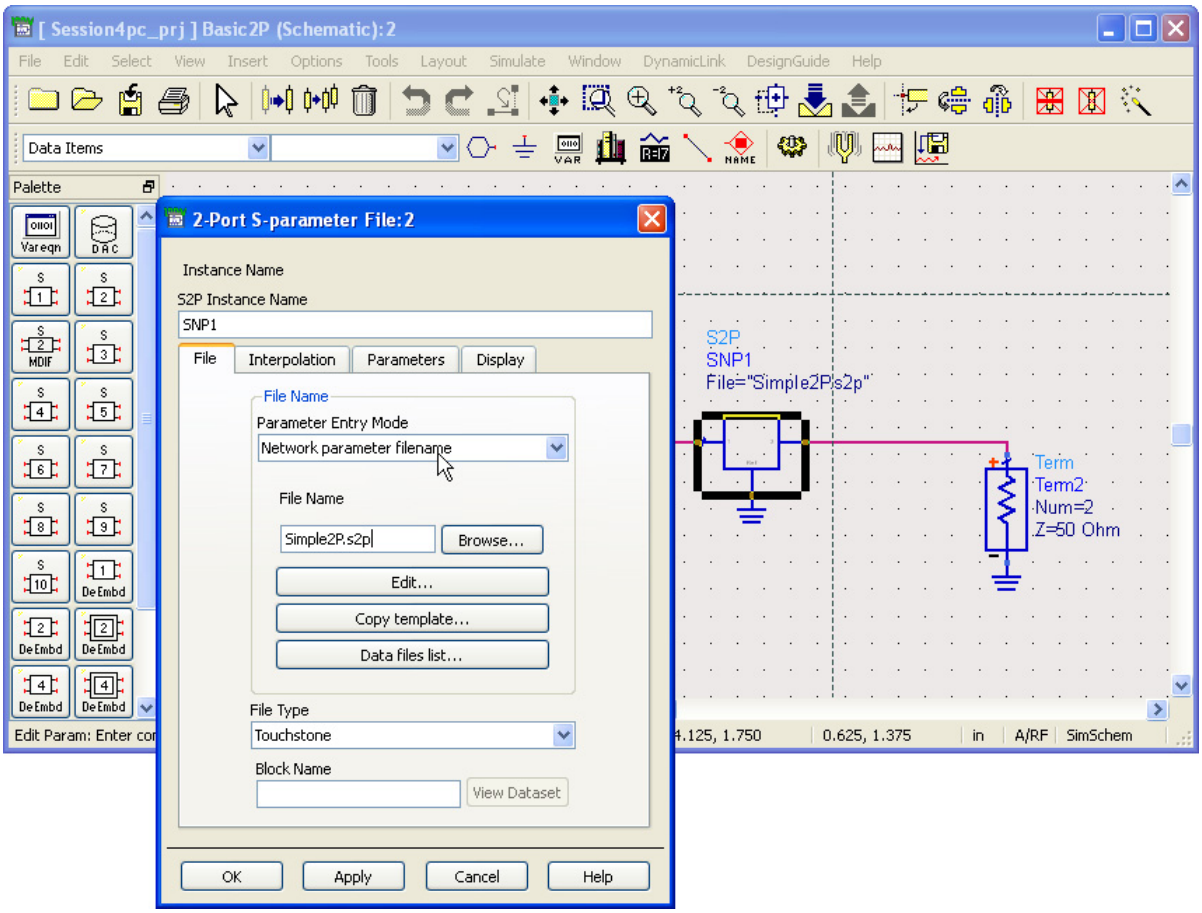
```
# frequency_unit S MA R impedance
freq magS11 angS11 magS12 angS12 magS13 angS13 magS14 angS14 ! 1st row
     magS21 angS21 magS22 angS22 magS23 angS23 magS24 angS24 ! 2nd row
     magS31 angS31 magS32 angS32 magS33 angS33 magS34 angS34 ! 3rd row
     magS41 angS41 magS42 angS42 magS43 angS43 magS44 angS44 ! 4th row
# frequency_unit S RI R impedance
freq reS11 imS11 reS12 imS12 reS13 imS13 reS14 imS14 ! 1st row
     reS21 imS21 reS22 imS22 reS23 imS23 reS24 imS24 ! 2nd row
     reS31 imS31 reS32 imS32 reS33 imS33 reS34 imS34 ! 3rd row
     reS41 imS41 reS42 imS42 reS43 imS43 reS44 imS44 ! 4th row
# frequency_unit S DB R impedance
freq dbS11 angS11 dbS12 angS12 dbS13 angS13 dbS14 angS14 ! 1st row
     dbS21 angS21 dbS22 angS22 dbS23 angS23 dbS24 angS24 ! 2nd row
     dbS31 angS31 dbS32 angS32 dbS33 angS33 dbS34 angS34 ! 3rd row
     dbS41 angS41 dbS42 angS42 dbS43 angS43 dbS44 angS44 ! 4th row
```

Example: A 2-Port with Constant Parameters

- As a very simple example consider a 2-Port that has frequency independent S-parameters

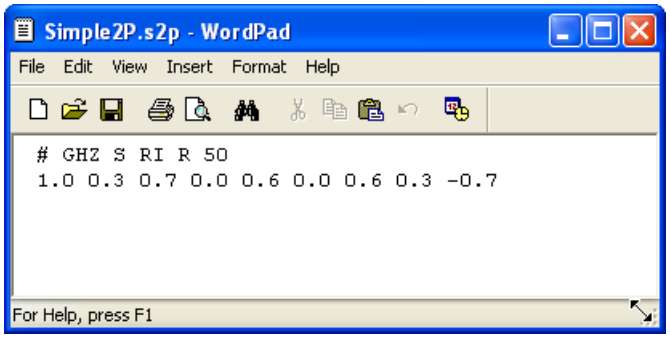
$$\mathbf{S} = \begin{bmatrix} 0.3 + j0.7 & j0.6 \\ j0.6 & 0.3 - j0.7 \end{bmatrix} \tag{4.1}$$

- The parameters are given in real/imaginary form, so we will use that form in the `.s2p` file we create
- In the schematic shown below we have placed a `S2P` element from the Data Items Palette

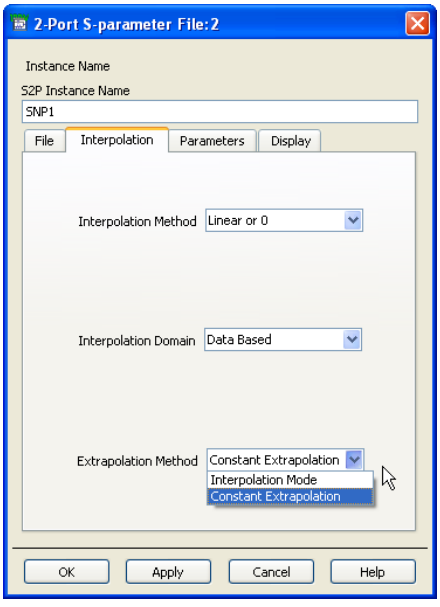


- Double-clicking on the `S2P` element brings up a dialog from which you can import a predefined `.s2p` file (in the capture the file was already created)
- Alternatively you can now create a file by scratch clicking

the edit button, which brings up WordPad



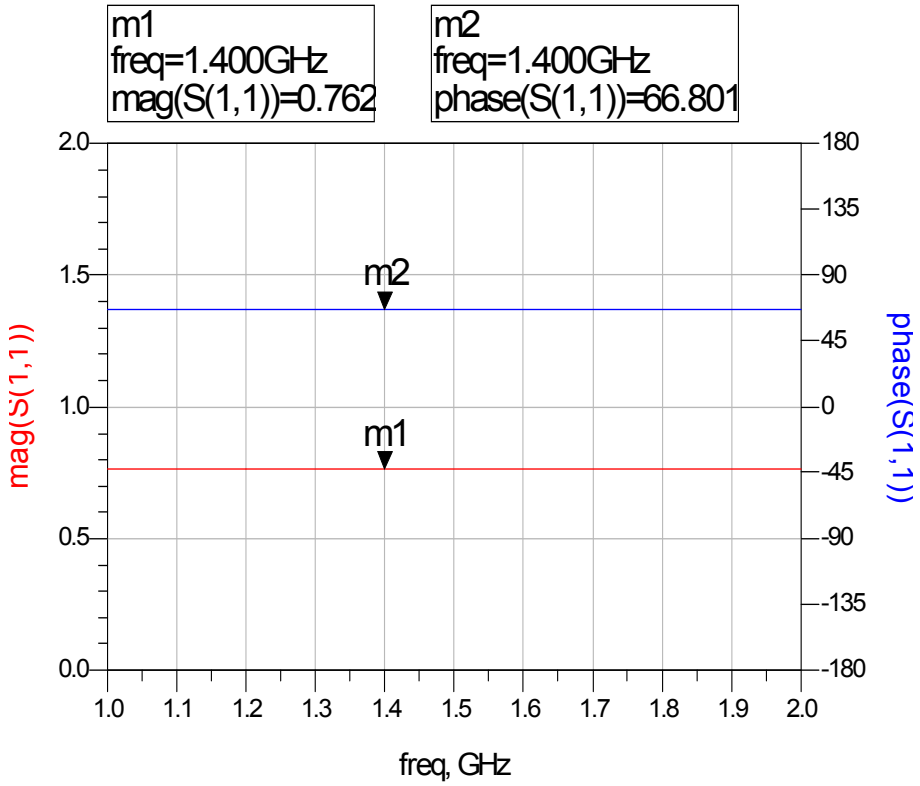
- The S-parameter date was entered as a single line below the options line
  - Note that frequency is in GHz, so the single frequency value for this .s2p file is 1.0 GHz
  - Just a single value in the data file can be extended to all frequencies by selecting Constant Extrapolation under the Interpolation tab



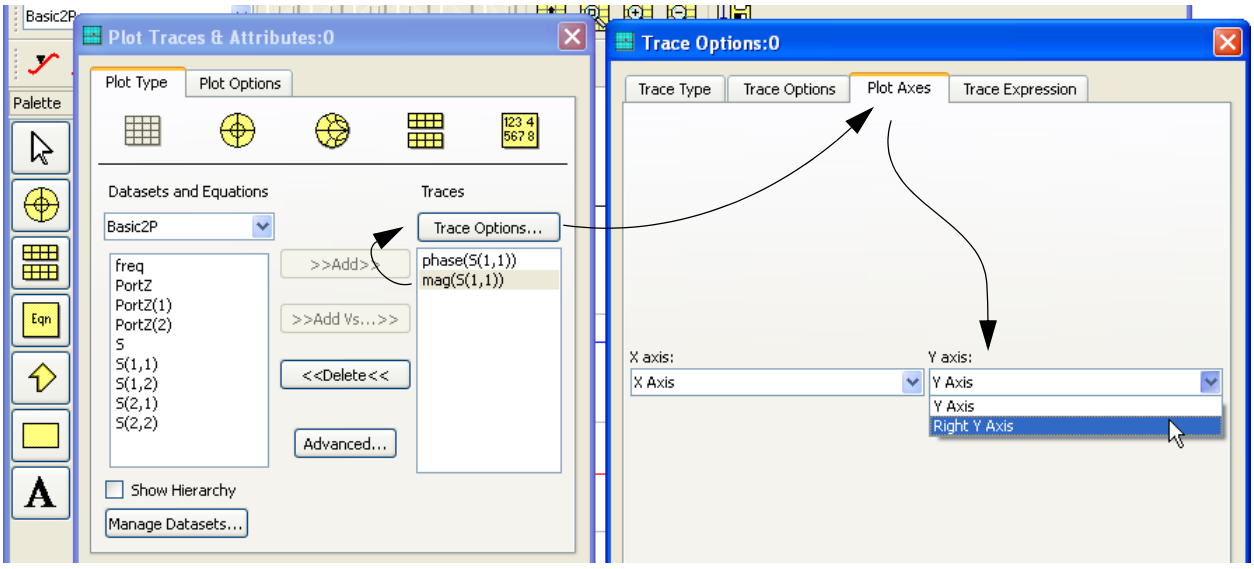
ADS will generally warn you if your sweep requires data extrapolation.

- For vendor data files, where there are many frequency values present, it is important to know the extent of the true data frequency range, so that extrapolation does not cause surprises

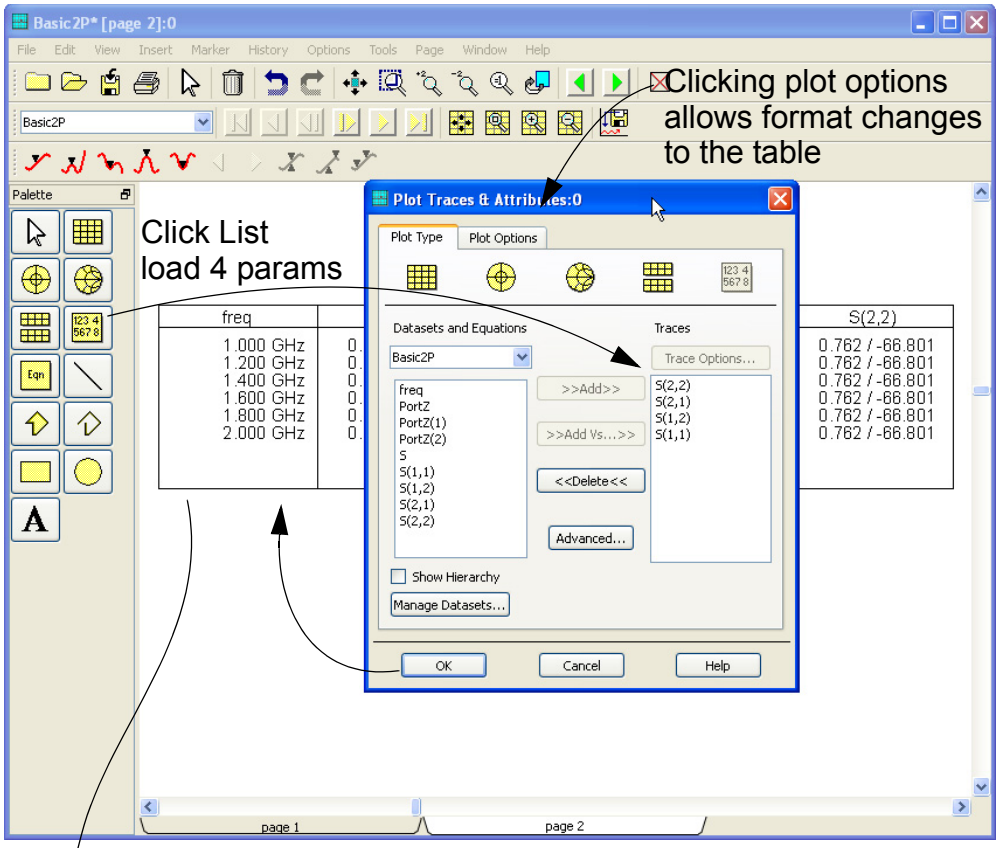
- In this example the S-parameter controller sweep range is set for 1–2 GHz in 200 MHz steps
- The magnitude and phase of S_{11} is shown below



  - In order to set up a plot with two y axes, we select Trace Options and then Plot Axes



- Using the marker display, we can firm that it is correct by computing the magnitude and angle of $S_{11} = 0.3 + j0.7 = 0.762\angle 66.8°$
- In this case a more useful display might be a List plot, which can be obtained

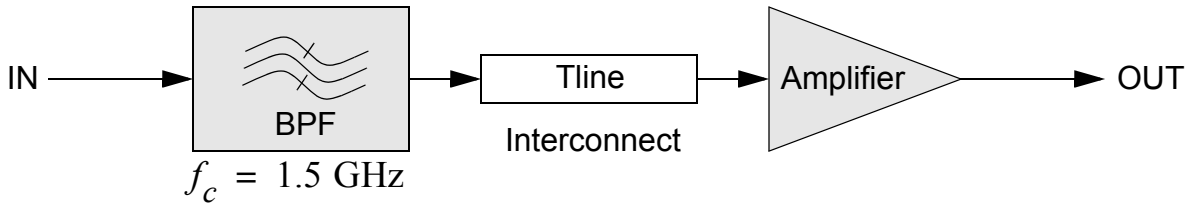


My SImple 2-Port

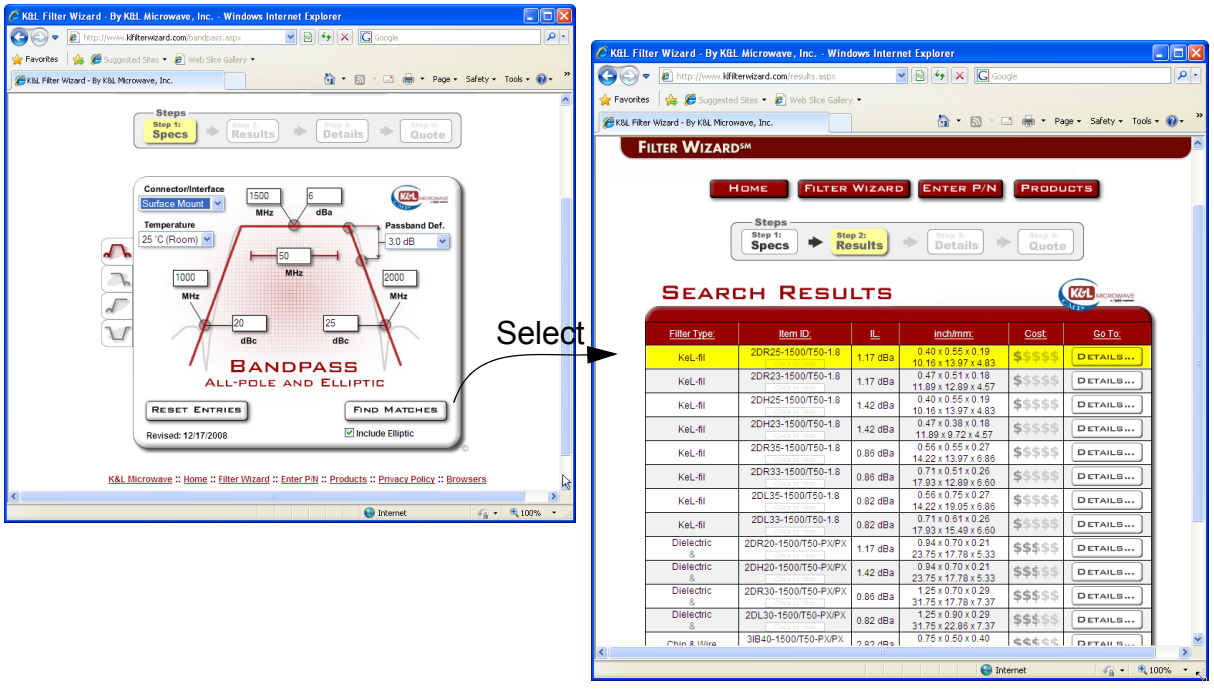
freq	S(1,1)	S(1,2)	S(2,1)	S(2,2)
1.000 GHz	0.762 / 66.801	0.600 / 90.000	0.600 / 90.000	0.762 / -66.801
1.200 GHz	0.762 / 66.801	0.600 / 90.000	0.600 / 90.000	0.762 / -66.801
1.400 GHz	0.762 / 66.801	0.600 / 90.000	0.600 / 90.000	0.762 / -66.801
1.600 GHz	0.762 / 66.801	0.600 / 90.000	0.600 / 90.000	0.762 / -66.801
1.800 GHz	0.762 / 66.801	0.600 / 90.000	0.600 / 90.000	0.762 / -66.801
2.000 GHz	0.762 / 66.801	0.600 / 90.000	0.600 / 90.000	0.762 / -66.801

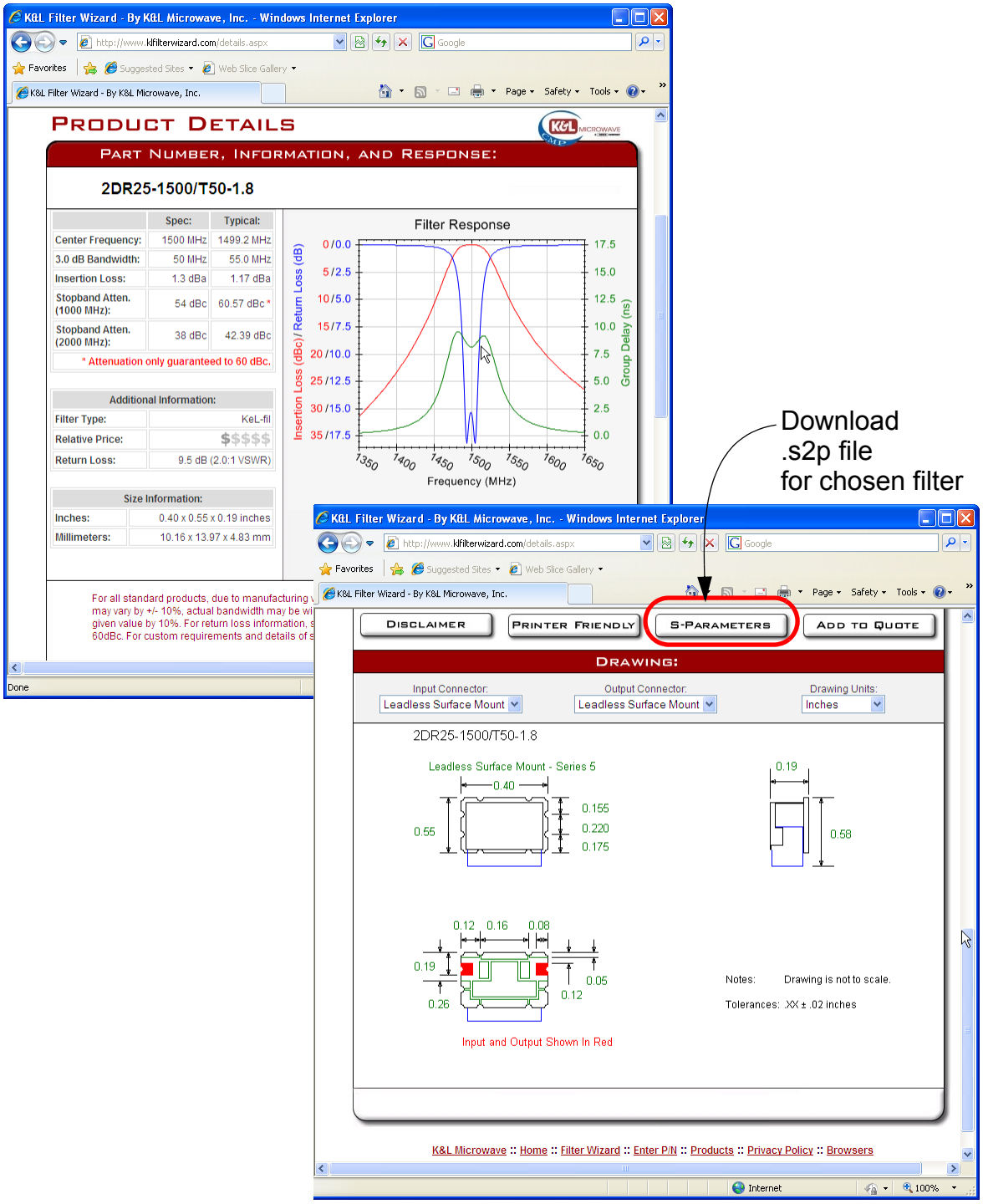
A Simple Subsystem Design

- Vendor S-parameter files can be very helpful in subsytem design
- In this section we consider a board level design of a filter–amplifier cascade

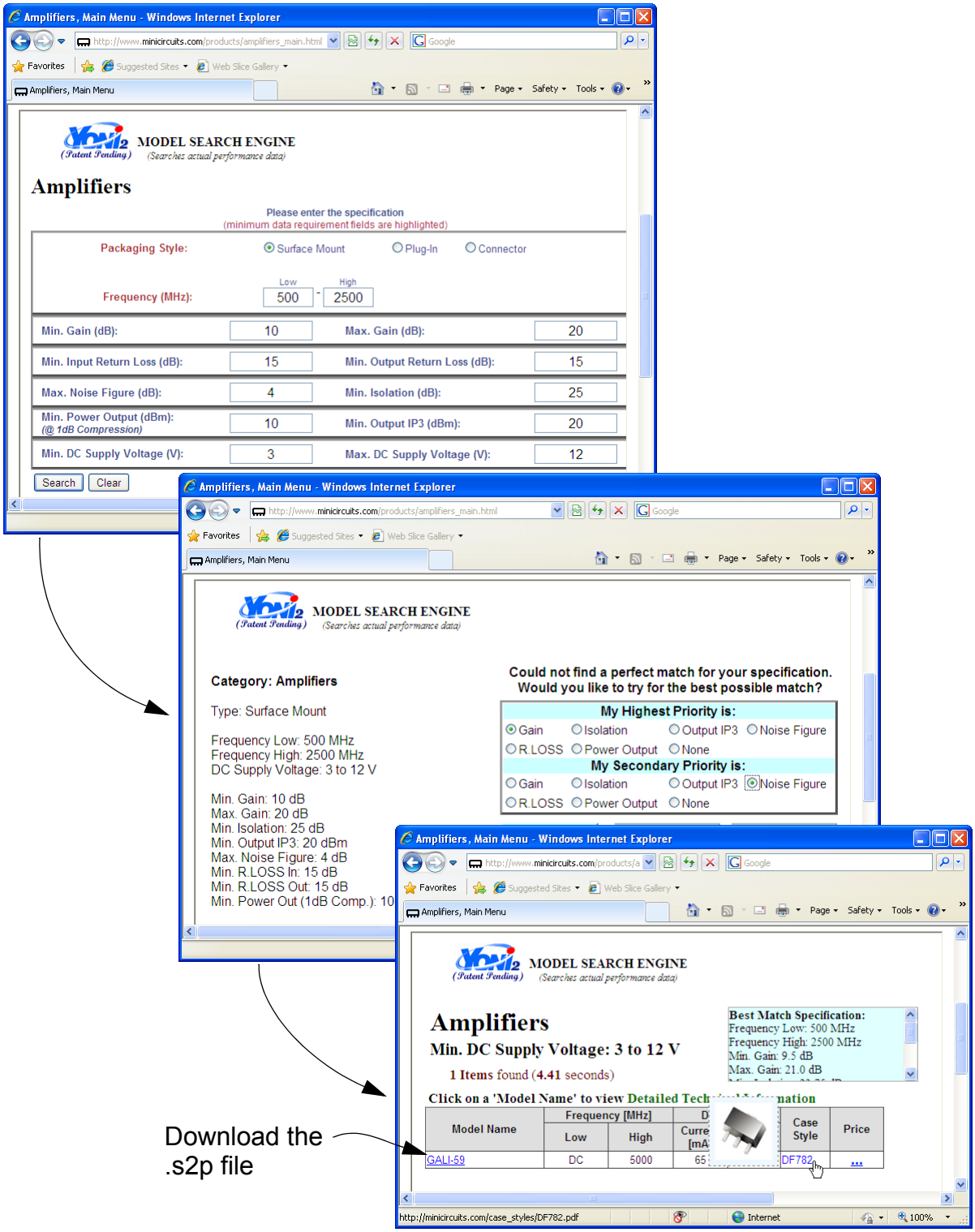


- The design center frequency is 1500 MHz
- We seek surface mount parts for the subsystem PCB
- *K&L Microwave* is used for the filter and *Mini Circuits* is used for the amplifier
- Use the Filter Wizard (`www.klfilterwizard.com`)



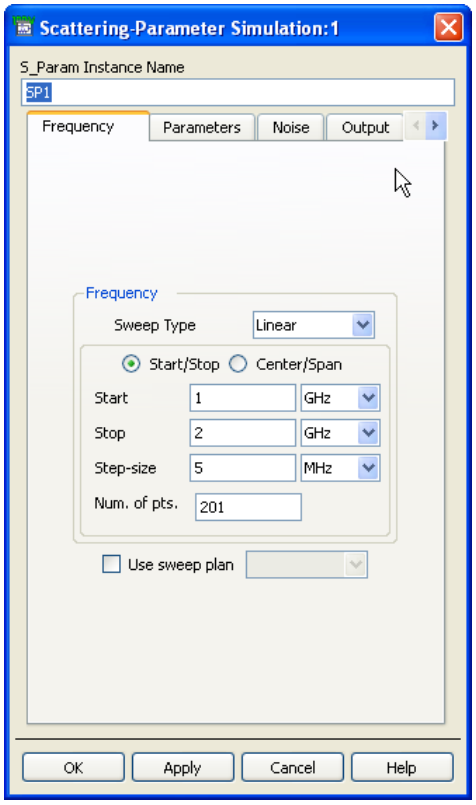


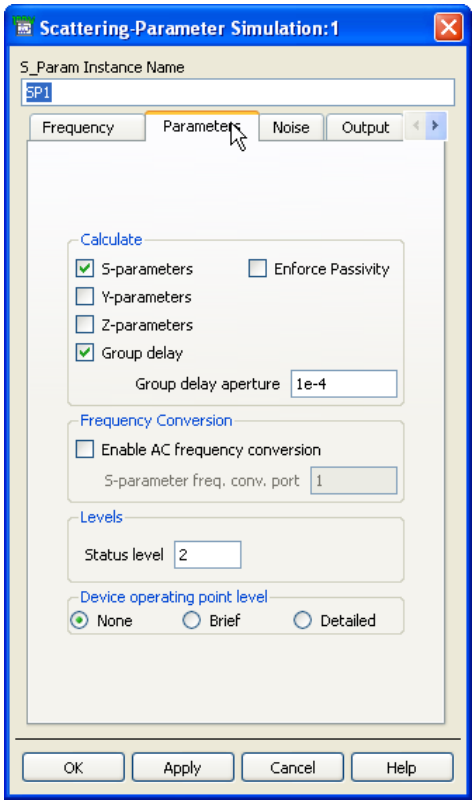
- We use the Mini Circuits *Model Search Engine* found at `www.minicircuits.com/products/amplifiers_main.html`



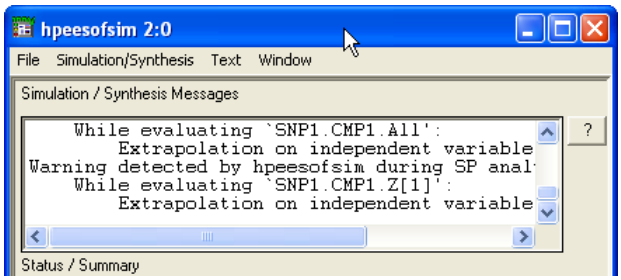
- We unpack the `.s2p` files and move them to the data folder inside the project directory

- We create a 2-port schematic consisting of the s2p filter model, a TLINE section, and the amplifier s2p model
  - On a new schematic we place two S2P elements and connect the .s2p files accordingly
  - An ideal transmission line of nominal electrical length 10° is placed as the interconnect
  - The port numbers are 1 and 2
- We create a second 2-port schematic of just the filter s2p model
  - The port numbers are 3 and 4
- A sweep from 1–2 GHz in 5 MHz steps is run, except now we configure the Parameters tab in the S-Parameter controller to also capture group delay information

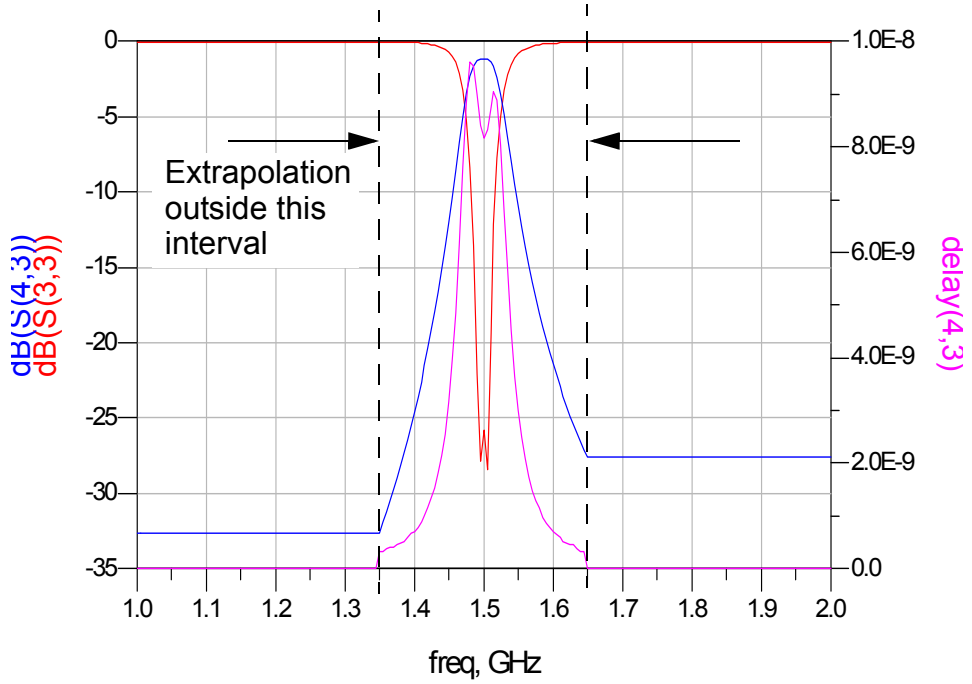




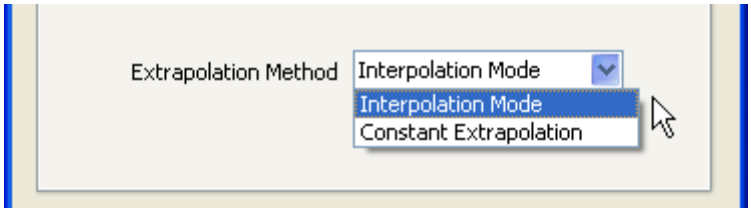
- In the simulation message window we receive a warning about independent variable extrapolation

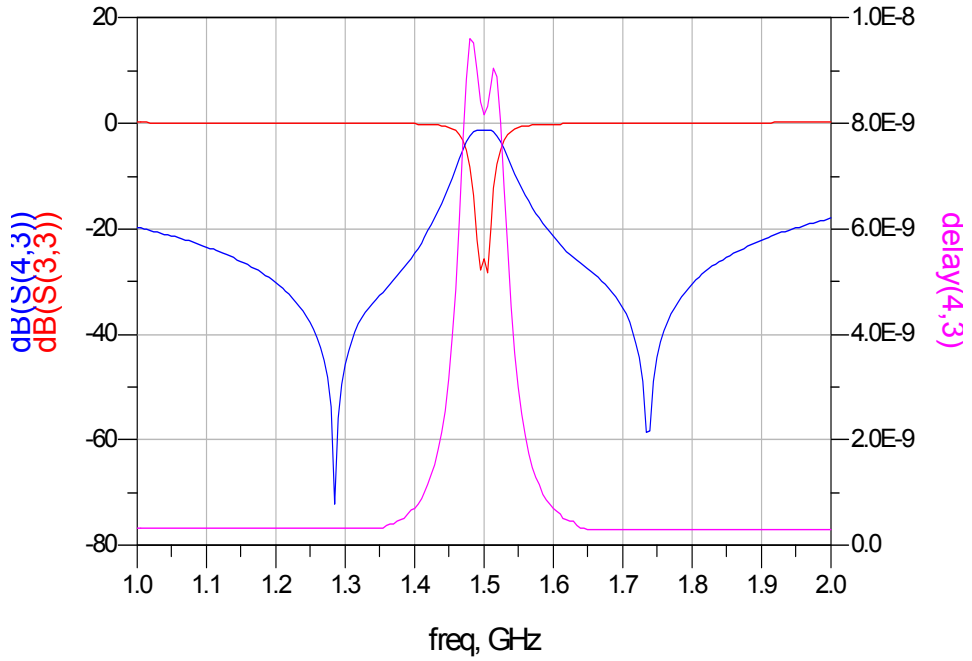


- Looking at the plot of S_{33} and S_{43} magnitude in db and group delay in s, we can see the impact of this warning

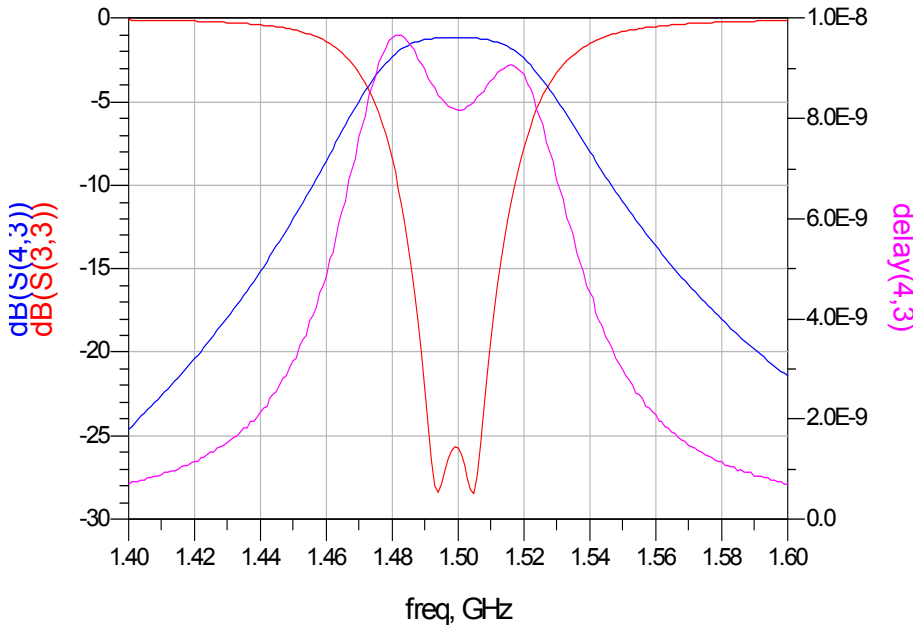


- The frequency span of the filter S-parameter data is limited to a fairly narrow frequency range
- We can change the extrapolation method for the s2p element



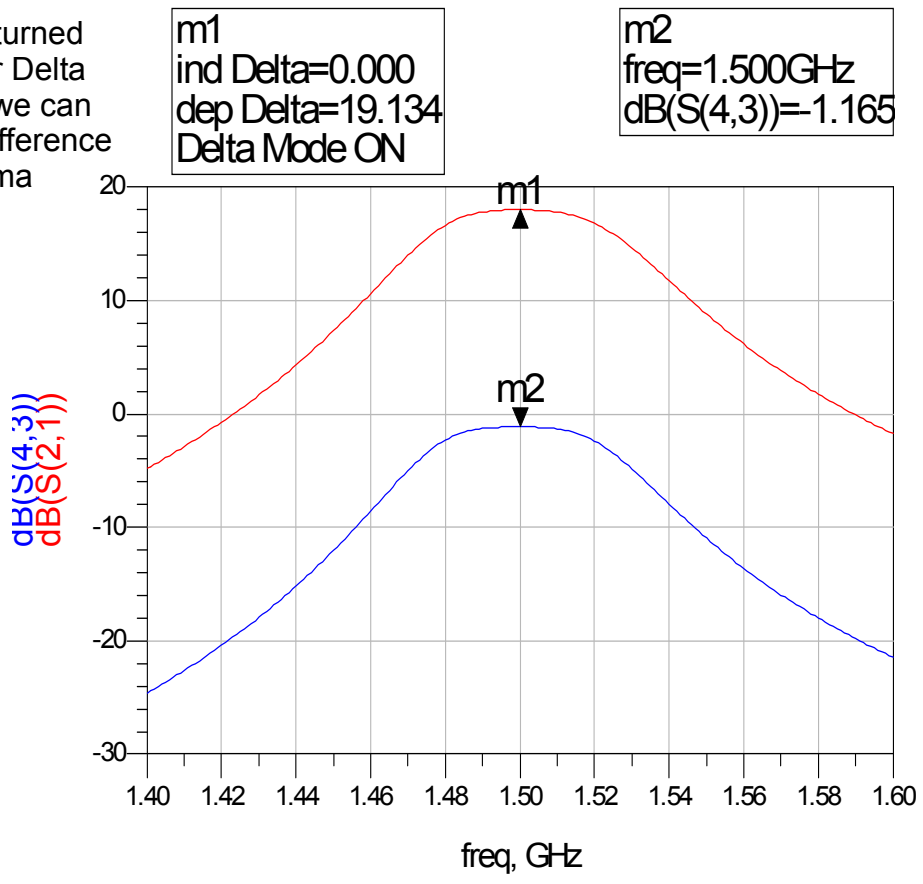


  - Here we see a perhaps more pleasant result, as we know that the filter S_{33} should be large out-of-band, but we will learn later that it is likely to be periodic for some filter types, hence we have no way of knowing if the extrapolation here is accurate of not
  - The other curves have a smoother look as well, but again the extrapolation can be dangerous; best not to take chances
  - It is best to confine the sweep to the interval supported by the data files in the simulation
- We narrow the sweep to run from 1.4 to 1.6 GHz and decrease the step size to 1 MHz
- The results for just the filter are shown below



- Creating another plot window, we now overlay gain plots (S_{21} and S_{43}), for the cascade and the filter alone, respectively

We have turned on marker Delta Mode so we can see the difference between ma and m2



- We observe that the gain difference between the filter alone and the amplifier is about 19 dB
  - Recall that an amplifier gain of 10–20 dB was requested, and a filter insertion loss of up to 6 dB was allowed

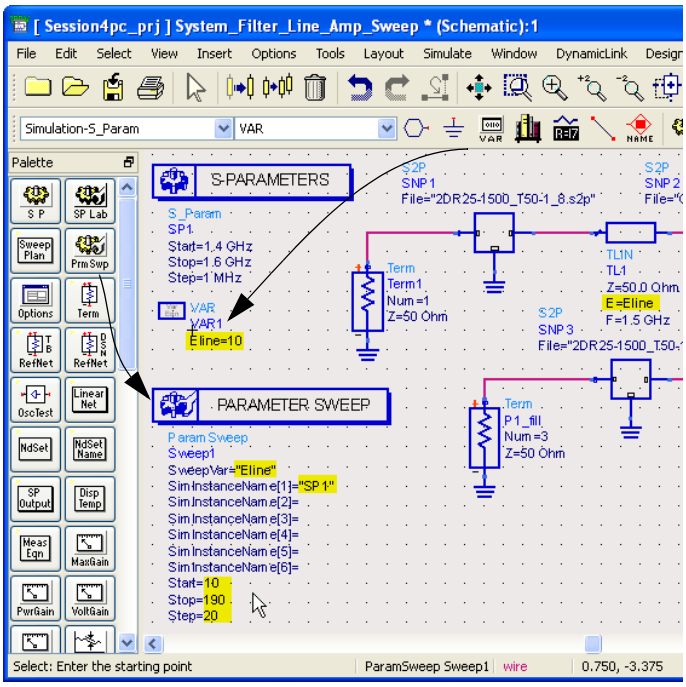
Parameter Sweeps

- To finish this session we will now consider parameter sweeping
- Parameter sweeping is discussed beginning on page 99 of the Agilent `cktsim.pdf` document
- The basic idea is that we wish to varying some parameter of the circuit/system we are simulating
  - We may in fact chose to hold say frequency fixed and just see the impact of some parameter variation, e.g., line electrical length, at a fixed operating frequency
- In ADS we can accompish parameter sweeps most easily using the Parameter Sweep controller, but more complex sweping can be accomplished with the use of the Sweep Plan controller

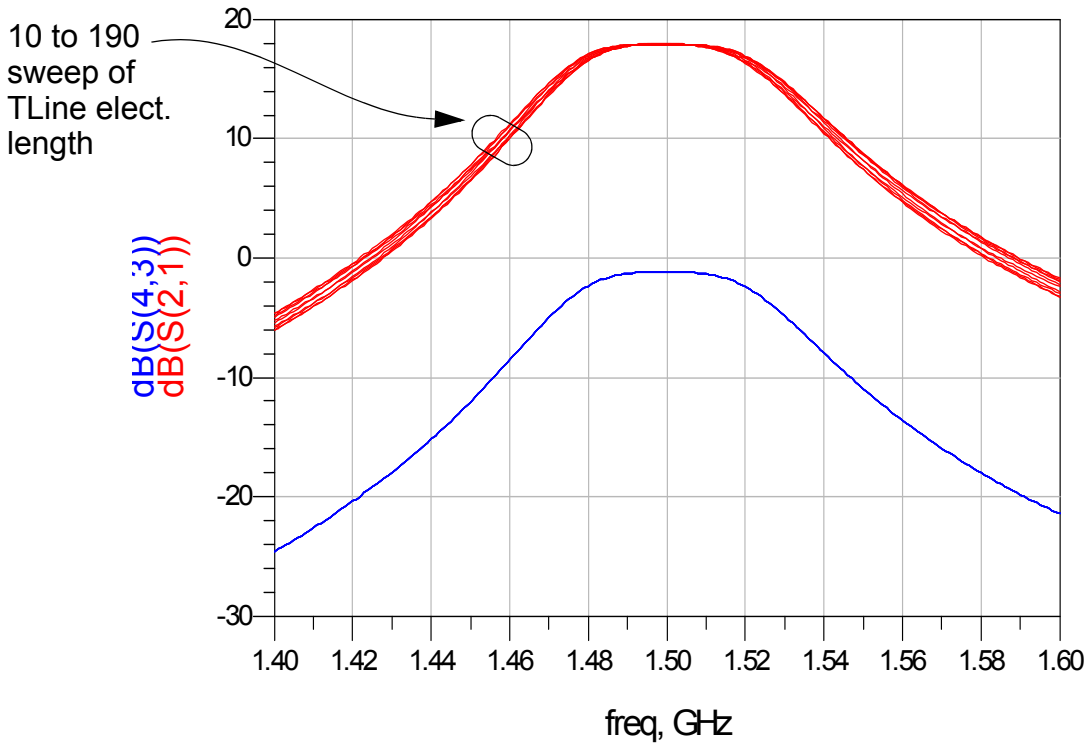
Component Interconnect Length Sensitivity

- In the filter/amplifier cascade simulation we set out to investigate changes in system gain as the electrical length of the filter–amplifier interconnect varies

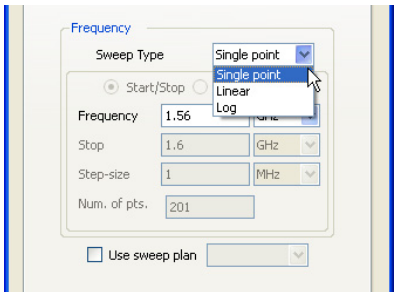
- Place a Parameter Sweep block and an Var block on the schematic
- In Var block we define the variable the will be swept, here Eline
- We list this variable in quotes in the Sweep block and the controller name in quotes below it (see yellow highlights)
- Finally set the parameter sweep range



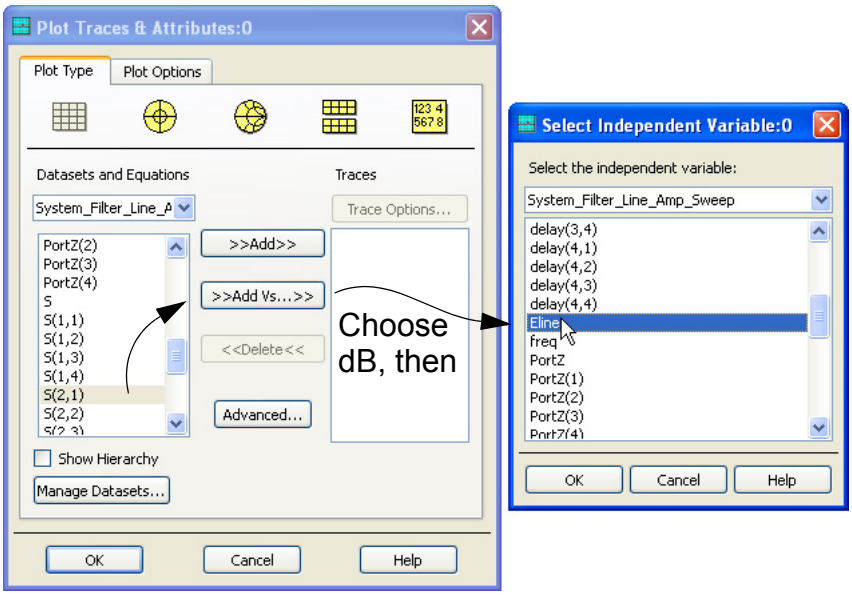
- We run the simulation and will obtain a family of curves, in this case S_{21} in dB



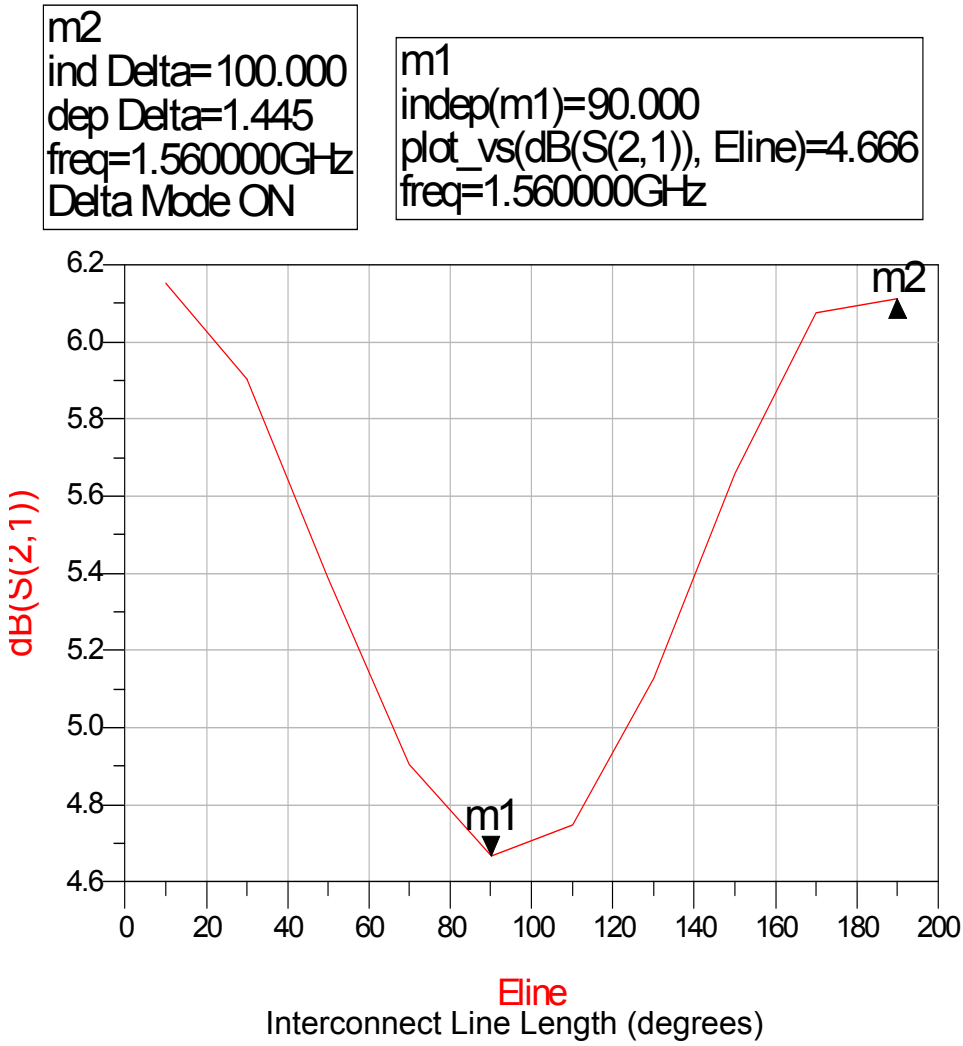
- We can hold the frequency fixed, at say the band edge frequency of 1.56 GHz and see how the gain varies a a function of the interconnect electrical length
- In the S-parameter controller we set the sweep type to fixed and then set the frequency to 1.56 GHz



- To set up a plot versus a sweep parameter variable choose Add Versus after selecting `S(2,1)`, then choose dB and finally a list to Select Independent Variable from appears where you can choose `Eline`



- The following plot appears



- We that at the band-edge a change interconnect length results a forward gain variation of about 1.45 dB
  - A finer parameter step would have resulted in a smoother plot
- Clearly, parameter sweeping adds a lot of capability to ADS
- Ther is also a Tune and Optimization capability that will be investigated sometime in the future