

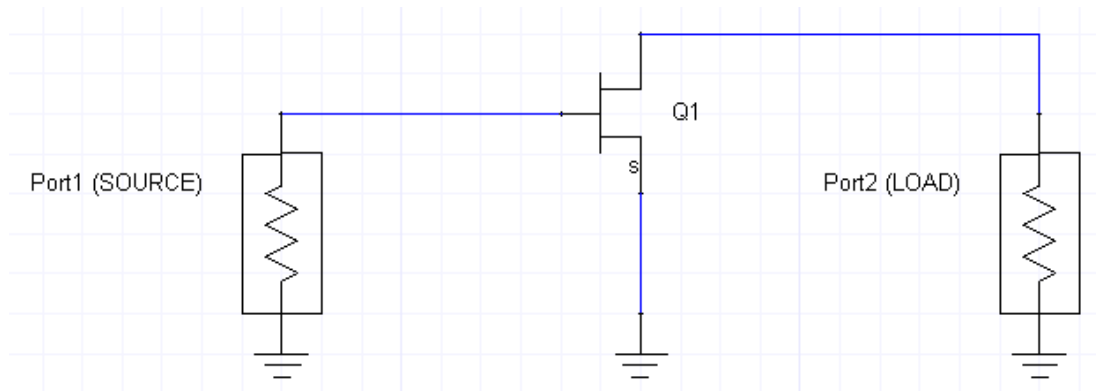
## Using Ansoft Designer to Simulate RF Amplifiers Characterized by S-parameters

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Ansoft Designer provides a large library of FET transistor amplifiers characterized by their physical properties. These JFETs, MOSFETs, and MESFETs can be found in the Project Manager window Component tab, Nonlinear -> FETs.

However, when designing amplifier source and load matching circuits, it is often much simpler to represent the FET as a simple 2-port network whose  $[S_{ij}]$  parameters are specified at midband and at band edge frequencies. These values are commonly provided by FET manufacturers. The purpose of this note is to explain how to use Designer to set up and simulate FET amplifiers characterized by their S-parameters.

**Example 1.** Consider an X-band MESFET amplifier used in a 50 ohm system, and having the following S-parameters:



Freq	S11(mag)	S11(deg)	S21(mag)	S21(deg)	S12(mag)	S12(deg)	S22(mag)	S22(deg)
9 GHz	.82	-145	1.72	42	.03	-18	.640	-109
10	.755	-162	1.65	26	.03	-19	.629	-122
11	.690	-187	1.67	17	.03	-20	.607	-133

(In Example 2 we will add source and load matching networks.) We begin by representing the transistor as a 2-port network characterized by its S-parameters at each of the three frequencies. We begin by creating a file with the S-parameter information. Use a text editor such as Notepad to create the following:

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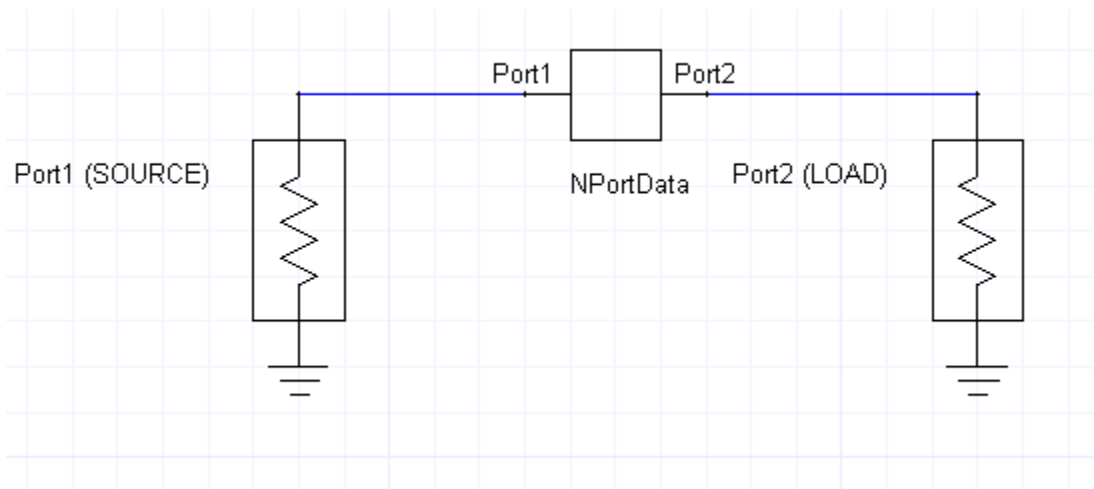
MESFET - Notepad
File Edit Format View Help
!X-band MESFET represented as a 2-port with S-parameters
!ECE 585 Designer example
!Freq (GHz) S11 S21 S12 S22
!S-parameters are specified as magnitude and phase (degrees)
9 .82 -145 1.72 42 .03 -18 .64 -109
10 .755 -162 1.65 26 .03 -19 .629 -122
11 .69 -187 1.67 17 .03 -20 .607 -133

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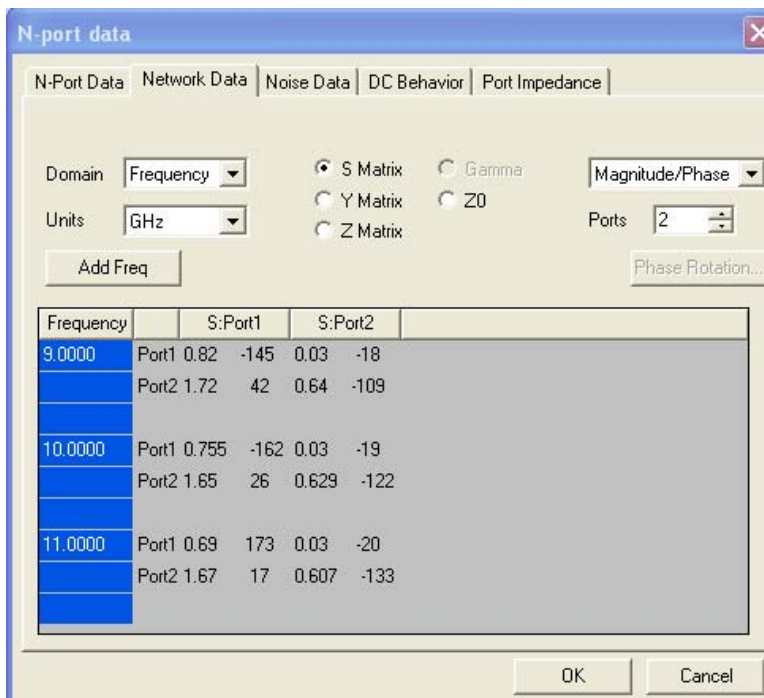
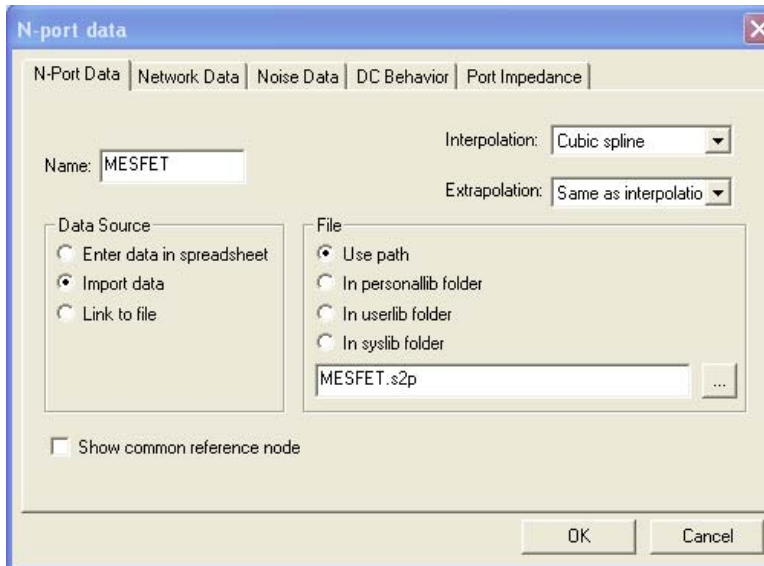
The four comment lines are preceded by an exclamation (!) sign. The three data lines are the frequency (GHz), followed by S11, S21, S12, and S22. Each is specified as magnitude and phase in degrees.

We want to save this as an ANSI file, not a text file. To do this, under Notepad File, choose Save As, and assign the file name as **MESFET.s2p**. (The suffix .s2p is important, as it tells Designer that this is a Touchstone-formatted file for a 2-port described by its scattering parameters.) Under Save As Type, choose All Files (not Text File). Under encoding, choose ANSI. You should save this in a subdirectory/folder with a descriptive name such as **MESFET-S-param**. (You can place this subdirectory either under the Ansoft Designer program default directory, or under a document directory of your choosing. Just remember where you put it.)

Next, open Designer (or Designer SV) and set up a circuit with two 50-ohm ports, and add a 2-port network to it by selecting N-port under Draw. You will be presented with the following N-port data dialog box. Give the data a name (e.g. MESFET), for Interpolation (of data between 9, 10, and 11 GHz) choose Cubic spline (this usually gives a better fit than Linear interpolation), and under File, choose Use path, and navigate to the MESFET.s2p file you created earlier. Complete the circuit hookup as shown below.



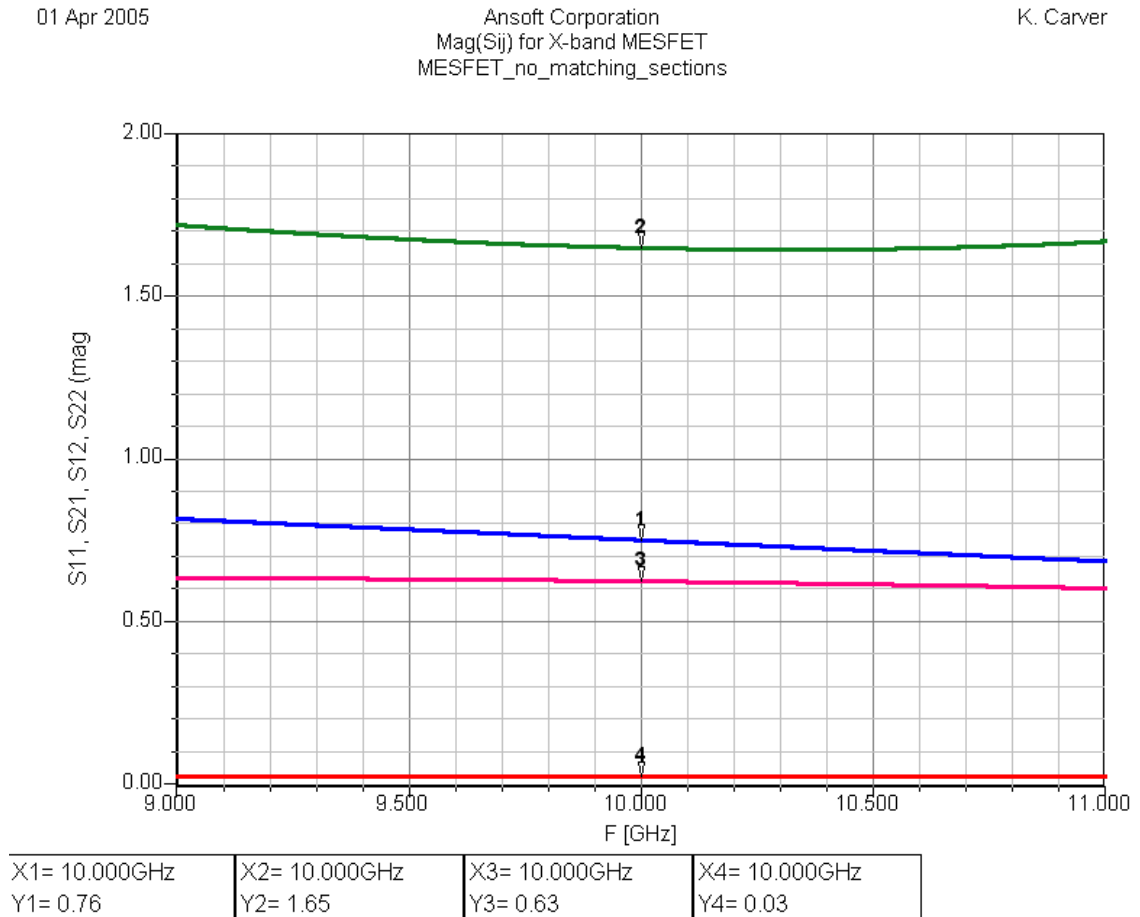
We next want to examine the Network Data to insure that it agrees with the MESFET.s2p file data. To do this, click on the Network Data tab at the top. This should display a table of  $S_{ij}$  values at 9, 10 and 11 GHz, as shown in the second screen capture below.



These  $S_{ij}$  network data values agree with the MESFET.s2p file values we created earlier, so the 2-port network is properly represented.

Returning to Designer, we next setup a frequency sweep from 9 to 11 GHz with a 10 MHz step. Under NWA1, use LIN 9GHz 11GHz 2MHz. We are now ready to analyze

the circuit. In the Project Manager window, under Analysis, choose Start Analysis. The simulation should be very fast for this simple circuit. We now want to plot the magnitudes of S11, S21, S12, and S22. In the Project Manager window, under Results, generate a rectangular graph with the magnitude of S11, S21, S12, and S22. Place a data marker at 10.000 GHz on each of the four response curves, to get this:

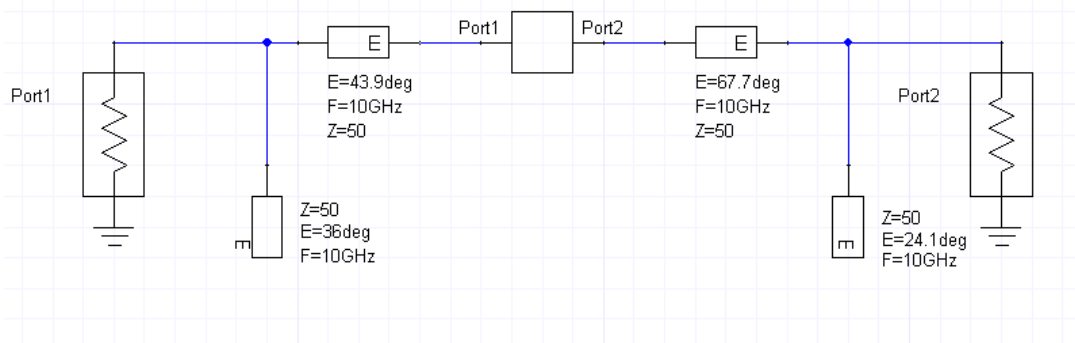


We can see that the four curves agree with the mid-band (10 GHz) values, and the two end-point (9 and 11 GHz) values. In between there is a smooth curve that interpolates between those values.

The power gain of this transducer is  $|S21|^2$ ; at 10 GHz, the power gain is  $(1.65)^2 = 2.723$  (4.35 dB). However, because the MESFET is mismatched to both the 50 ohm input source and the 50 ohm output load, we will not achieve that gain with this simple circuit. Note that at 10 GHz,  $|S11| = 0.76$  and  $|S22| = .63$ . This means that the input port has a return loss of  $20 \log(0.76) = -2.38$  dB and the output port has a return loss of  $20 \log(0.63) = -4.01$  dB.

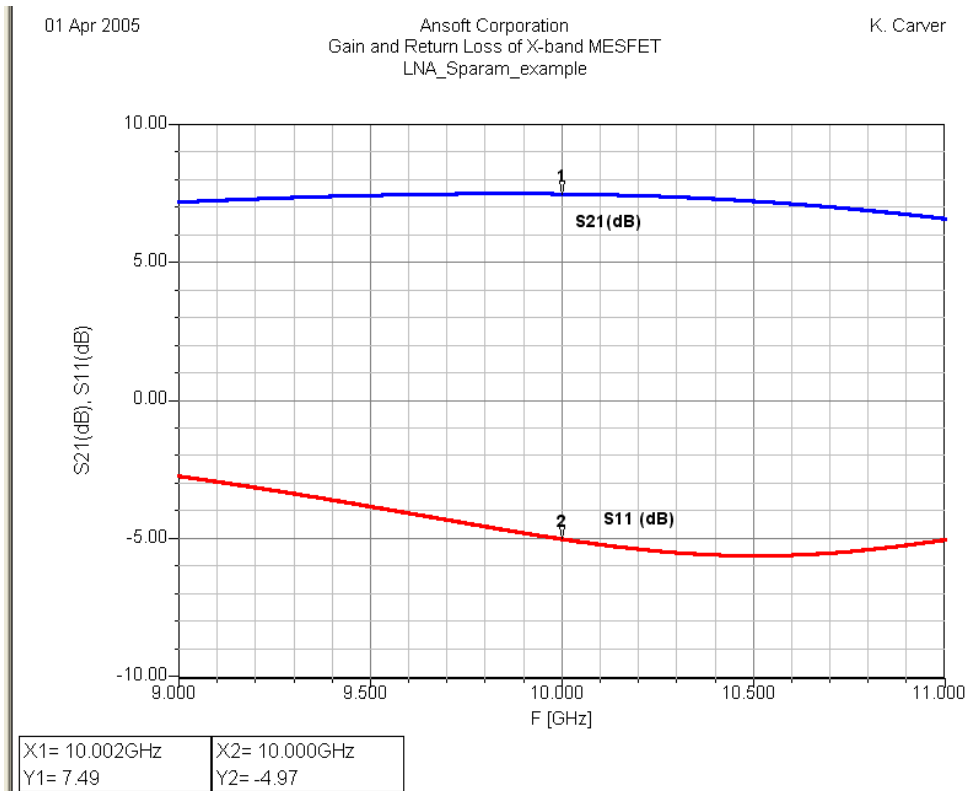
This is the end of Example 1.

**Example 2.** We now add two simple matching circuits to our X-band MESFET amplifier, one at the source and the other at the load. Each matching circuit is a single-stub tuner using 50-ohm lines. Both stubs are open-circuited.



This design (discussed in the lecture notes) provides an overall power gain at midband of 7.4 dB at 10 GHz and a broadband gain response (little variation in  $S_{21}$  over the 9 – 11 GHz range). At midband, the source (port 1) matching network has a gain of 2 dB, and the load (port 2) matching network has a gain of 1 dB. When added to the 4.35 dB gain of the transistor, the overall midband power gain is 7.35 dB.

In Designer, we again set up a NWA1 frequency sweep from 9 to 11 GHz, do an Analysis, and plot the overall gain ( $20 \log |S_{21}|$ ) and the return loss at the input ( $20 \log |S_{11}|$ ). The resulting response is:



The simulated midband gain of the amplifier is 7.5 dB, with little variation over the 9 – 11 GHz. At 11 GHz, the gain drops to 6.8 dB. However, the return loss is rather poor, especially at 9 GHz (-2.9 dB). If we change the matching circuits to provide maximum gain at midband, and give up some bandwidth, we can greatly improve the midband return loss. This is discussed in the lecture notes.

This is the end of Example 2.