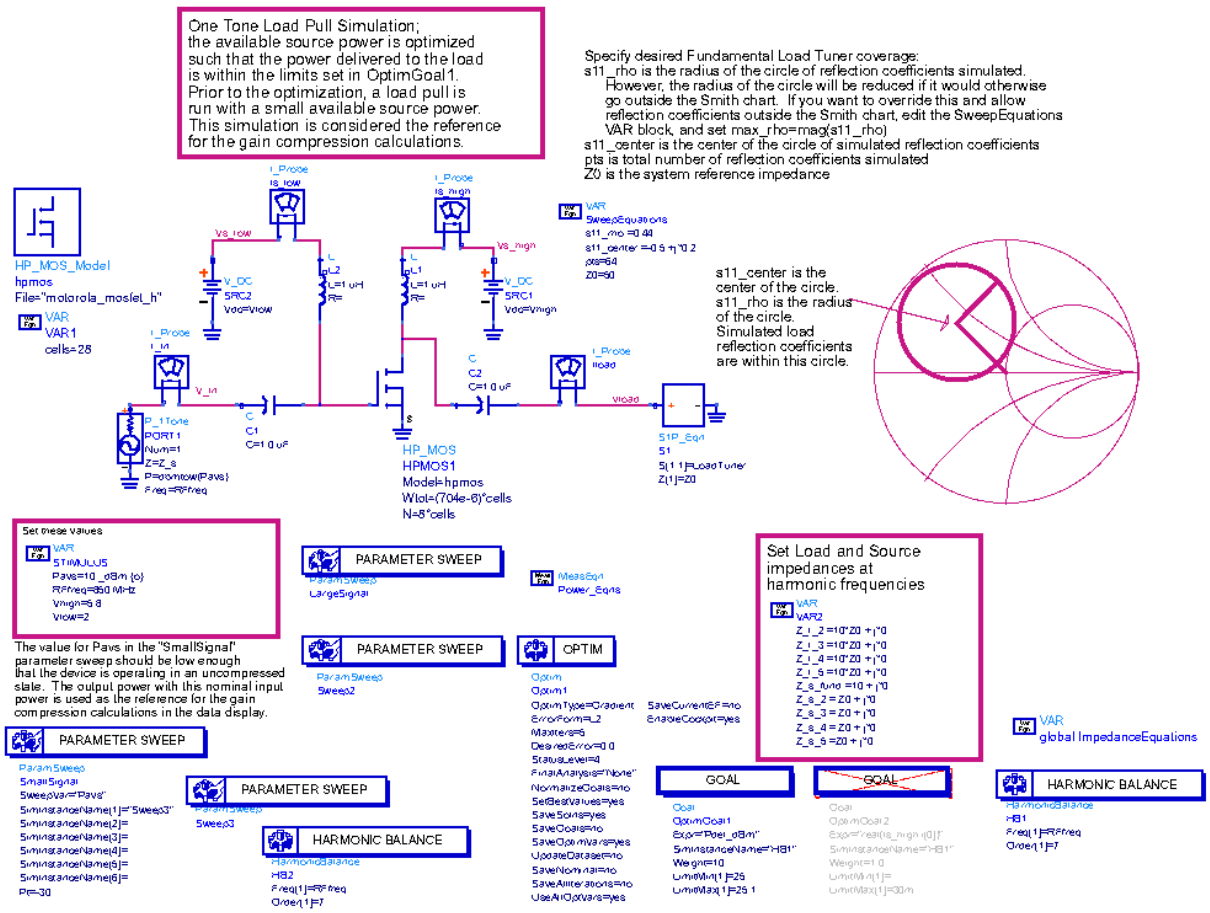
ADS load pull simulations for constant output power

Harmonic Balance 1-Tone simulation (HB1Tone_LoadPull_ConstPdel):

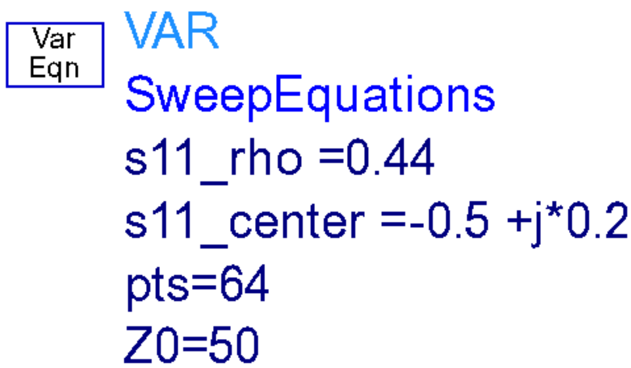
This setup sweeps the load reflection coefficient in a circular region of the Smith Chart and optimizes the source power level for each load reflection coefficient until the desired power is delivered to the load. The data display shows contours of constant PAE, bias current, gain, and gain compression. The input reflection coefficient is also shown for a particular load that you specify. This allows you to pick the optimal load that produces the best PAE, gain, gain compression, or bias current, or make trade-offs amongst these specifications.

The lower left **SmallSignal** and **Sweep3** parameter sweeps are only used to obtain output powers when the device is being driven with a small signal. These output powers are used as references in the gain compression computations.



When using this schematic, there are a number of different things you need to specify. First, you would replace the device with your device or amplifier. You have to set the bias voltages or modify the bias network, as needed. However, the data display calculates the DC power consumption assuming current probe **Is_low** is connected to supply voltage node **Vs_low** and current probe **Is_high** is connected to supply voltage node **Vs_high**. If you delete any of these or re-name them, you will have to modify the **Pdc** equation on the corresponding data display so the DC power consumption is computed correctly.

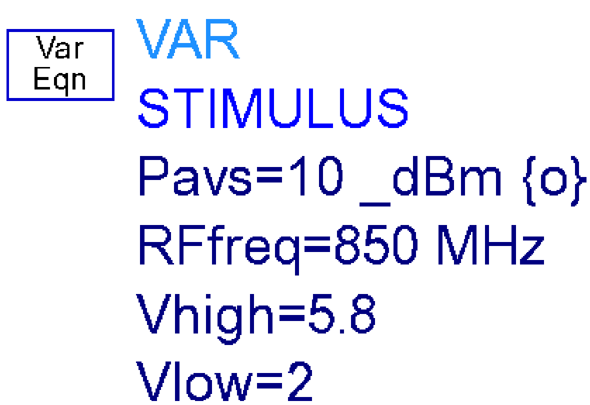
You have to specify the center and radius of the circle of the reflection coefficients.



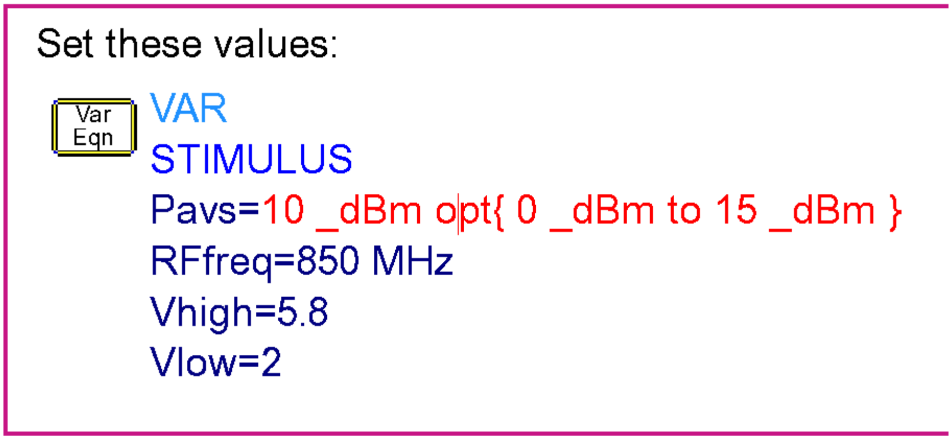
These are set by the **s11_center** and **s11_rho** variables (**s11_rho** is automatically reduced in order to keep the reflection coefficient <1.) If the device or amplifier is potentially unstable and the circle of reflection coefficients that you specify includes the unstable region, the simulation may run into convergence problems. This would be due to the device wanting to oscillate. A solution to this problem is to add stabilizing components at the input, output, or in parallel with the device. You may want to use a simulation setup for this purpose, **DesignGuide > Amplifier > S-Parameter Simulations > Feedback Network Optimization to Attain Stability.** Another solution is to specify the circle of reflection coefficients such that the unstable region is avoided.

You also have to specify the number of reflection coefficient points to be simulated, **pts**, and the reference impedance, **Z0**.

You have to specify the nominal and allowed range of the available source power, **Pavs**.



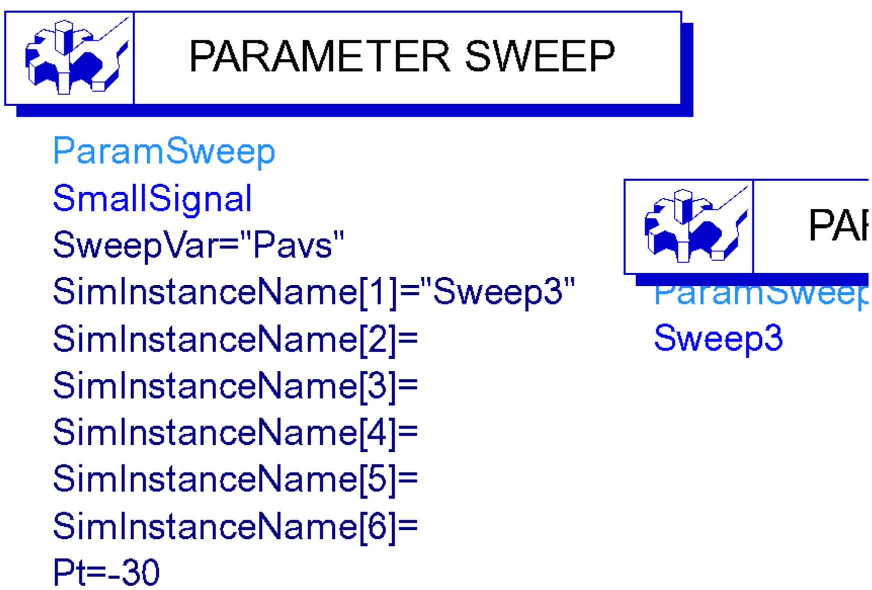
Prior to starting on-screen editing



While performing on-screen editing

During the optimization, this variable is adjusted within the limits until the power that you want is delivered to the load. The nominal value of **Pavs** does not matter that much, since it will only be used as the initial value for the first optimization. Depending on how high a power you want delivered to the load and the gain of the device, you may have to adjust the maximum allowed value of **Pavs**.

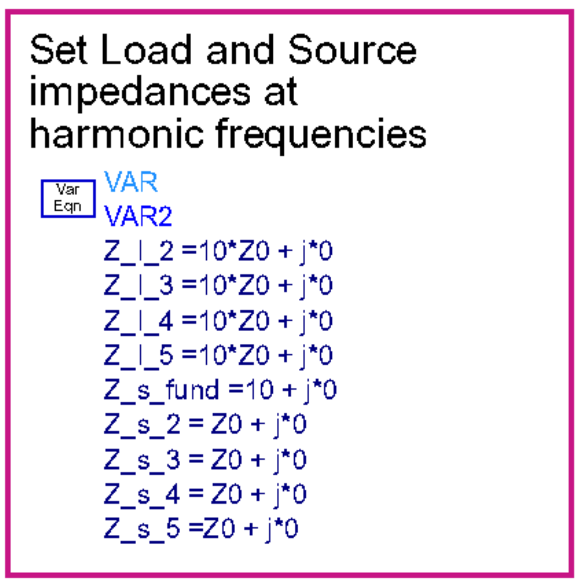
On the **SmallSignal** Parameter Sweep, you should make sure the value is small enough that the device behaves linearly.



The power delivered to the load with this "small signal" available source power is kept as the reference for the gain compression computation. You specify the desired power to be delivered to the load in **OptimGoal1**.

In this case, we want the power delivered to be between 25 and 25.1 dBm. With this value and a maximum **Pavs** value of 15 dBm, we are effectively specifying that the lowest transducer power gain we will accept is 10 dB.

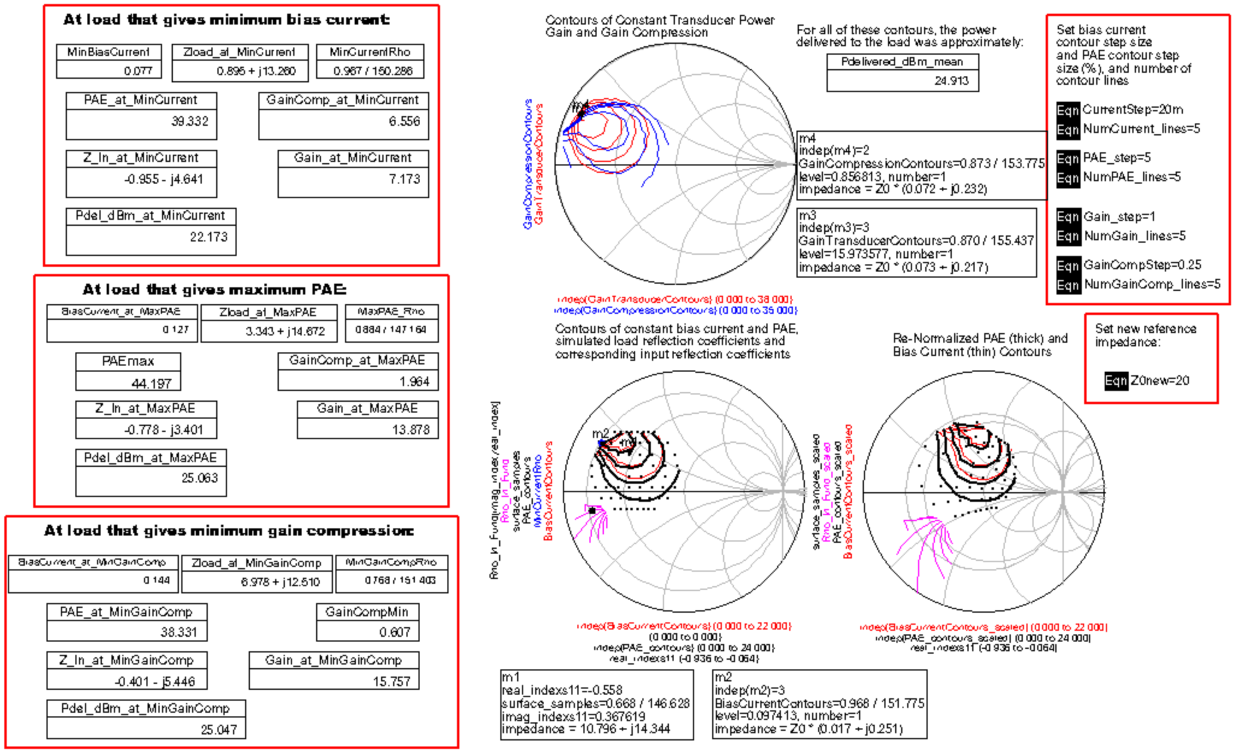
You may also specify different load and source impedances at the harmonic frequencies and (for the source) at the fundamental frequency.



Because the simulation includes an optimization, you launch the simulation by clicking on the optimization icon (if using ADS 2009 Update 1 or later.) If instead you just launch the simulation by hitting the F7 key or selecting **Simulate > Simulate**, an optimization will not be run and the data display will not display the simulation results.

Optimization Icon

After running the optimization, this **HB1Tone_LoadPull_ConstPdel** data display shows the results.



To see the contours effectively, you may need to change the **CurrentStep, PAE_step, Gain_step, and GainCompStep** variables. These set the step sizes between the contours. As stated above, if you have modified the bias network, you will have to edit the **Pdc** equation on the **Equations** page.

Power-Added Efficiency (PAE) and PAE contour calculations:

The Pdc equation assumes the schematic has nodes named Vs_low and Vs_high as well as current probes named Is_low and Is_high. If your schematic is different, you must modify this equation.

Eqn Pdc=real(Is_low.i[0,0]*Vs_low[0,0] +Is_high.i[0,0]*Vs_high[0,0])

Also, the bias supply current calculations only include the current in the probe **Is_high**. If you change the name of the current probe, you will need to edit the **BiasCurrent** equation on the **Equations** page.

The upper Smith Chart shows contours of constant gain and gain compression. The lower left Smith Chart shows contours of constant bias current and power-added efficiency (PAE), as well as the simulated load reflection coefficients and the corresponding input reflection coefficients. The lower right Smith Chart shows the same data on a Smith Chart with a different reference impedance.

In the red boxes on the left side are data that correspond to a particular optimal condition such as minimum bias current, maximum PAE, or minimum gain compression. However, you have to make sure that the desired power delivered was actually achieved. For example, at the load or reflection coefficient that gave the minimum bias current, the power delivered was < 23 dBm. This minimum bias current load is very close to 0 Ohms, and it is very difficult to deliver any power to it. The gain (transducer power gain) and gain compression with this load are unreasonable, also.

At load that gives minimum bias current:

MinBiasCurrent	Zload_at_MinCurrent	MinCurrentRho
0.077	0.895 + j13.260	0.967 / 150.286

PAE_at_MinCurrent	GainComp_at_MinCurrent
39.332	6.556

Z_In_at_MinCurrent	Gain_at_MinCurrent
-0.955 - j4.641	7.173

Pdel_dBm_at_MinCurrent
22.173

The load that corresponds to the maximum PAE is very close to the one that corresponds to the minimum bias current, but the power delivered meets the 25 dBm requirement and the gain and gain compression values are much more reasonable.

At load that gives maximum PAE:

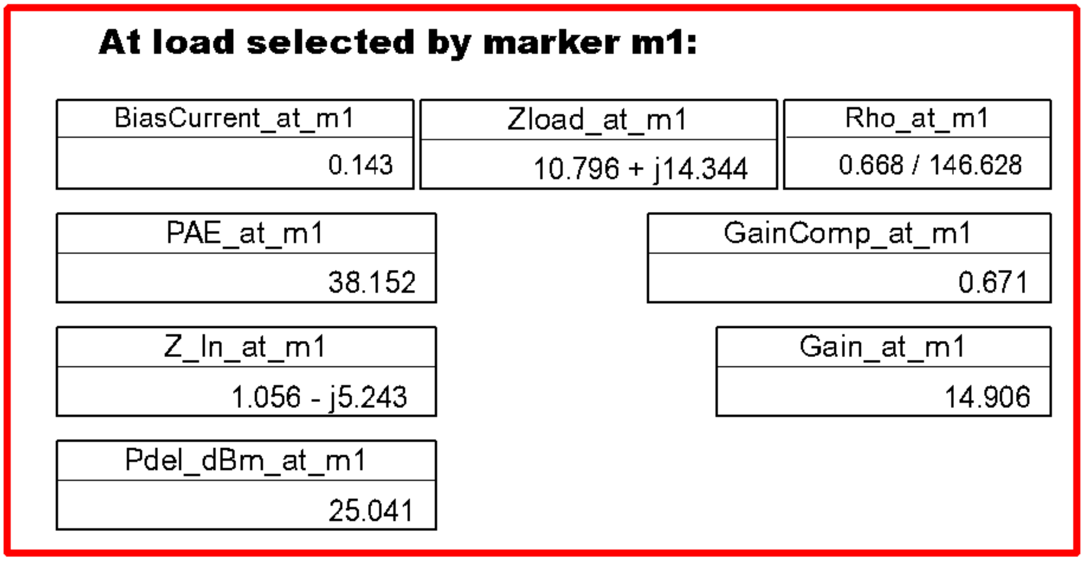
BiasCurrent_at_MaxPAE	Zload_at_MaxPAE	MaxPAE_Rho
0.127	3.343 + j14.672	0.884 / 147.164

PAEmax	GainComp_at_MaxPAE
44.197	1.964

Z_In_at_MaxPAE	Gain_at_MaxPAE
-0.778 - j3.401	13.878

Pdel_dBm_at_MaxPAE
25.063

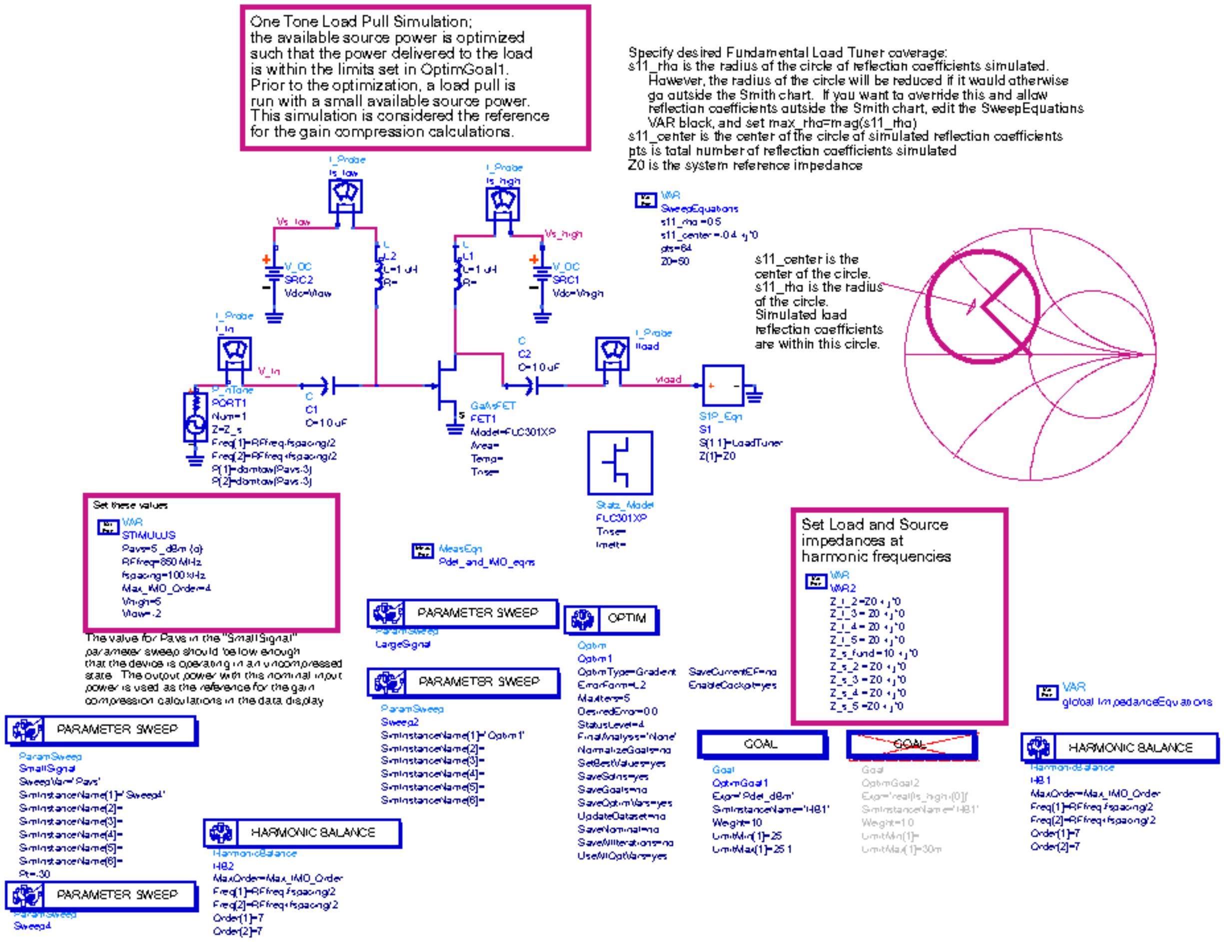
You also have the option of selecting any of the simulated load reflection coefficients with marker m1. The corresponding data appears in a separate box.



This enables you to see potential trade-offs. For example, for this load impedance, the PAE is worse, but the amount of gain compression is much less. Also the input reflection coefficient now has a positive real part, which should aid stability.

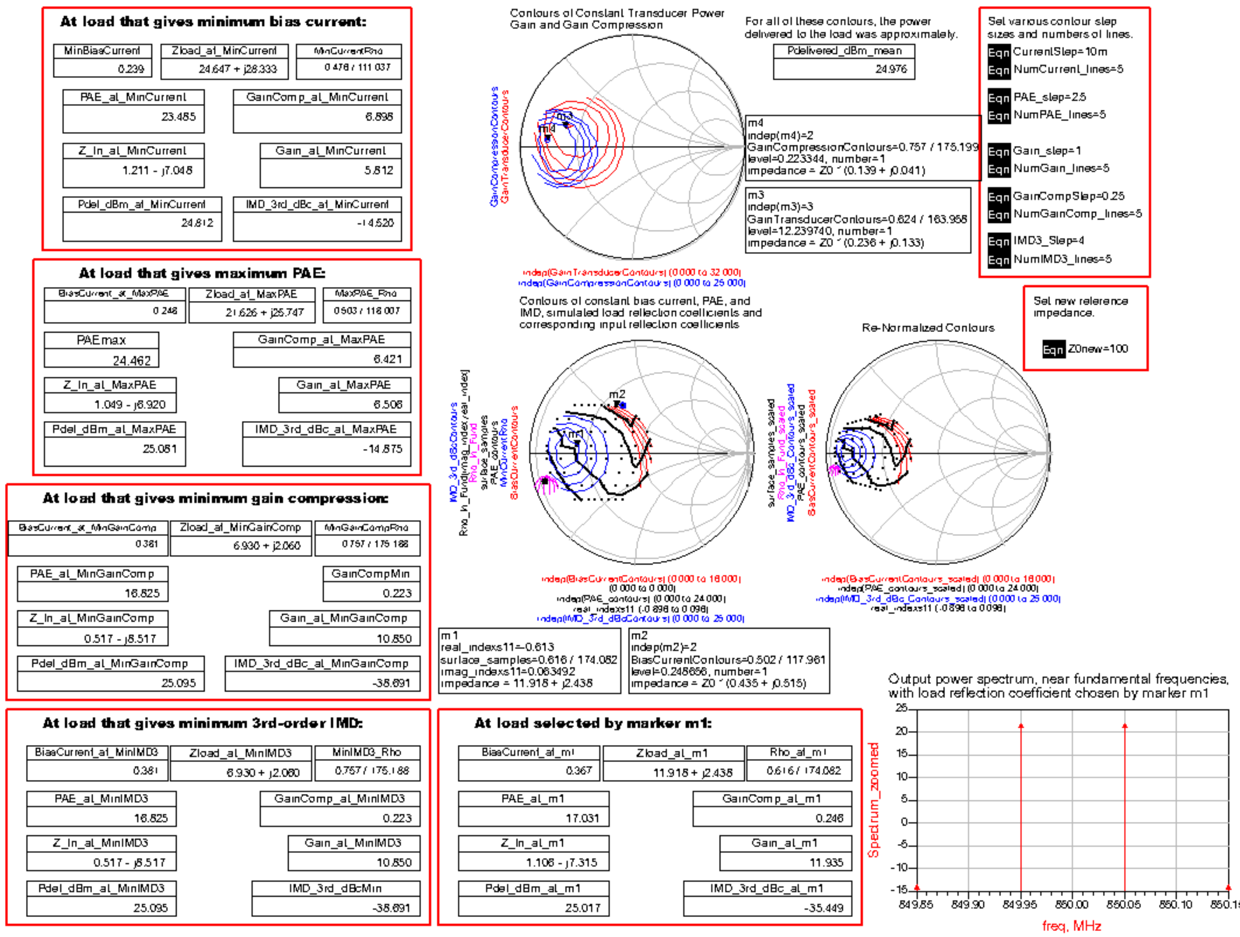
Harmonic Balance 2-Tone simulation (HB2Tone_LoadPull_ConstPdel):

This simulation setup and data display is nearly identical to the one above, except that now two tones are supplied instead of one. A 2-tone test signal stresses the device more because of its much higher peak-to-average ratio. The data display from this simulation shows the same information as above and also includes intermodulation distortion. (Note that a different device is used.)



There are two new variables you have to specify, the frequency spacing between the two tones **fspacing,** and the maximum order of intermodulation distortion tones to be included in the simulation **Max_IMD_Order**.

The simulation results include similar information as shown above, with the addition of intermodulation distortion.



There is a clear trade-off between PAE and distortion. For this bias point, if you want maximum PAE, you suffer a lot of gain compression and intermodulation distortion.

How long does this 2 tone simulation take? With 64 different load reflection coefficients, the simulation required less than 12 seconds.

At load that gives maximum PAE:

BiasCurrent_at_MaxPAE	0.248
Zload_at_MaxPAE	21.626 + j25.747
MaxPAE_Rho	0.503 / 118.007
PAEmax	24.462
GainComp_at_MaxPAE	6.421
Z_In_at_MaxPAE	1.049 - j6.920
Gain_at_MaxPAE	6.506
Pdel_dBm_at_MaxPAE	25.081
IMD_3rd_dBc_at_MaxPAE	-14.875

Tolerating a lower PAE allows much lower gain compression and intermodulation distortion.

At load that gives minimum 3rd-order IMD:

BiasCurrent_at_MinIMD3	0.381
Zload_at_MinIMD3	6.930 + j2.060
MinIMD3_Rho	0.757 / 175.188
PAE_at_MinIMD3	16.825
GainComp_at_MinIMD3	0.223
Z_In_at_MinIMD3	0.517 - j8.517
Gain_at_MinIMD3	10.850
Pdel_dBm_at_MinIMD3	25.095
IMD_3rd_dBcMin	-38.691