21.3 Load-Pull Simulations

The Load Pull Simulation Guide is available in the schematic window under the **DesignGuide** menu.

21.3.1 Objective

Shows how to do load-pull simulations to generate contours that indicate load impedances. These contours cause a certain power to be delivered to the load whenthey are presented to the output of a device along with the specified source impedances and available source power.

21.3.2 Setup

1. "HB1Tone_LoadPull" is a simulation set-up that generates actual contour lines for output power and power-added efficiency.

2. "HB2Tone_LoadPull" is identical to "HB1Tone_LoadPull" except that it shows all the equations, and includes some explanatory text.

3. "HB1Tone_LoadPull.dds" displays the output power and power-added efficiency contours and includes information on the equation syntaxs.

4. "ReflectionCoefUtility.dds" shows how the variables s11rho and s11centerdetermine the circular region of the Smith Chart within which load reflection coefficients are generated.

5. "HB1Tone_LoadPullMagPh" is identical to "HB1Tone_LoadPull", except that it uses a much simpler simulation setup. Instead of generating loads in a circular region of the Smith chart, the magnitude and phase of the load reflection coefficient are swept independently.

6. "HB1Tone_LoadPull_ConstPdel" uses an optimization to vary parameters on the schematic until a desired power is delivered to each load impedance. Contours of constant power-added efficiency and constant bias current are plotted on the data display.

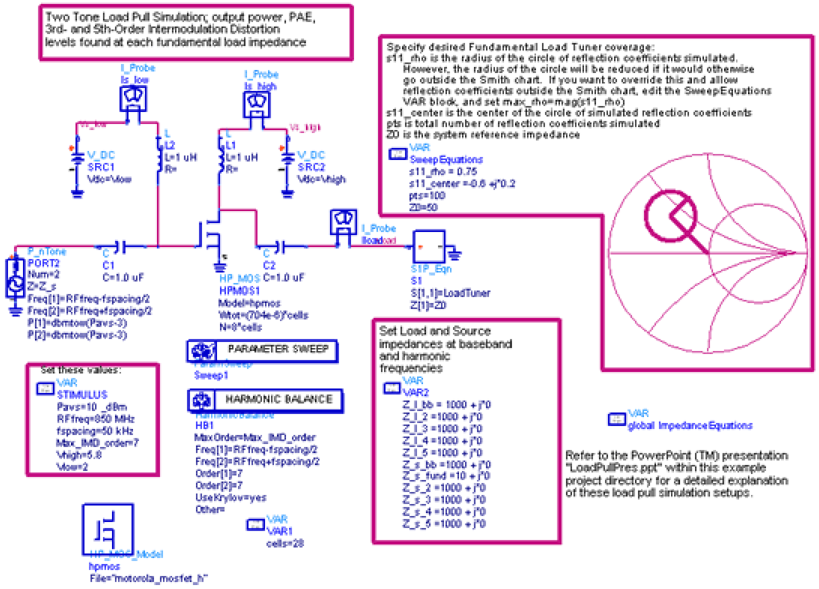
7. "LoadPullMagPh_ConstPdel" is similar to "HB1Tone_LoadPull_ConstPdel",except that it varies the magnitude and phase of the load reflection coefficient rather than sweeping out a circular region of the Smith chart. Also the data display has contours of constant operating and transducer power gain.

8. "HB2Tone_LoadPull" is a simulation set-up that generates actual contour lines for output power, power-added efficiency, third-order intermodulation distortion, and fifth-order intermodulation distortion.

9. "HB2Tone_LoadPull.dds" has the contour plots on one page, and the equations used to calculate output power, power-added efficiency, third-order intermodulation distortion, and fifth-order intermodulation distortion on another.

10. "HB2Tone_LoadPullMagPh" is identical to "HB2Tone_LoadPull", except that it uses a much simpler simulation setup. Instead of generating loads in a circular region of the Smith chart, the magnitude and phase of the load reflection coefficient are swept independently.

11. "contours" shows the old method of generating load pull contours, that was used in ADS before release 1.3. It generates load-pull contours on a Smith chart.These contours indicate load impedances that, when presented to the output of advice (along with the specified source impedances and available source power),would cause a certain power delivered to the load. "contours.dds"is the corresponding data display.



Two Tone Load Pull Simulation; output power, PAE,
3rd- and 5th-Order Intermodulation Distortion
levels found at each fundamental load impedance

Specify desired Fundamental Load Tuner coverage:
s11_rho is the radius of the circle of reflection coefficients simulated.
However, the radius of the circle will be reduced if it would otherwise go outside the Smith chart. If you want to override this and allow reflection coefficients outside the Smith chart, edit the SweepEquations VAR block, and set max_rho=mag(s11_rho)
s11_center is the center of the circle of simulated reflection coefficients
pts is total number of reflection coefficients simulated
Z0 is the system reference impedance

VAR
SweepEquations
s11_rho = 0.75
s11_center =-0.6 +j*0.2
pts=100
Z0=50

P_nTone
PORT2
Num=2
Z=Z_s
Freq[1]=RFfreq-fspacing/2
Freq[2]=RFfreq+fspacing/2
P[1]=dbmtow(Pavs-3)
P[2]=dbmtow(Pavs-3)

HP_MOS
HPMOS1
Model=hpmos
Wtot=(704e-6)*cells
N=8*cells

S1P_Eqn
S1
S[1,1]=LoadTuner
Z[1]=Z0

Set these values:

VAR
STIMULUS
Pavs=10 _dBm
RFfreq=850 MHz
fspacing=50 kHz
Max_IMD_order=7
Vhigh=5.8
Vlow=2

PARAMETER SWEEP
ParamSweep
Sweep1

HARMONIC BALANCE
HarmonicBalance
HB1
MaxOrder=Max_IMD_order
Freq[1]=RFfreq-fspacing/2
Freq[2]=RFfreq+fspacing/2
Order[1]=7
Order[2]=7
UseKrylov=yes
Other=

VAR
VAR1
cells=28

HP_MOS_Model
hpmos
File="motorola_mosfet_h"

Set Load and Source impedances at baseband and harmonic frequencies

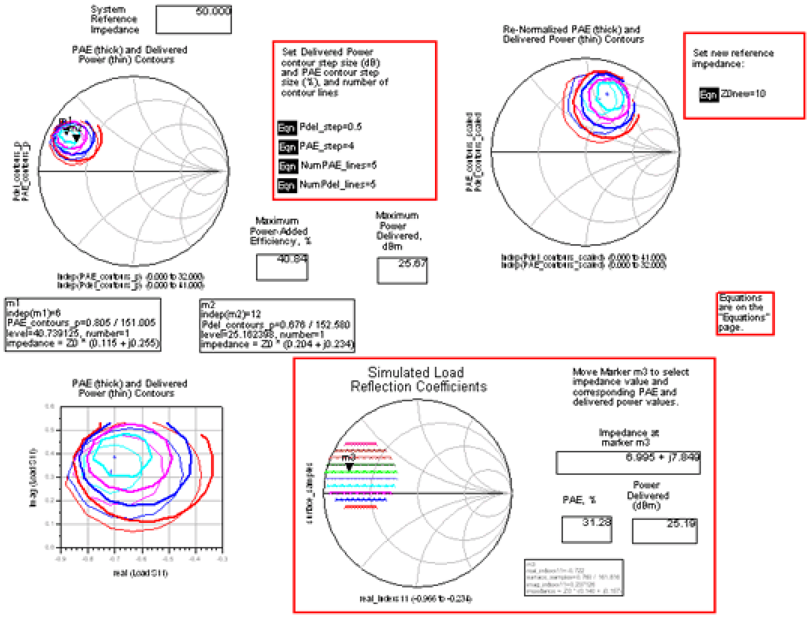
VAR
VAR2
Z_l_bb = 1000 + j*0
Z_l_2 =1000 + j*0
Z_l_3 =1000 + j*0
Z_l_4 =1000 + j*0
Z_l_5 =1000 + j*0
Z_s_bb =1000 + j*0
Z_s_fund =10 + j*0
Z_s_2 =1000 + j*0
Z_s_3 =1000 + j*0
Z_s_4 =1000 + j*0
Z_s_5 =1000 + j*0

VAR
global ImpedanceEquations

Refer to the PowerPoint (TM) presentation "LoadPullPres.ppt" within this example project directory for a detailed explanation of these load pull simulation setups.

21.3.3 Analysis

Figure 1: Output power and PAE set-up


PAE (thick) and Delivered
Power (thin) Contours
m1
m2
Pdel_contours_p
PAE_contours_p
indep(PAE_contours_p) (0.000 to 32.000)
indep(Pdel_contours_p) (0.000 to 41.000)
Re-Normalized PAE (thick) and
Delivered Power (thin) Contours
PAE_contours_scaled
Pdel_contours_scaled
indep(Pdel_contours_scaled) (0.000 to 41.000)
indep(PAE_contours_scaled) (0.000 to 32.000)
PAE (thick) and Delivered
Power (thin) Contours
imag (Load S11)
real (Load S11)
Simulated Load
Reflection Coefficients
m3
imag_indexs11
real_indexs11 (-0.966 to -0.234)

System Reference Impedance: 50.000

Set Delivered Power contour step size (dB) and PAE contour step size (%), and number of contour lines

Eqn Pdel_step=0.5

Eqn PAE_step=4

Eqn NumPAE_lines=5

Eqn NumPdel_lines=5

Maximum Power-Added Efficiency, %: 40.84

Maximum Power Delivered, dBm: 25.67

Set new reference impedance:

Eqn Z0new=10

m1
indep(m1)=6
PAE_contours_p=0.805 / 151.005
level=40.739125, number=1
impedance = Z0 * (0.115 + j0.255)

m2
indep(m2)=12
Pdel_contours_p=0.676 / 152.580
level=25.162398, number=1
impedance = Z0 * (0.204 + j0.234)

Equations are on the "Equations" page.

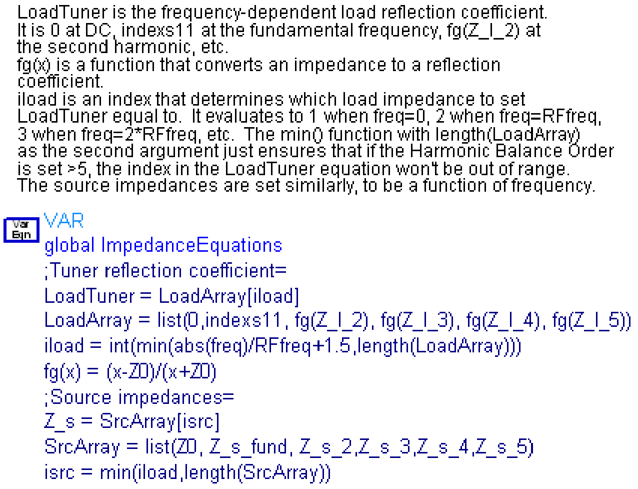
Move Marker m3 to select impedance value and corresponding PAE and delivered power values.

Impedance at marker m3: 6.995 + j7.849

PAE, %: 31.28

Power Delivered (dBm): 25.19

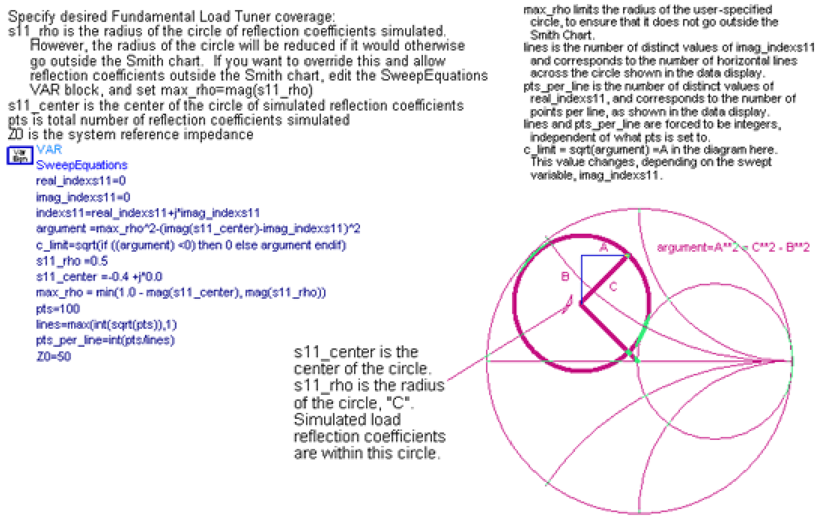
Figure 2: Load Tuner equation



LoadTuner is the frequency-dependent load reflection coefficient.
It is 0 at DC, indexs11 at the fundamental frequency, fg(Z_l_2) at
the second harmonic, etc.
fg(x) is a function that converts an impedance to a reflection
coefficient.
iload is an index that determines which load impedance to set
LoadTuner equal to. It evaluates to 1 when freq=0, 2 when freq=RFfreq,
3 when freq=2*RFfreq, etc. The min() function with length(LoadArray)
as the second argument just ensures that if the Harmonic Balance Order
is set >5, the index in the LoadTuner equation won't be out of range.
The source impedances are set similarly, to be a function of frequency.

```
Var
Eqn VAR
global ImpedanceEquations
;Tuner reflection coefficient=
LoadTuner = LoadArray[iload]
LoadArray = list(0,indexs11, fg(Z_l_2), fg(Z_l_3), fg(Z_l_4), fg(Z_l_5))
iload = int(min(abs(freq)/RFfreq+1.5,length(LoadArray)))
fg(x) = (x-Z0)/(x+Z0)
;Source impedances=
Z_s = SrcArray[isrc]
SrcArray = list(Z0, Z_s_fund, Z_s_2,Z_s_3,Z_s_4,Z_s_5)
isrc = min(iload,length(SrcArray))
```

Figure 3: Fundamental Load Tuner coverage and sweep equation



Specify desired Fundamental Load Tuner coverage:
s11_rho is the radius of the circle of reflection coefficients simulated.
However, the radius of the circle will be reduced if it would otherwise go outside the Smith chart. If you want to override this and allow reflection coefficients outside the Smith chart, edit the SweepEquations VAR block, and set max_rho=mag(s11_rho)
s11_center is the center of the circle of simulated reflection coefficients
pts is total number of reflection coefficients simulated
Z0 is the system reference impedance

```
VAR
SweepEquations
real_indexs11=0
imag_indexs11=0
indexs11=real_indexs11+j*imag_indexs11
argument =max_rho^2-(imag(s11_center)-imag_indexs11)^2
c_limit=sqrt(if ((argument) <0) then 0 else argument endif)
s11_rho =0.5
s11_center =-0.4 +j*0.0
max_rho = min(1.0 - mag(s11_center), mag(s11_rho))
pts=100
lines=max(int(sqrt(pts)),1)
pts_per_line=int(pts/lines)
Z0=50
```

max_rho limits the radius of the user-specified circle, to ensure that it does not go outside the Smith Chart.
lines is the number of distinct values of imag_indexs11 and corresponds to the number of horizontal lines across the circle shown in the data display.
pts_per_line is the number of distinct values of real_indexs11, and corresponds to the number of points per line, as shown in the data display.
lines and pts_per_line are forced to be integers, independent of what pts is set to.
c_limit = sqrt(argument) =A in the diagram here. This value changes, depending on the swept variable, imag_indexs11.

s11_center is the center of the circle. s11_rho is the radius of the circle, "C". Simulated load reflection coefficients are within this circle.

21.3.4 Notes

- Simulation controller used: Harmonic Balance.
- Only the impedance at the fundamental frequency is varied. Impedances at harmonic frequencies are set independently but they are not varied in this example. Detailed information on setting up the load and source impedances for the load-pull can be found in the example descriptions.
- See also the example workspace Loadpull Simulations in ADS

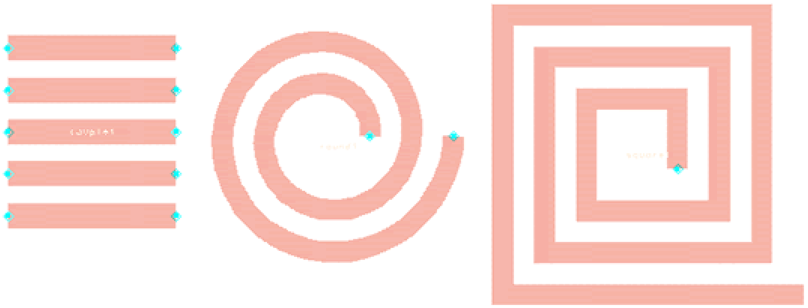
21.4 Radar Applications Guide

The Radar Applications Guide is available from the schematic window under the **DesignGuide** menu.

21.4.1 Objective

The objective of the Radar Applications guide is to demonstrate the capability of Advanced Design System to simulate Pulse compression simulation in a radar system and to demonstrate IFM receiver simulation for EW application.

- "FM-CW Radar Simulation" demonstrates a simple Doppler radar simulation using envelope simulator. A user defined target model is implemented. The echo signal is a function of target range, velocity, and cross-section. The Doppler shift in frequency is plotted.



34.6.3 Notes

- For another example of a FET refer to /examples/RFIC/GCC_FET_wrk.

34.7 Loadpull Simulations in ADS

Location: $HPEESOF_DIR/examples/RF_Board/LoadPull_wrk

34.7.1 Objective

This example shows how to do load-pull simulations. These simulations generate contours that indicate load impedances that when presented to the output of a device (along with the specified source impedance and available source power) would cause a certain power to be delivered to the load.

34.7.2 Setup

These simulations are discussed in detail in two PDF files in this example workspace directory, **LoadPullPres.pdf** and **LoadPullConstPdel.pdf**. You may view them with Adobe Reader. This example shows how to do load-pull simulations. These simulations generate contours that indicate load impedances that, when presented to the output of a device (along with the specified source impedances and available source power), would cause a certain power to be delivered to the load. Note that only the impedance at the fundamental frequency is varied (although these setups could be modified easily to allow varying an impedance at an arbitrary harmonic frequency.) Impedances at the harmonic frequencies may be set independently.

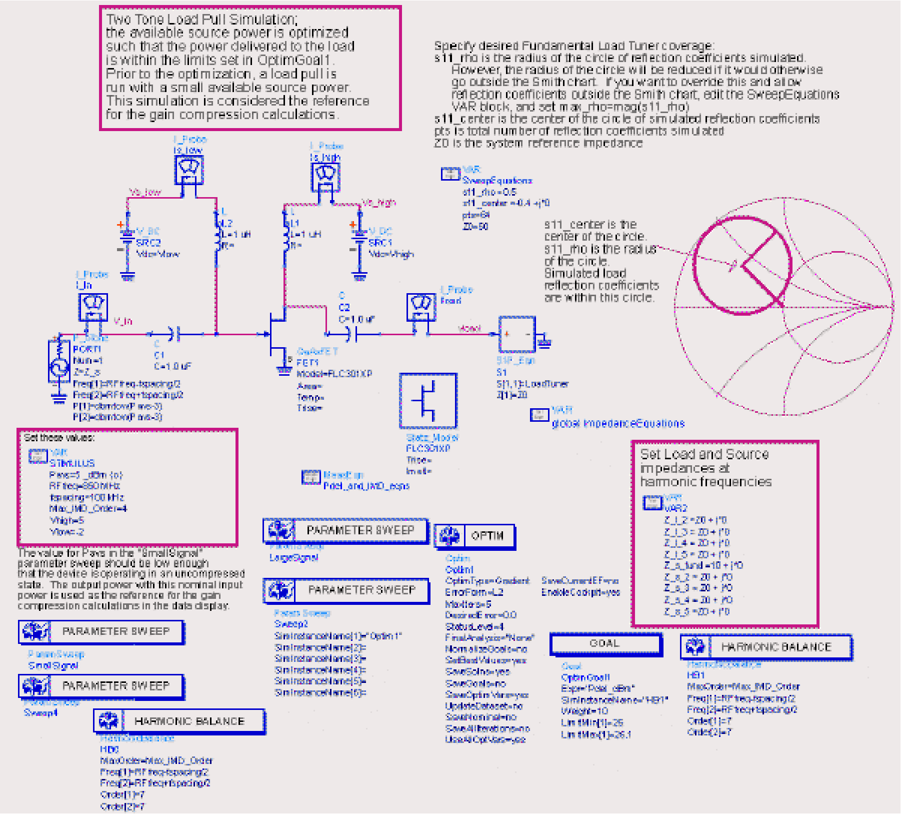
1. **HB1Tone_LoadPull** is a simulation set-up that generates actual contour lines for output power and power-added efficiency.

2. The schematic **HB1Tone_LoadPull_eqns** is identical to **HB1Tone_LoadPull**, except that it shows all the equations, and includes some explanatory text.

3. **HB1Tone_LoadPull.dds**, displays the output power and PAE contours and has an equations page with some documentation of their syntaxes.
4. **ReflectionCoefUtility.dds** shows how the variables s11rho and s11center determine the circular region of the Smith Chart within which load reflection coefficients are generated.
5. **HB1Tone_LoadPullMagPh** is identical to **HB1Tone_LoadPull**, except that it uses a much simpler simulation setup. Instead of generating loads in a circular region of the Smith Chart, the magnitude and phase of the load reflection coefficient are swept independently.
6. **HB1Tone_LoadPullPSweep** includes a power sweep at each load, so you may see the gain compression characteristics of the device.
7. **HB1Tone_LoadPull_vsFreq** repeats the fixed available source power simulation as a function of frequency.
8. **HB1Tone_LoadPull_ConstPdel** uses an optimization to vary the available source power on the schematic until a desired power is delivered to each load impedance. Contours of constant power-added efficiency, constant bias current, constant gain, and constant gain compression are plotted on the data display.
9. **LoadPullMagPh_ConstPdel** is similar to **HB1Tone_LoadPull_ConstPdel**, except that it varies the magnitude and phase of the load reflection coefficient rather than sweeping out a circular region of the Smith Chart. Also the data display has contours of constant operating and transducer power gain.
10. **HB2Tone_LoadPull** is a simulation set-up that generates actual contour lines for output power, power-added efficiency, third-order intermodulation distortion, and fifth-order intermodulation distortion.
11. **HB2Tone_LoadPull.dds** has the contour plots on one page, and the equations used to calculate output power, PAE, 3rd-order IMD, and 5th-order IMD on another.
12. **HB2Tone_LoadPull_ConstPdel** uses an optimization to vary the available source power on the schematic until a desired power is delivered to each load impedance. This is run with two input tones so includes contours of constant intermodulation distortion.
13. **HB2Tone_LoadPullMagPh** is identical to **HB2Tone_LoadPull**, except that it uses a much simpler simulation setup. Instead of generating loads in a circular region of the Smith Chart, the magnitude and phase of the load reflection coefficient are swept independently.
14. **TwoTone_LoadPullEnv** shows a method of running a two-tone load pull simulation by amplitude modulating a one-tone signal. It uses the Envelope simulator. In some extreme cases, this might be worthwhile because it uses less memory than a 2-tone harmonic balance simulation.

15. **TwoTone_LoadPullEnvMagPh** is similar to **TwoTone_LoadPullEnv**, except that it sweeps out a pie-shaped region of the Smith Chart instead of a circular region.

34.7.3 Analysis



Two Tone Load Pull Simulation; the available source power is optimized such that the power delivered to the load is within the limits set in OptimGoal1. Prior to the optimization, a load pull is run with a small available source power. This simulation is considered the reference for the gain compression calculations.

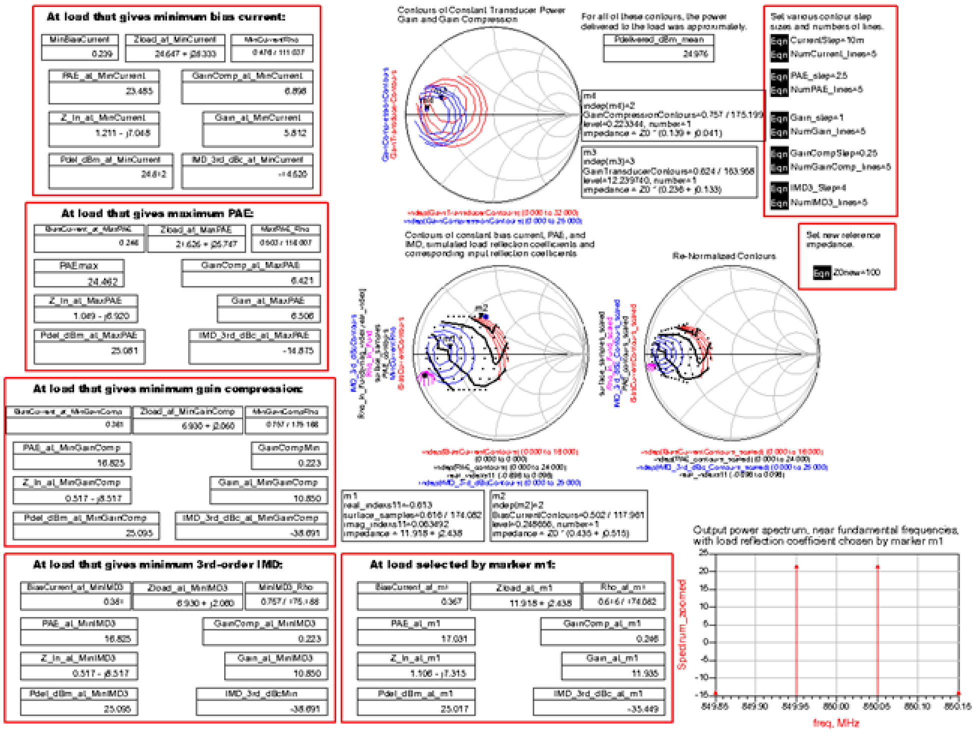
Specify desired Fundamental Load Tuner coverage:
s11_rho is the radius of the circle of reflection coefficients simulated.
 However, the radius of the circle will be reduced if it would otherwise go outside the Smith chart. If you want to override this and allow reflection coefficients outside the Smith chart, edit the SweepEquations VAR block, and set max_rho=mag(s11_rho)
s11_center is the center of the circle of simulated reflection coefficients
pts is total number of reflection coefficients simulated
Z0 is the system reference impedance

s11_center is the center of the circle. s11_rho is the radius of the circle. Simulated load reflection coefficients are within this circle.

Set these values:

The value for Pavs in the "SmallSignal" parameter sweep should be low enough that the device is operating in an uncompressed state. The output power with this nominal input power is used as the reference for the gain compression calculations in the data display.

Set Load and Source impedances at harmonic frequencies



At load that gives minimum bias current:

MinBiasCurrent	Zload_at_MinCurrent	MinCurrentRho
0.239	24.647 + j28.333	0.476 / 111.037

PAE_at_MinCurrent	GainComp_at_MinCurrent
23.485	6.898

Z_in_at_MinCurrent	Gain_at_MinCurrent
1.211 - j7.048	5.812

Pdel_dBm_at_MinCurrent	IMD_3rd_dBc_at_MinCurrent
24.812	-14.620

At load that gives maximum PAE:

BiasCurrent_at_MaxPAE	Zload_at_MaxPAE	MaxPAE_Rho
0.246	21.626 + j26.747	0.503 / 116.007

PAEmax	GainComp_at_MaxPAE
24.462	6.421

Z_in_at_MaxPAE	Gain_at_MaxPAE
1.049 - j6.920	6.506

Pdel_dBm_at_MaxPAE	IMD_3rd_dBc_at_MaxPAE
25.081	-14.875

At load that gives minimum gain compression:

BiasCurrent_at_MinGainComp	Zload_at_MinGainComp	MinGainCompRho
0.381	6.930 + j2.060	0.757 / 175.188

PAE_at_MinGainComp	GainCompMin
16.825	0.223

Z_in_at_MinGainComp	Gain_at_MinGainComp
0.517 - j8.517	10.850

Pdel_dBm_at_MinGainComp	IMD_3rd_dBc_at_MinGainComp
25.093	-38.691

At load that gives minimum 3rd-order IMD:

BiasCurrent_at_MinIMD3	Zload_at_MinIMD3	MinIMD3_Rho
0.381	6.930 + j2.060	0.757 / 175.188

PAE_at_MinIMD3	GainComp_at_MinIMD3
16.825	0.223

Z_in_at_MinIMD3	Gain_at_MinIMD3
0.517 - j8.517	10.850

Pdel_dBm_at_MinIMD3	IMD_3rd_dBcMin
25.093	-38.691

Contours of Constant Transducer Power Gain and Gain Compression

For all of these contours, the power delivered to the load was approximately.

Pdelivered_dBm_mean
24.976

m4
indep(m4)=2
GainCompressionContours=0.757 / 175.199
level=0.223344, number=1
impedance = Z0 * (0.139 + j0.041)

m3
indep(m3)=3
GainTransducerContours=0.624 / 163.968
level=12.239740, number=1
impedance = Z0 * (0.236 + j0.133)

Set various contour step sizes and numbers of lines.

Eqn CurrentStep=10m
Eqn NumCurrent_lines=5
Eqn PAE_step=2.5
Eqn NumPAE_lines=5
Eqn Gain_step=1
Eqn NumGain_lines=5
Eqn GainCompStep=0.25
Eqn NumGainComp_lines=5
Eqn IMD3_Step=4
Eqn NumIMD3_lines=5

Set new reference impedance.

Eqn Z0new=100

Contours of constant bias current, PAE, and IMD, simulated load reflection coefficients and corresponding input reflection coefficients

Re-Normalized Contours

m1
real_indexs11=-0.613
surface_samples=0.616 / 174.082
imag_indexs11=0.063492
impedance = 11.918 + j2.438

m2
indep(m2)=2
BiasCurrentContours=0.502 / 117.981
level=0.248666, number=1
impedance = Z0 * (0.435 + j0.515)

At load selected by marker m1:

BiasCurrent_at_m1	Zload_at_m1	Rho_at_m1
0.367	11.918 + j2.438	0.616 / 174.082

PAE_at_m1	GainComp_at_m1
17.031	0.248

Z_in_at_m1	Gain_at_m1
1.106 - j7.313	11.935

Pdel_dBm_at_m1	IMD_3rd_dBc_at_m1
25.017	-35.449

Output power spectrum, near fundamental frequencies, with load reflection coefficient chosen by marker m1

GainCompressionContours
GainTransducerContours
indep(GainTransducerContours) (0.000 to 32.000)
indep(GainCompressionContours) (0.000 to 29.000)
m4
m3
m2
m1
IMD_3rd_dBcContours
Rho_in_Fund
surface_samples
PAE_contours
BiasCurrentContours
indep(BiasCurrentContours) (0.000 to 18.000)
indep(PAE_contours) (0.000 to 24.000)
real_indexs11 (-0.898 to 0.098)
indep(IMD_3rd_dBcContours) (0.000 to 29.000)
indep(BiasCurrentContours_scaled) (0.000 to 18.000)
indep(PAE_contours_scaled) (0.000 to 24.000)
indep(IMD_3rd_dBc_Contours_scaled) (0.000 to 29.000)
real_indexs11 (-0.898 to 0.098)
Spectrum_zoomed
25
20
15
10
5
0
-5
-10
-15
849.85
849.90
849.95
850.00
850.05
850.10
850.15
freq, MHz

34.8 Low Power Mixer for Pager Applications

Location: $HPEESOF_DIR/examples/RF_Board/MixerPager_wrk

34.8.1 Objective

This examples shows a complete design of a low power mixer using Advanced Design System (ADS) for pager applications. Vdd is 1V, RF is at 900MHz, LO is 855MHz. It also shows a comparison between the ideal simulation and that from the layout.

34.8.2 Setup

1. DC operation point set up is achieved through three designs. "DC_curves" obtains the I-V curve of the device. "BiasPoint" establishes the operating point and bias resistor values. "BiasNet" checks the S-parameter of the biased device.

2. "Compression" shows two methods for calculating the compression point of the device.

3. "RFIFmatc

4. "LOdrive" calculates the mixer response as Lo drive sweeps.