Transceiver Block Simulation with SmartSpice RF

Introduction

Mixers, balanced modulators, and detectors are the key components in transceiver design. They operate on the principle of combining two frequencies to produce a third one. Design goals for such circuits are the high dynamic range, low noise figure, minimum distortion, and good suppression or isolation between various ports. Accurate nonlinear device models are essential to getting good simulation results for the active and passive circuits with different schematic configuration.

This application note describes how to use SmartSpice RF to provide simulation and measurement of the most important characteristics of the building blocks of the standard communication circuits.

Active Double Balanced Mixer Simulation

The simulations described are applied to the active double balanced mixer shown in Figure 1. The basic characteristics will be considered based on the test bench shown in Figure 2.
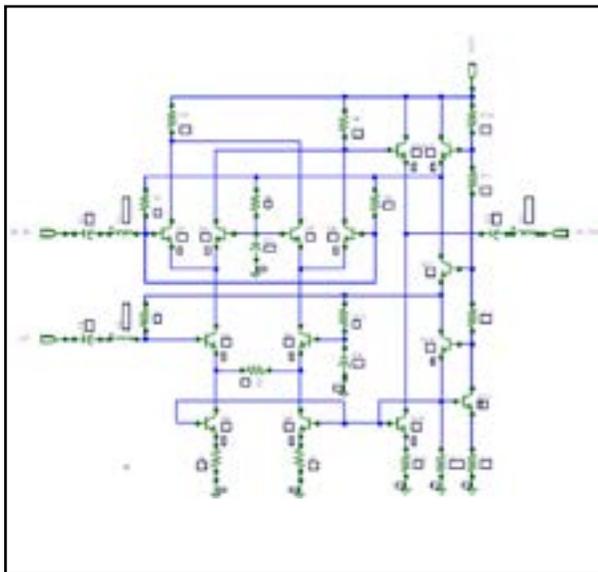

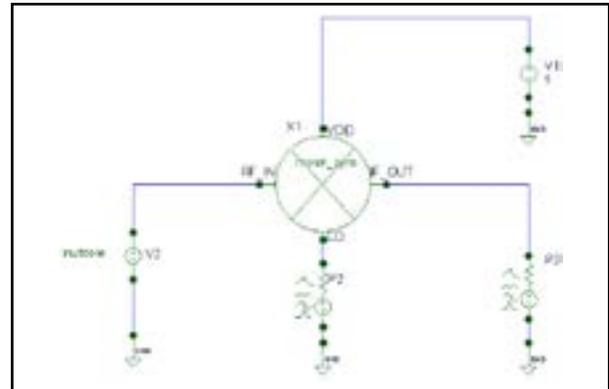Figure 1. Double Balanced Mixer Schematic.

Figure 2. Double Balanced Mixer Simulation setup.

Conversion Gain

The voltage conversion gain is the ratio of the RMS voltages of the IF and RF signals. The measurements can be provide by using the following statements:

.HTF v(out,gnd)
+ LIN 21 50Meg 500Meg
+ FUND=1750meGHz nharm=10
+ SB= (-1,1)
.let HTF Conversion_Gain='db(tfh1_V2)'

The simulation results are shown in Figure 3.

RF=2000MHz   Conversion Gain=10.26dB
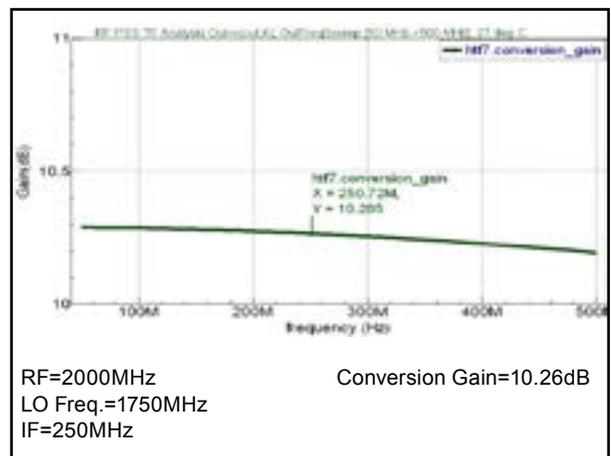LO Freq.=1750MHz
IF=250MHz

Figure 3. Conversion Gain plot.

Conversion Gain vs LO Power

This simulation shows how mixer conversion gain depends on LO power. The measurements can be provide by using the following statements:

.HTF v(out,gnd)
+ LIN 1 250Meg 250Meg
+ FUND=1750meGHz nharm=10
+ SB=(-1,1)
+ sweep lo -30dBm 5dBm 1dBm
.let HTF Conversion_Gain='db(tfh1_V2)'
.measure htf Con_Gain find Conversion_Gain at='abs(fc)'

The simulation results are shown in Figure 4.

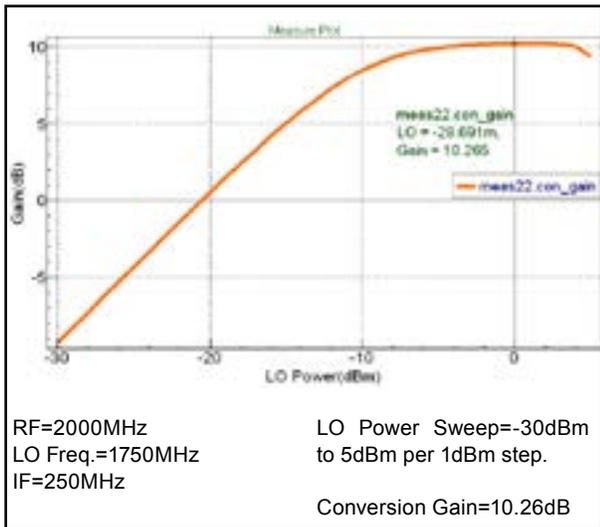| RF=2000MHz	LO Power Sweep=-30dBm
LO Freq.=1750MHz	to 5dBm per 1dBm step.
IF=250MHz	
	Conversion Gain=10.26dB

Figure 4. Conversion Gain versus LO Power plot.

1dB Compression Point

The 1dB compression point is the point at which a 1-dB reduction in mixer output occurs when RF input signal level is increased.

The measurement can be provide by using the following statements:

.param f1=250meghz
.SPECTRAL
+ FUND1=1750MegHz nharm1=5
+ FUND2=2000Meghz nharm2=5
+ ORDER=4 waves
+ SWEEP prf -30dBm -5dBm 1dBm
.let spect_sp pout=r(@P3[pout])
.MEASURE SPECT_SP dBm find pout at='abs(f1)'
.MEASURE MEAS r_1dbCompression COMPR1DB dBm EP=-28

The simulation results are shown in Figure 5.

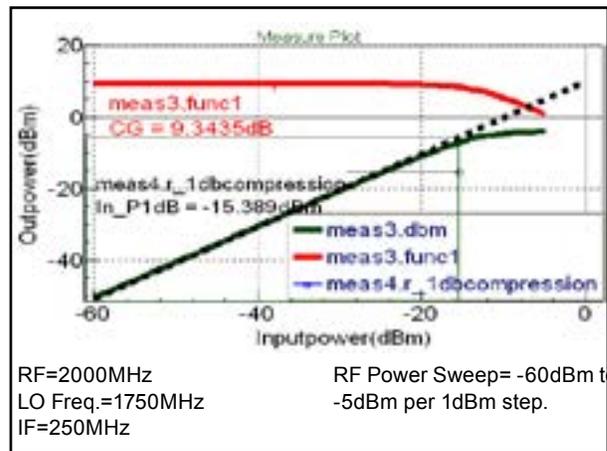| RF=2000MHz	RF Power Sweep= -60dBm to
LO Freq.=1750MHz	-5dBm per 1dBm step.
IF=250MHz	

Figure 5. 1dB Compression Point plot.

Third Order Intercept Point

The 3rd order intercept point (IP3) is an imaginary point where the desired output-product curve intersected with the curve of the third-order product. The greater the IP3 number means, the higher dynamic range of the mixer. The measurements can be provide by using the following statements:

.param f1=250meghz f3=254meghz
.SPECTRAL
+ FUND1=1750MegHz nharm1=5
+ FUND2=2000Meghz nharm2=5
+ FUND3=2002Meghz nharm3=5
+ ORDER=4
+ Solver=matrix_free_gmres
+ SWEEP prf -30dBm 0dBm 2dBm
.let spect_sp pout=r(@P3[pout])
.MEASURE SPECT_SP POUT_1 find pout at='abs(f1)'
.MEASURE SPECT_SP POUT_3 find pout at='abs(f3)'
.MEASURE MEAS IP3 IP3 POUT_1 POUT_3 EP=-11 gain=7

The simulation results are shown in Figure 6.

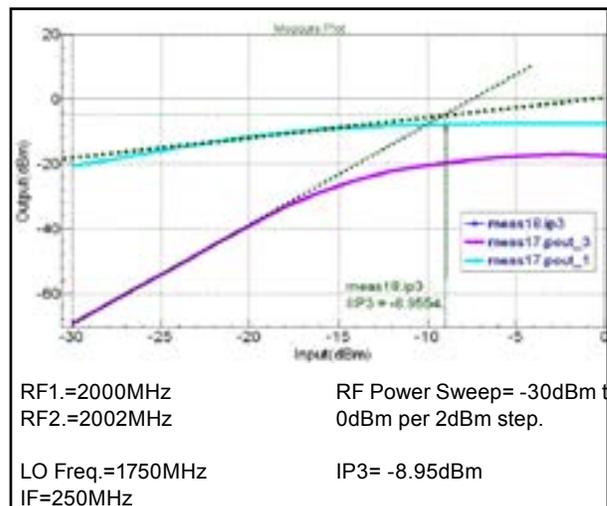| RF1.=2000MHz	RF Power Sweep= -30dBm to
RF2.=2002MHz	0dBm per 2dBm step.
LO Freq.=1750MHz	IP3= -8.95dBm
IF=250MHz	

Figure 6. Third Order Intercept Point plot.

Intermodulation Distortion

The Intermodulation Distortion (IMD) is manifested as additional unwanted circuit responses to one of the most strong signals in the circuit passband.

The measurement of the IMD products can be provide by using the following statements:

.param f1=250meghz f3=254meghz
.SPECTRAL
+ FUND1=1750MegHz nharm1=5
+ FUND2=2000Meghz nharm2=5
+ FUND3=2002Meghz nharm3=5
+ ORDER=4
+ Solver=matrix_free_gmres
.LET SPECT_SP
+Pout_dBm='(30.0+10.0*log10(0.5*mag(v(out))*mag(v(out))/100))'

The simulation results are shown in Figure 7.

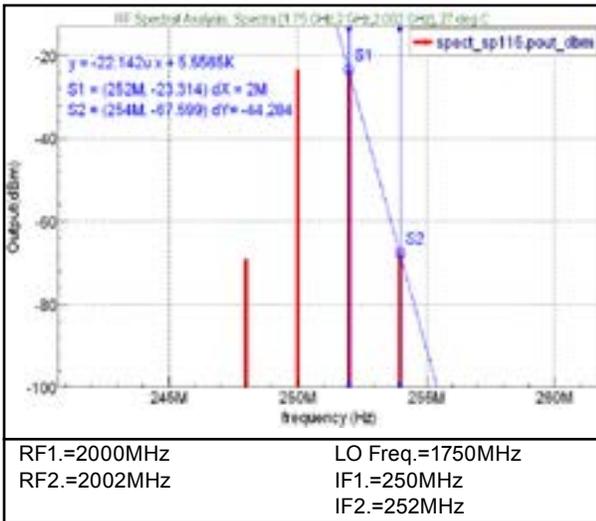| RF1.=2000MHz | LO Freq.=1750MHz |
| RF2.=2002MHz | IF1.=250MHz |
| | IF2.=252MHz |

Figure 7. Intermodulation Distortion plot.

Port-to-Port Signal Isolation

Port-to-Port signal isolation considers how much LO energy can appear at the RF or IF ports to create additional frequencies through unwanted mixing action and depends on mixer architecture.

The measurement can be provide by using the following statements:

.param prf=-30_dBm lo=0_dBm
.param f1=250meghz f3=254meghz
.SPECTRAL
+ FUND1=1750MegHz nharm1=5
+ FUND2=2000Meghz nharm2=5
+ ORDER=4

+ Solver=matrix_free_gmres
+ annotate=3

.LET SPECT_SP

+Pout_dBm='(30.0+10.0*log10(0.5*mag(v(out))*mag(v(out))/100))'

The simulation results are shown in Figure 8.

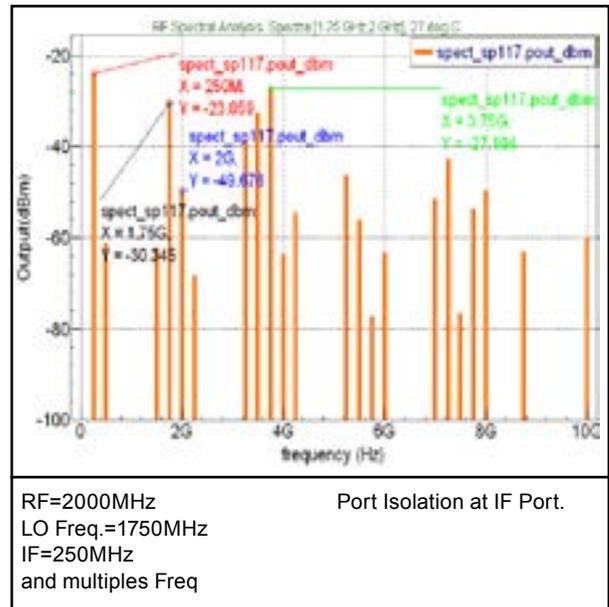| RF=2000MHz | Port Isolation at IF Port. |
LO Freq.=1750MHz	
IF=250MHz	
and multiples Freq	

Figure 8. Port-to-Port Isolation plot.

Transient analysis with IF low pass filter.

Block diagram of the mixer with IF low pass filter is shown in Figure 9.
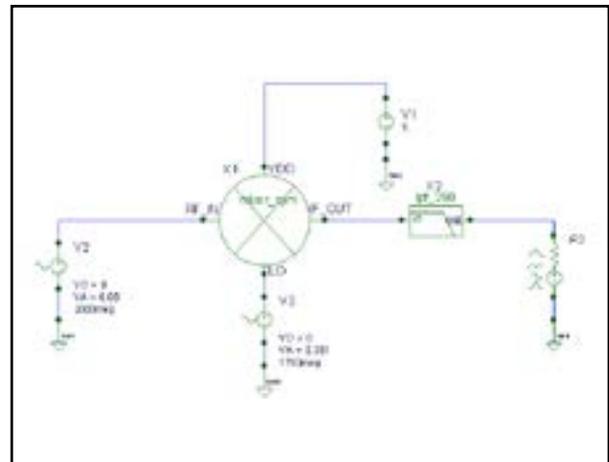

Figure 9. Mixer with Low Pass Filter Simulation setup.

The measurement of conversion gain can be provided by using statements:

.LET con_gain = db(rms(tran2.v(out))/rms(tran2.v(rf)))

The simulation results are shown in Figures 10 and 11.

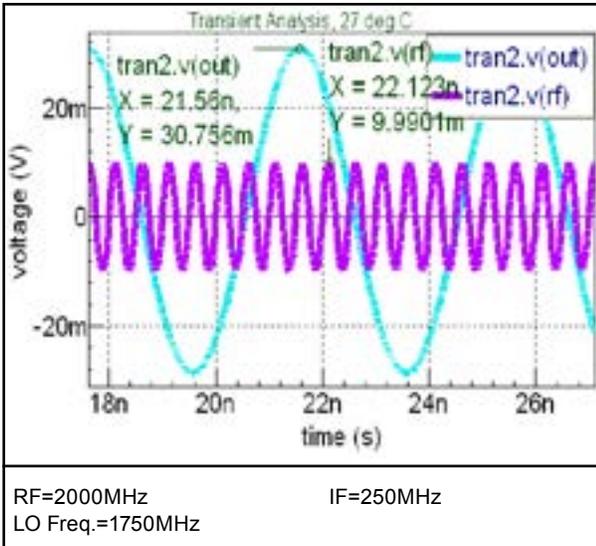|	
RF=2000MHz	IF=250MHz
LO Freq.=1750MHz	

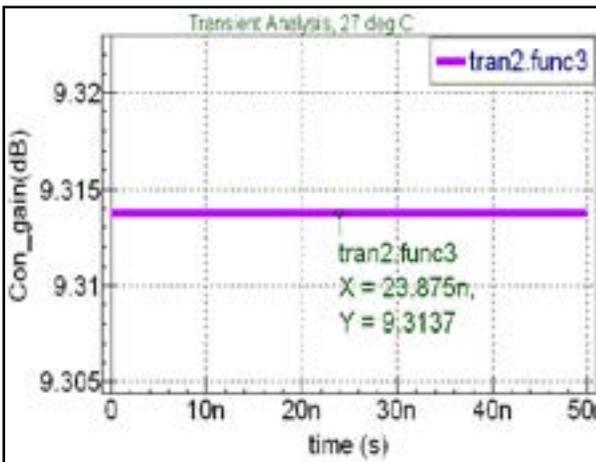Figure 10. Input-Output Waveforms plot.

Figure 11. Conversion Gain in time-domain plot.

Conclusion

This application note has described the basic setup for simulation and measurement for the building blocks of the transceiver design with SmartSpice RF.