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RF Mixer Metasystem Behavioral Model

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RF Mixer Metasystem Behavioral Model

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The SystemView mixer metasystem described below is based on measurements taken from a hardware I/Q Down-converter (**Figure 1**) module available from ELANIX, Inc. Although the model is based on measurements of the Mini-Circuits™ SRA1-1, a simple procedure is included to adapt the model to other mixers.

This Metasystem approximates the operation of an RF mixer over a reasonable range of input amplitudes. A controlled amount of noise, RF and LO port leakage is also present at the output. The metasystem in **Figure 2** works as follows: Each of the inputs to the mixer is passed through a Function Limiter. The limiter parameters Min Input and Max Output are set equal to each other to cause the token to operate as a clipping function. A signal with an amplitude less than the limit value will pass through unchanged while amplitudes larger than the limits are clipped. Each of the two clipping tokens are followed by a Polynomial token that gives an offset voltage to the signals, simulating less than perfectly matched diodes. These offset values determine the amount of LO and RF leakage present at the IF output. The amplitude of the RF signal is reduced by 0.5 dB before going into the multiplier token to simulate the transformer losses. The amplitude of the clipped LO signal is increased before going into the multiplier token. To be consistent with a hardware mixer that has a negative output when both inputs are the same phase, the multiplier output is inverted. A base value for the noise may be set, and this base value may be set up or down by entering a dB parameter in the gain token. The model has no provision to limit the mixer's frequency response. Another limitation of the model is the mixer performs mixing no matter how weak the LO becomes.

In these examples the mixer input frequencies are around 10.7 MHz. The SystemView sample rate is set to about 10 times the input frequency, 102.4 Mega-samples per second (MSPs) to be exact. This is necessary because the mixer's harmonics mix with the sampling rate frequency causing aliasing spurs down at the lower frequencies. Since the higher order spurs are lower amplitude, their aliasing effect is less visible. The use of power-of-two numbers avoids the bin-splitting effects when the FFT is performed and gives a cleaner display for this particular test. Setting the Freq. Res. parameter to a round number is helpful here when specifying the SystemView time values.

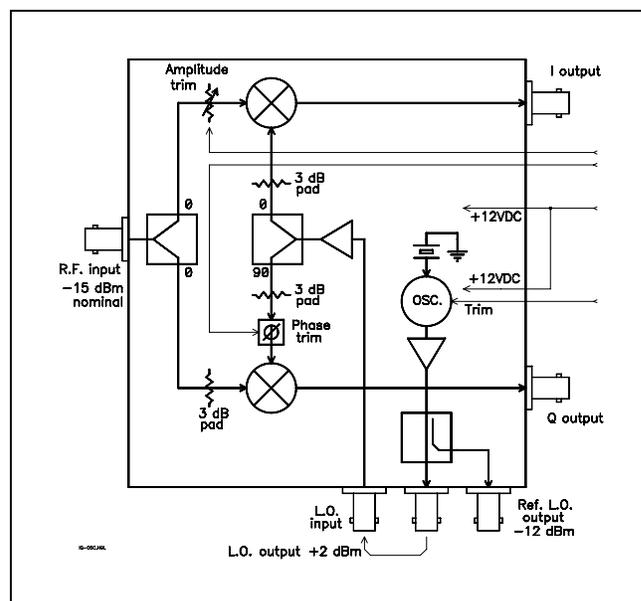


Figure 1. Block Diagram of the Elanix IQ-200-RF-10.7 MHz down-converter module.

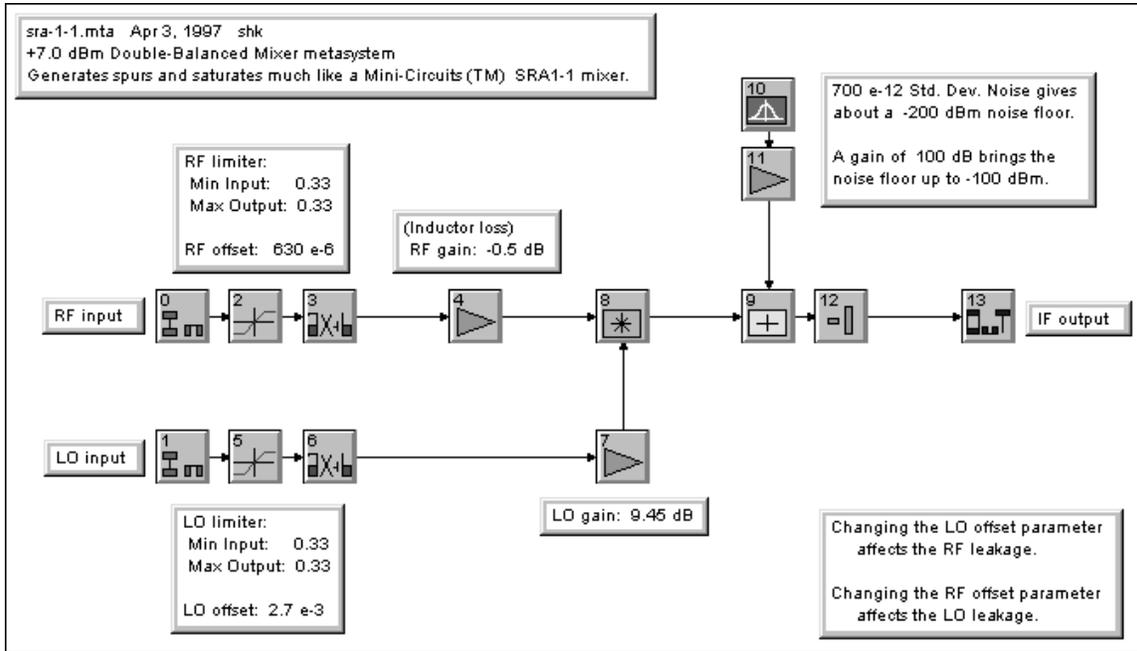


Figure 2. Mixer Metasystem (sra1-1.mta).

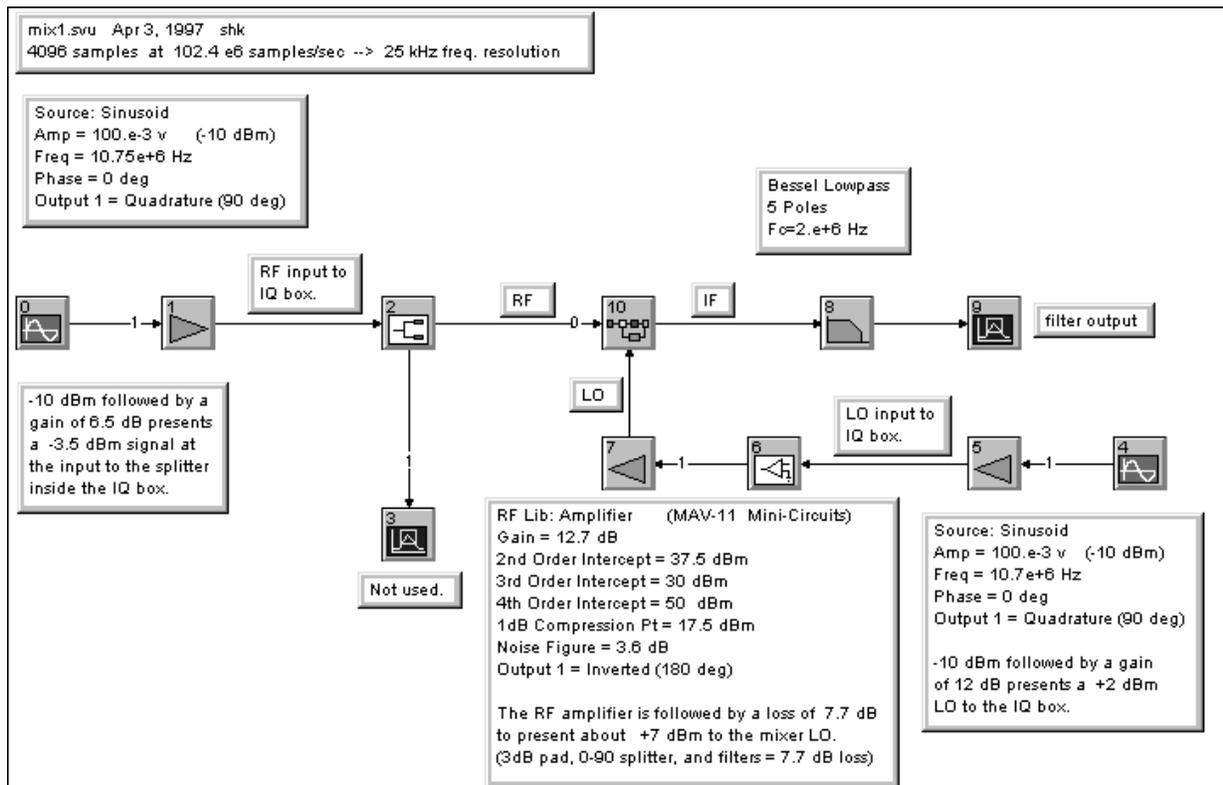


Figure 3. Mixer test system with normal amplitude inputs.

Figure 3 (mix1.svu) shows an amplitude test of a mixer being fed by two sine waves and its filtered output going to a sink for viewing. The parameters are set as follows:

RF and LO clipping voltage:	0.330 volts
RF port input:	-10 dBm
LO port input:	+7 dBm

The LO gain in the metasystem is adjusted to +9.45 dB to get an IF output of 56.5 mv zero-peak to match the hardware measurement.

The filtered output of the test system in **Figure 3** is plotted in **Figure 4**. Notice that with normal amplitude inputs the output is an accurate sinewave.

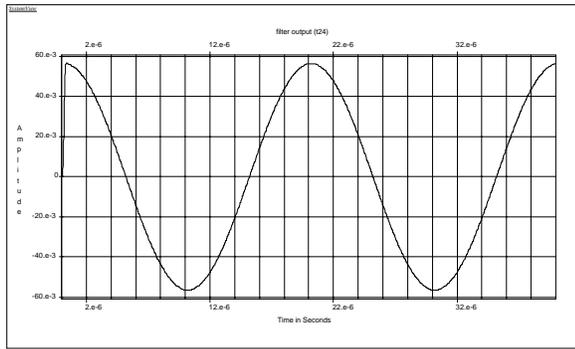


Figure 4. The IF output in Figure 3 is 56.5 mV zero-peak.

For the next test the amplitude at the RF port of the mixer in **Figure 3** was increased from -10 dBm to +8.2 dBm. This is done by changing the parameter of gain token 1 in **Figure 3** from 6.5 dB to 25 dB. This increases the zero-peak output to 246 mv, and the sinewave becomes triangular in shape (**Figure 5**). A portion of the example file mix2.svu is shown that uses the higher gain parameter (**Figure 6**). If a greater output is desired, go back to the mix1.svu system (the lower gain system) and increase both the RF and LO the clipping voltage. Then readjust the metasystem LO gain to the desired value in the mix1.svu test. Now repeat the mix2.svu test. An oscilloscope was used to make the hardware measurements in **Table 1**. The SystemView measurements were made using the parameters in the metasystem file sra1-1.mta.

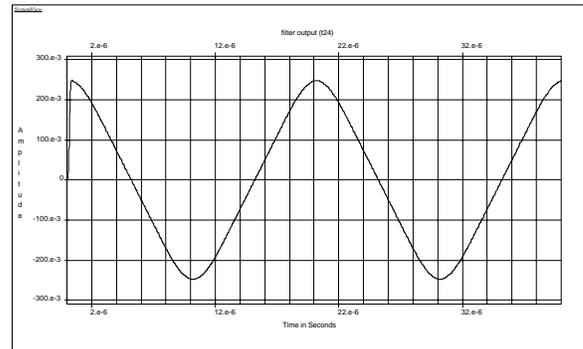


Figure 5. The IF output in Figure 5 is 246 mV zero-peak.

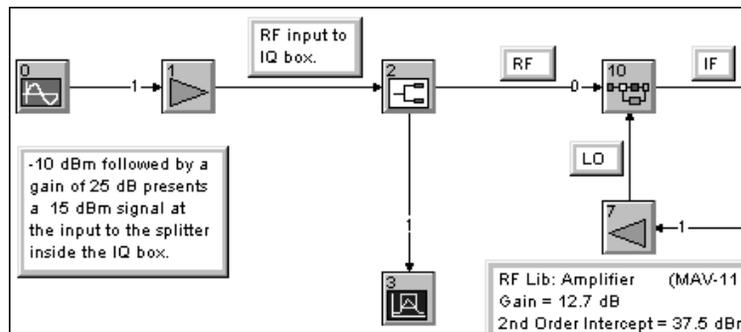


Figure 6. A portion of mix2.svu, the mixer test system with a high amplitude RF input.

Power input to the 0-0 deg splitter. (dB)	Power lost in 0-0 deg splitter and the 3dB pad. (dB)	Power input to the RF port. (dB)	Measured hardware filtered IF output zero-peak. (mv)	Calculated SystemView filtered IF output zero-peak. (mv)
-3.5	6.5	-10.0	56.5	56.5
+1.0	6.5	-5.5	95.0	95.0
+5.0	6.5	-1.5	150	150
+10.0	6.5	+3.5	223	223
+15.0	6.5	+8.5	246	246

Table 1. Measured and simulated mixer outputs with various input amplitudes.

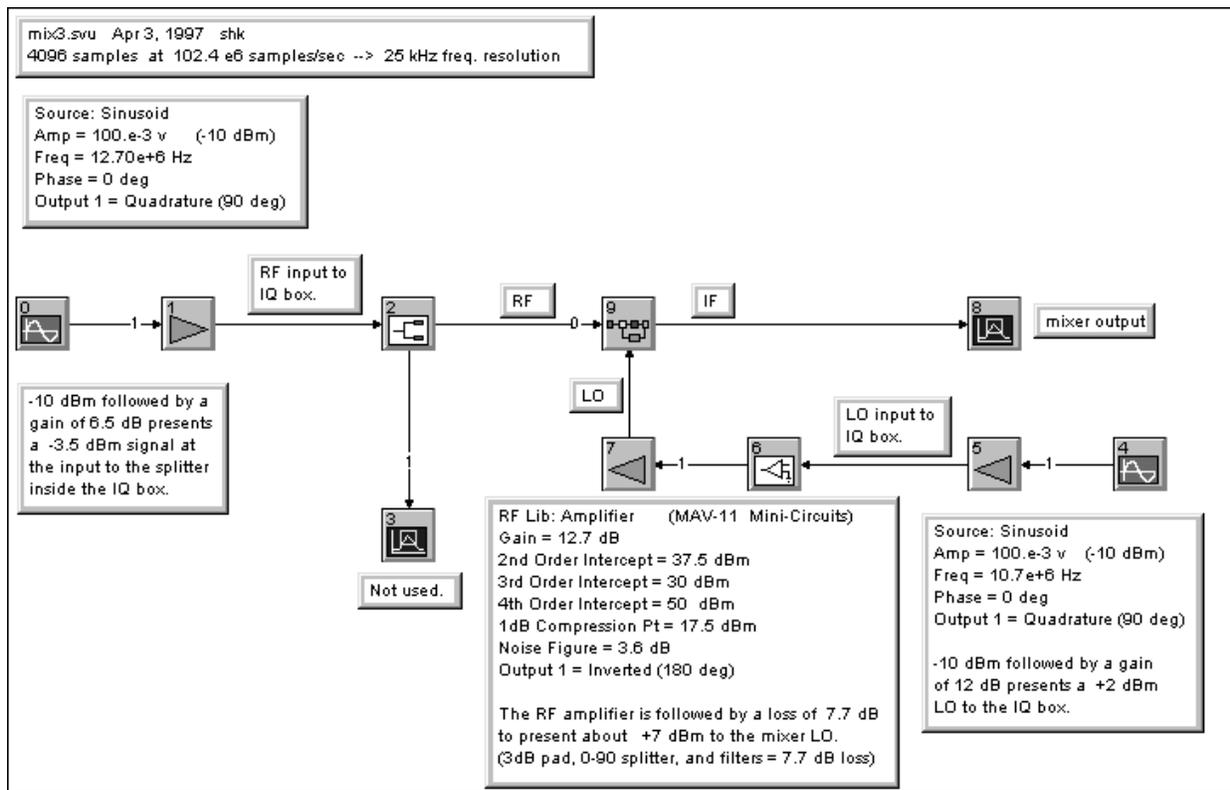


Figure 7. Mixer spurs test system, mix3.svu.

Now that the transfer function of the mixer has been established its time to examine the harmonics that are generated by the mixing process. The system in **Figure 7** is similar to **Figure 3** but, the RF frequency has been changed from 10.750 MHz to 12.700 MHz. Also, the lowpass filter has been removed. The LO frequency remains at 10.700 MHz.

Figure 8 shows the mixer spurs. The plot grid has been disabled to allow cleaner viewing. The two main sum and difference frequencies of 2 MHz and 23.4 MHz are each at -15 dBm. Notice the RF port leakage, -57 dB @ 12.7 MHz, and LO port leakage, -53 dB @ 10.7 MHz. In **Figure 9** the previous plot has been scaled by setting the Y-Axis Maximum to -9 dBm and the Y-Axis Minimum to -71 dBm. The amplitudes of the spurs closely match the measured spurs (within 2 dBm). When different amplitudes of RF and LO leakage are required they may be set as follows:

Adjust the RF offset parameter to get the desired LO leakage.

Adjust the LO offset parameter to get the desired RF leakage.

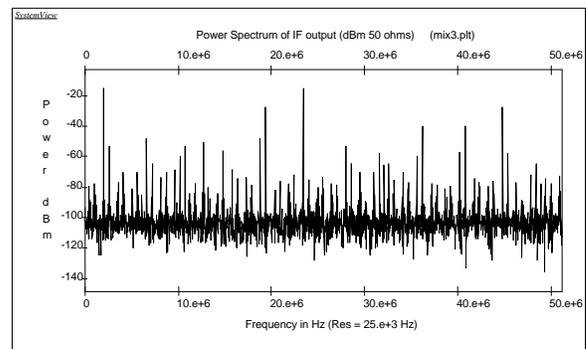


Figure 8. Mixer spur test system output.

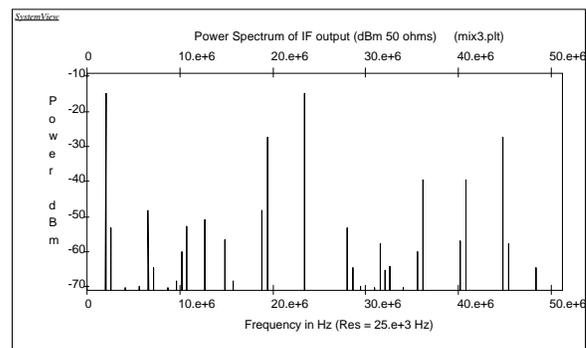


Figure 9. Mixer spur test system output, scaled.

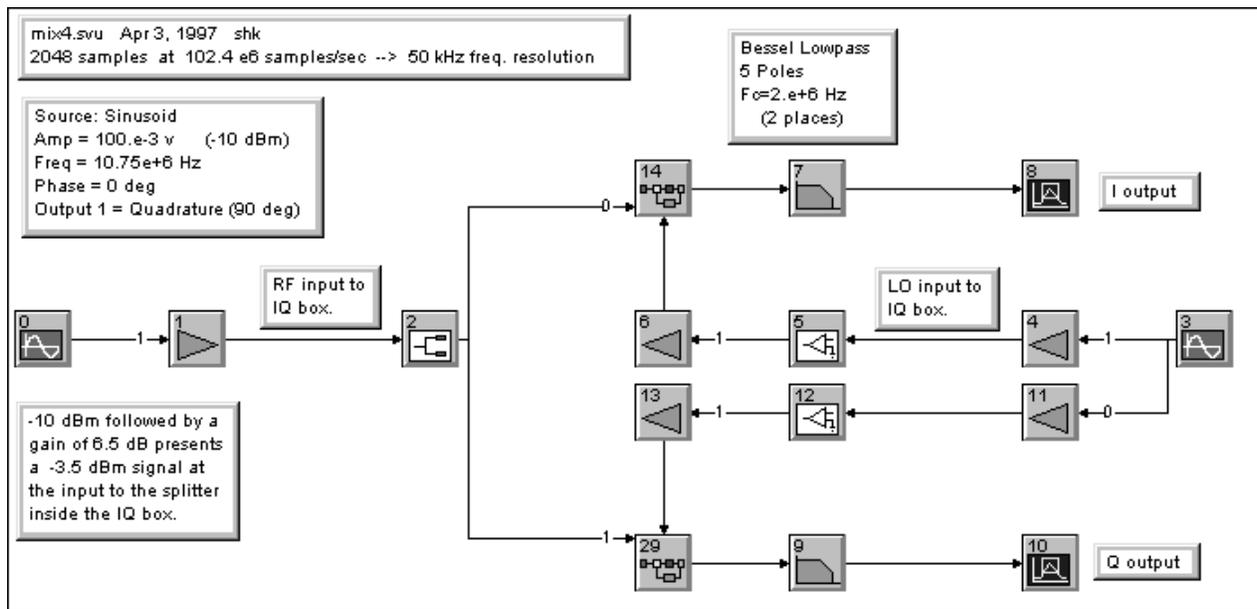


Figure 10. IQ Down converter system, mix4.svu.

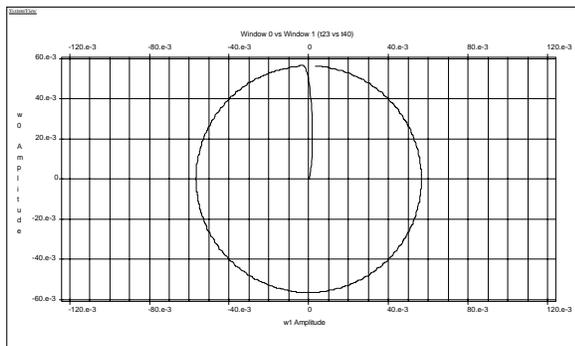


Figure 11. RF input to mixer is -10 dBm, scatter plot.

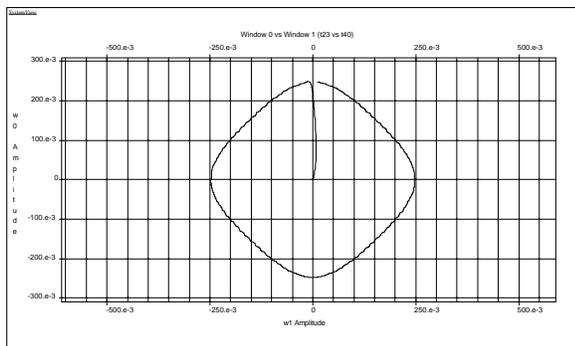


Figure 12. RF input to mixer is +8.5 dBm, scatter plot.

Figure 10 shows the SystemView model of an IQ down converter, with a pair of Bessel lowpass filters.

SystemView can also plot the X vs Y (Scatter Plot) as shown in **Figure 11**. Select Calculator, Style, Scatter Plot (default), w0:I output vs w1:Q output. With the RF input at a relatively low input power of -10 dBm the mixers are operating in a linear mode and produce a circular plot.

Figure 12 shows a diamond shaped plot when the input to the mixer's RF ports is raised to +8.5 dBm (+15 dBm input to the box instead of -3.5 dBm). In both cases the LO mixer ports are operated at +7 dBm.

More Information

For more information on SystemView simulation software please contact:

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Or visit our web home page (<http://www.elanix.com>) to download an evaluation version of the software that can these simulations as well as other user entered designs.

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