Mixer_JFET1.mcd. Mixer model with a JFET. Series shown is for a J310. The total current in mA is

$$12.35 + 11.2 \cdot u + 2.505 \cdot u^2$$

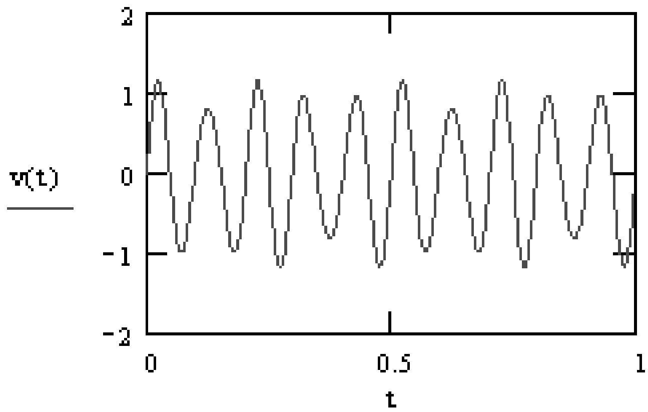
where u is the voltage relative to the bias value of -2. This was the expansion point for the Taylor series above, which we derived for the measured J310 with Vp=-4.2 and Idss=45 mA.

Let's now put some sinusoids into this. Consider a sum of two sine waves as the input, u.

$f_1 := 10$ $\quad f_2 := 14$ $\quad t := 0, .002 .. 1$ MHz and microseconds.

$\omega_1 := 2 \cdot \pi \cdot f_1$ $\quad \omega_2 := 2 \cdot \pi \cdot f_2$ $\quad k := 2.505$ $\quad L := 1$ $\quad r := 0.2$ k is coef of quadratic term.

$v(t) := \sin(\omega_1 \cdot t) + .2 \cdot \sin(\omega_2 \cdot t)$ The LO is 1 volt, with an RF of 0.2 volt.



Now we put the voltage into the terms of the current model.

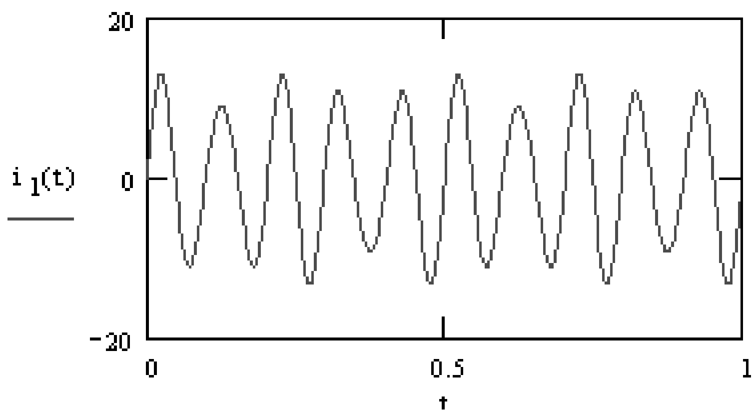
$$12.35 + 11.2 \cdot u + 2.505 \cdot u^2$$

The first term is just the bias current. There is no dependance on voltage.

The second term is the linear one. The linear current is then

$i_1(t) := 11.2 \cdot \sin(\omega_1 \cdot t) + 2.24 \cdot \sin(\omega_2 \cdot t)$ Define G as 11.2, a transconductance.

$i_1(t) = G \cdot L \cdot \sin(\omega_1 \cdot t) + G \cdot r \cdot \sin(\omega_2 \cdot t)$ $\quad G := 11.2$



With k=2.505, the coefficient of the 2nd order term, L=1, and r=0.2, the second order term becomes

$$k \cdot (L \cdot \sin(\omega_1 \cdot t) + r \cdot \sin(\omega_2 \cdot t))^2$$

$k \cdot L^2 \cdot \sin(\omega_1 \cdot t)^2 + 2 \cdot k \cdot L \cdot \sin(\omega_1 \cdot t) \cdot r \cdot \sin(\omega_2 \cdot t) + k \cdot r^2 \cdot \sin(\omega_2 \cdot t)^2$ The first and last terms yield harmonics and dc.

The viable trig idendity for the middle term is

$$\sin(x)\cdot\sin(y) = \frac{\cos(x-y)-\cos(x+y)}{2}$$

This will eventually produce the sum and difference frequencies.

And, for the end terms, $\sin(x)^2 = \frac{(1-\cos(2\cdot x))}{2}$

$$k\cdot L^2\cdot\sin\left(\omega_1\cdot t\right)^2 + 2\cdot k\cdot L\cdot\sin\left(\omega_1\cdot t\right)\cdot r\cdot\sin\left(\omega_2\cdot t\right) + k\cdot r^2\cdot\sin\left(\omega_2\cdot t\right)^2$$

$$k\cdot L^2\cdot\frac{\left[1-\cos\left[2\cdot\left(\omega_1\cdot t\right)\right]\right]}{2} + 2\cdot k\cdot L\cdot r\cdot\frac{\cos\left(\omega_1\cdot t-\omega_2\cdot t\right)-\cos\left(\omega_1\cdot t+\omega_2\cdot t\right)}{2} + k\cdot r^2\cdot\frac{\left[1-\cos\left[2\cdot\left(\omega_2\cdot t\right)\right]\right]}{2}$$

$$\frac{1}{2}\cdot k\cdot L^2 - \frac{1}{2}\cdot k\cdot L^2\cdot\cos\left(2\cdot\omega_1\cdot t\right) + k\cdot L\cdot r\cdot\cos\left(-\omega_1\cdot t+\omega_2\cdot t\right) - k\cdot L\cdot r\cdot\cos\left(\omega_1\cdot t+\omega_2\cdot t\right) + \frac{1}{2}\cdot k\cdot r^2 - \frac{1}{2}\cdot k\cdot r^2\cdot\cos\left(2\cdot\omega_2\cdot t\right)$$

$$\frac{1}{2}\cdot k\cdot L^2 - \frac{1}{2}\cdot k\cdot L^2\cdot\cos\left(2\cdot\omega_1\cdot t\right) + k\cdot L\cdot r\cdot\cos\left[\left(\omega_2-\omega_1\right)\cdot t\right] - k\cdot L\cdot r\cdot\cos\left[\left(\omega_2+\omega_1\right)\cdot t\right] + \frac{1}{2}\cdot k\cdot r^2 - \frac{1}{2}\cdot k\cdot r^2\cdot\cos\left(2\cdot\omega_2\cdot t\right)$$

This is the result of just the 2nd order term in the expansion and shows outputs at DC, the second harmonic of the RF, second harmonic of the LO, difference frequency, and sum frequency.

The linear term contributes $i_1(t) = G\cdot L\cdot\sin\left(\omega_1\cdot t\right) + G\cdot r\cdot\sin\left(\omega_2\cdot t\right)$ mA.

The original bias was 12.35 mA. So, the current spectra becomes:

DC: $12.35 + \frac{1}{2}\cdot k\cdot L^2 + \frac{1}{2}\cdot k\cdot r^2 = 13.6526$ (A slight change, a "detection" of the LO and RF.)

4 MHz:	$k\cdot L\cdot r = 0.501$	-8 dBm
10 MHz:	$G\cdot L = 11.2$	18.9 dBm
14 MHz:	$G\cdot r = 2.24$	5 dBm
20 MHz:	$\frac{1}{2}\cdot k\cdot L^2 = 1.2525$	-0.1 dBm
24 MHz:	$k\cdot L\cdot r = 0.501$	-8 dBm
28 MHz:	$\frac{1}{2}\cdot k\cdot r^2 = 0.0501$	-28 dBm

Now that we have a current spectra, let's put a load in the drain of the FET. We will start with 50 Ohms, but use a ferrite transformer with a turns ratio of 5:1. This will create a drain load of 50*25 = 1.25K-Ohms. The current in the load will be 5 times that shown (except for DC.) Now, we will calculate the powers in dBm.

Note that the output at the LO frequency is nearly enough to drive the device into saturation.

Assume that the input gate was terminated in 50 Ohms and that the LO and RF were applied to that. Then, there is a net conversion loss. The RF signal was 0.2 v peak, or -4 dBm. The conversoin gain is then -4 dB. Moreover, the conversion gain is about 13 dB below the linear gain. This is less than our earlier 12 dB rule of thumb, but this LO drive is less than optimum. More LO of 2 v peak would produce higher conversion gain with no change in linear gain.