UNIVERSITY OF OULU

FACULTY OF INFORMATION TECHNOLOGY AND ELECTRICAL ENGINEERING

521402S Telecommunications Circuit Design

Simulation exercise #03

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1. Explaining the meaning of the voltage sources in the test bench.

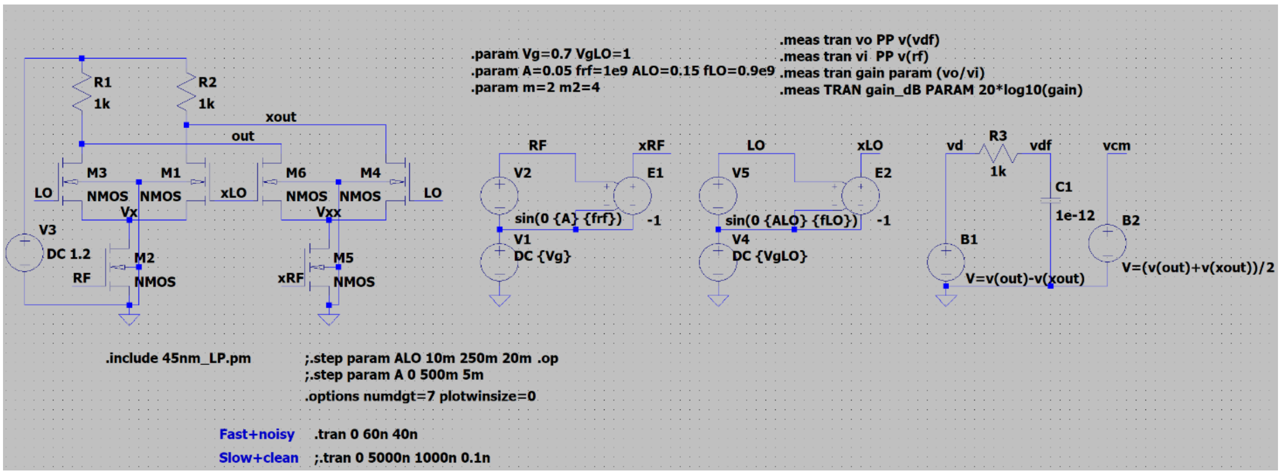

Figure 1. The provided testbench (.meas are modified and stepping expressions)

- V3 provides the supply voltage for the mixer (Vdd).
- V1 provides the DC bias for the RF transistors (Common mode RF signal) whereas V2 and E1 provide differential RF signal to switch the tail current in each mixer branch.
- V4 provides the DC bias for the LO transistors (Common mode LO signal) whereas V5 and E2 provide differential LO signal to steer the current between the two paths in each mixer branch.
- B1 results in the differential output signal whereas B2 results in the common mode output signal.

2. Studying the drain current in M1, M2, M3 and explaining how the mixer operates.

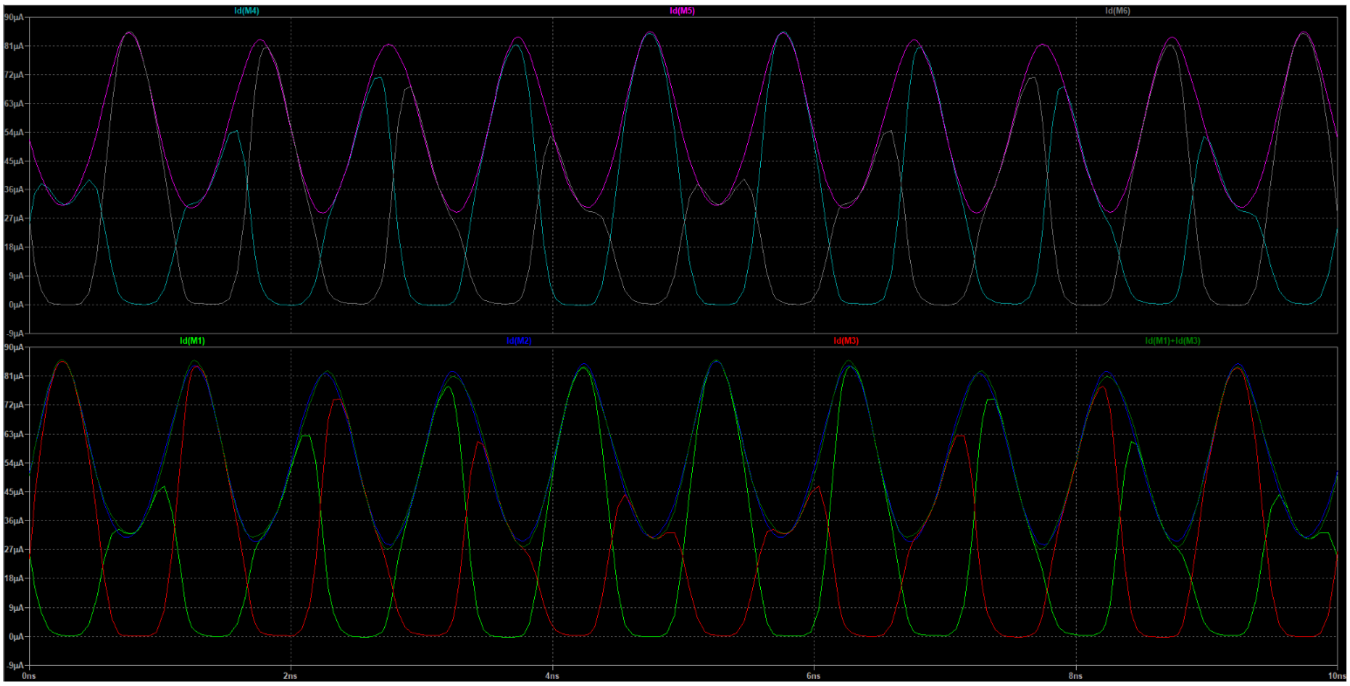
Figure 2. M1, M2, M3 and M4, M4, M6 drain currents

M2 drain current is fixed around 50 µA (due to RF bias) and it's modulated by the applied RF signal. This current is steered between M1 and M3 due to the applied differential LO signal. Since the LO signal doesn't have the same frequency/phase as RF signal, the current is not steered equally between M1 and M3, but their sum always equals to M2 drain current (M1 and M3 constitute a differential pai and M2 is the tail current for it). The same is happening for the differential pair formed by M4, M6, and its tail current is controlled by M5 but in opposite phases.

Since the bias current is modulated by the RF signal and the switching quad transistors' drain currents (M1, M2, M6, M4) is also modulated by the LO signal, the drain voltages of the quad contain RF and LO frequencies and their mixing products and by taking a differential output we can extract the signal of interest.

3. Checking the waveforms in RF, LO, s1, s2, out, xout.

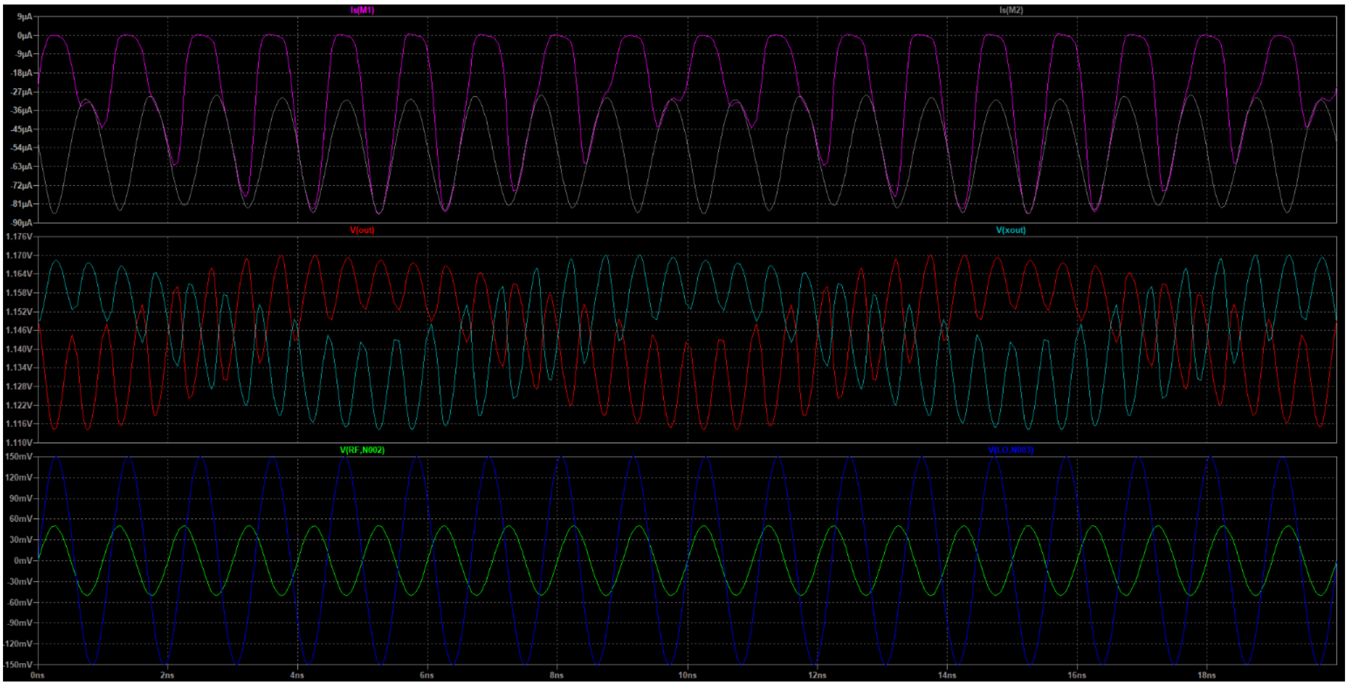

Figure 3. RF, LO, s1, s2, out, xout waveforms

Using the FFT operation, checking the strongest frequency components in node voltages and marking them.

Node	Frequency(s) [MHz]	Amplitude [dBV]
M3.d, M6.d, out	100	-38.57
M1.d, M4.d, xout	100	-38.57
M2.d, M1.s, M3.s, Vx	1800	-31.75
M5.d, M4.s, M6.s, Vxx	1800	-31.75
vLO	900	-19.51
vRF	1000	-29.08
vCM	1800	-55.22
vDF	100	-34.2

4. Measuring and documenting the conversion gain.
   Without enabling the stepping of LO amplitude (A_{LO}=0.15V), the conversion gain is -4.7 dB.
5. Sweeping LO amplitude and plotting conversion gain vs. LO mag

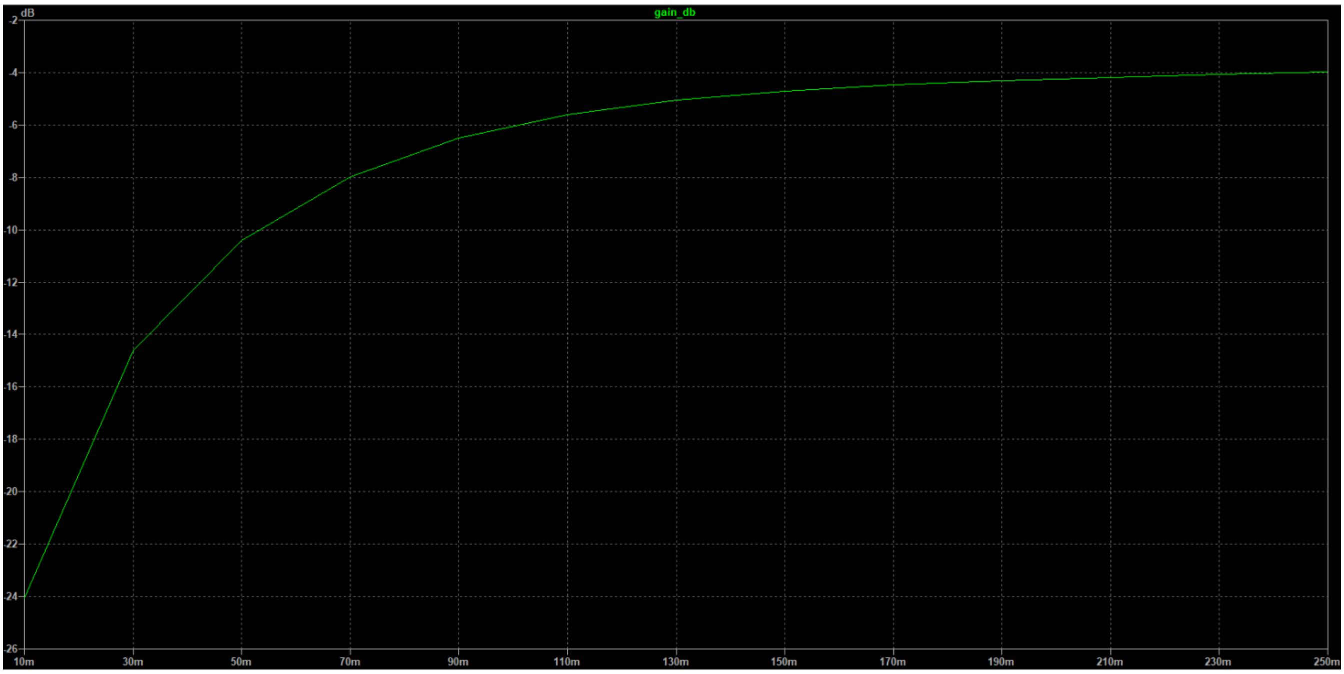

Figure 4. Conversion gain vs. LO amplitude

6. Selecting conversion gain (in fact loss) depends on the overall performance of the mixer when considering the noise, LO and RF feedthrough and harmonics requirements and the LO port compression. Since the conversion gain saturates at -4 dB with around 230 mV of LO amplitude, selecting a bit lower LO amplitude would be acceptable like 200mV.

7. Sweeping RF amplitude and plotting conversion gain vs. RF mag

The second stepping command is uncommented in Figure 1. The maximum achievable conversion gain is -4.15 dB and the 1dB compression point happens at 212.73 mV of RF amplitude.

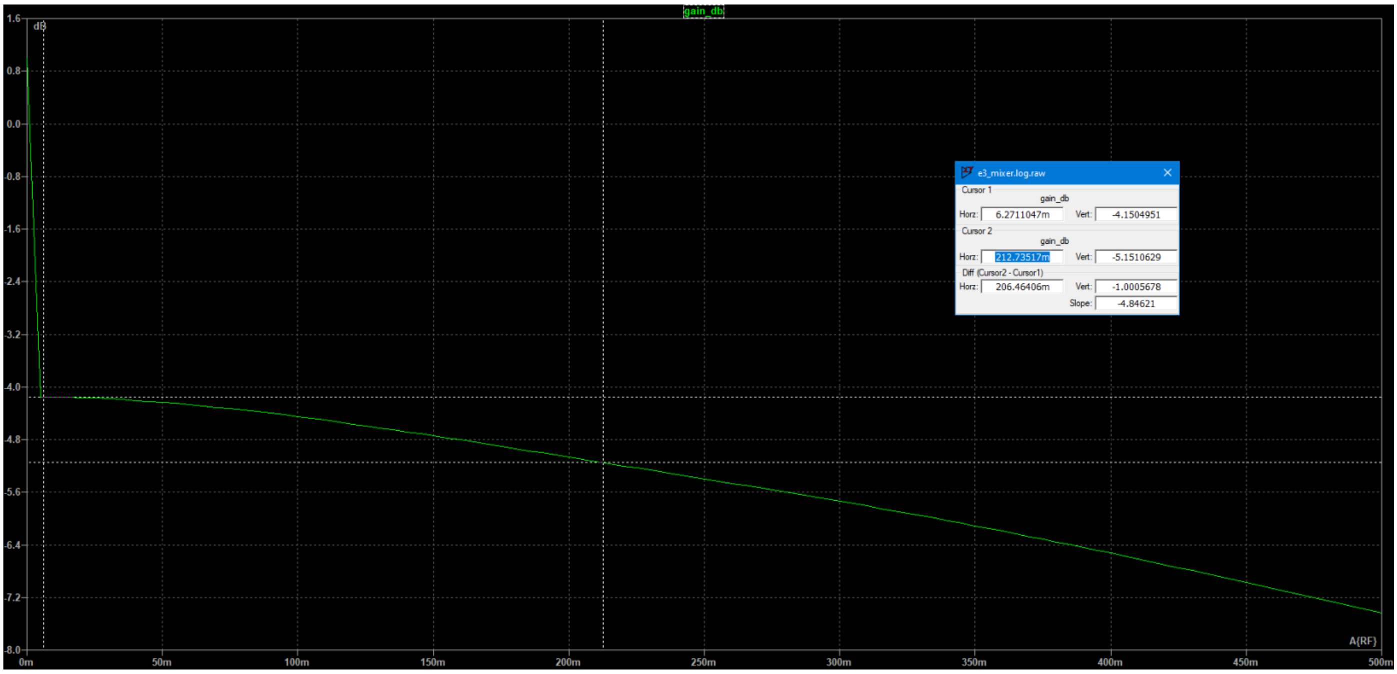

Figure 5. Conversion gain vs. RF amplitude

8. Modifying the test bench for IIP3 simulation.

   The test bench can be modified for IIP3 simulation by adding another voltage source (V6 in Figure 6), and the frequencies for V2 and V6 where set such that they lay on the same side of the center frequency of operation (2GHz) and they have the same spacing (V2 having 1.010 GHz and V6 having 1.020 GHz sinwave with the same amplitude).

   IIP3 is calculated by: IIP3 = (input signal level) + 0.5(Level difference to OP3 products)

   Then OIP3 is derived by referring IIP3 to the output (i.e multiply by the gain).

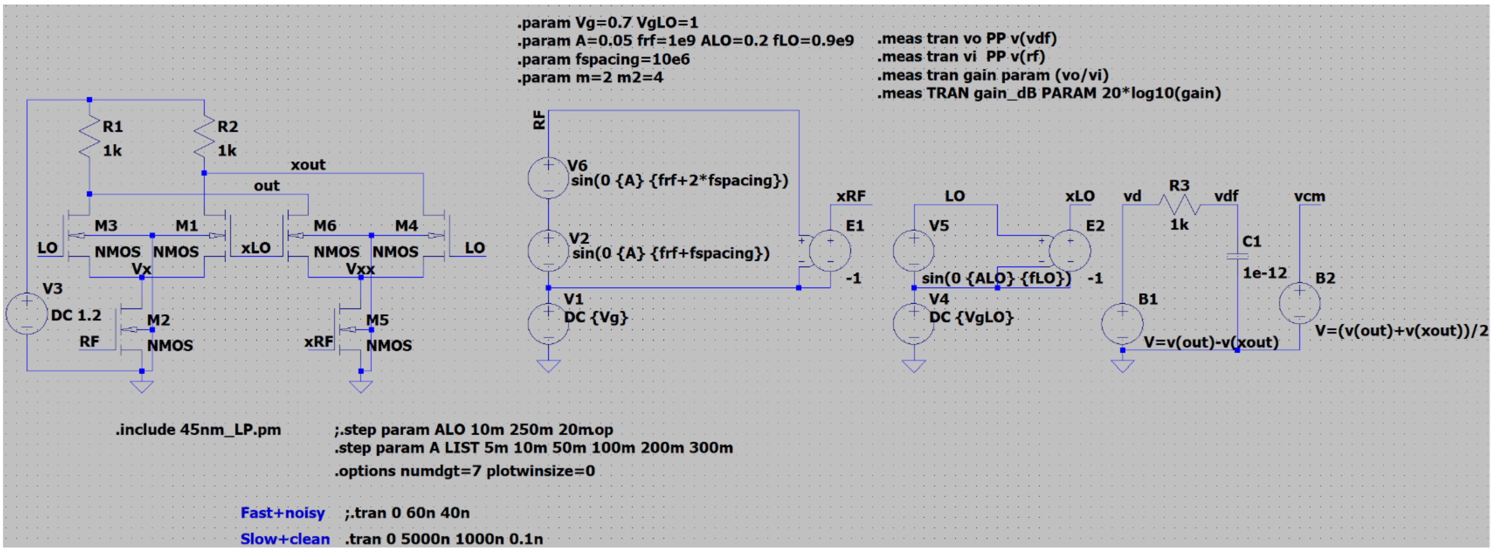

Figure 6. IIP3 test bench

Figure 7 shows the FFT of the output signal with markers set to A=50mV (level of input tones). Here the calculation are using dBV (not power “dB/dBm”)

IIP3 = (-29.10) + 0.5(19.67)= -19.265 dBV =108.83 mV

It would be much easier if one could use the .meas statements with the FFt to extract the IIP3 plot.

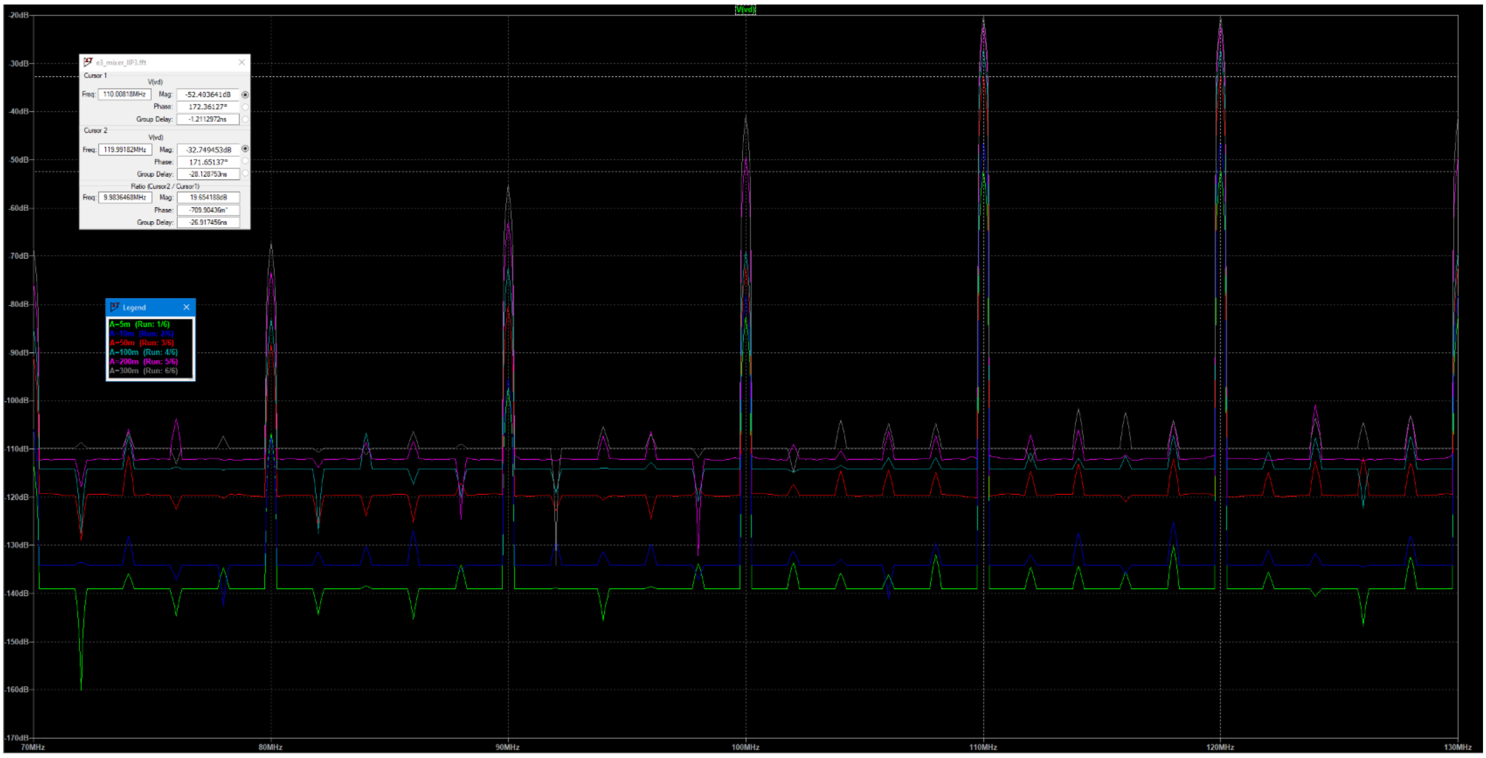

Figure 7. FFT of output in IIP3 test bench