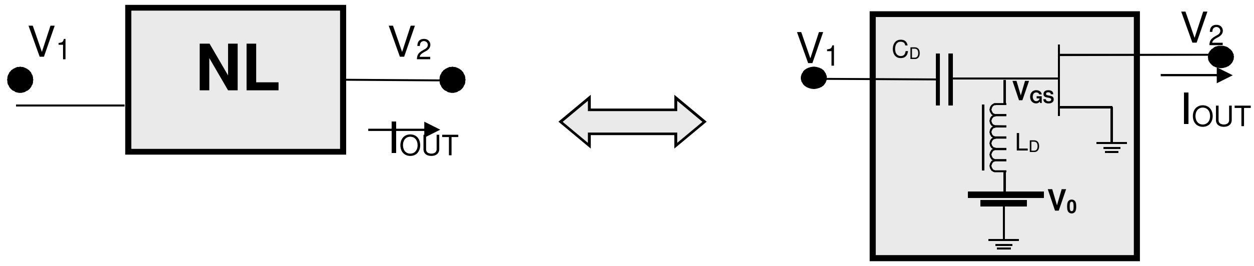
Tutorial (SEM cold-FET Mixer)

The following cold-FET mixer (biased @ V_{DS0}=0 V) is used to design a SEM up-converter where the LO signal V_1 is applied to the gate, which is biased @ ($V_{GS0}= V_0$) while the IF input signal is applied to the drain using a low-pass filter and the output signal is extracted at the drain port using a high-pass filter.



The nonlinear operation of the cold-FET (NL) is expressed by the 2 following equations that give the output current I_{OUT} as a function of input and output control voltages V_1 and V_2:

$$V_{GS} = V_0 + V_1 \quad \textbf{(eq1)}$$ where V_0 is a constant (gate bias voltage)

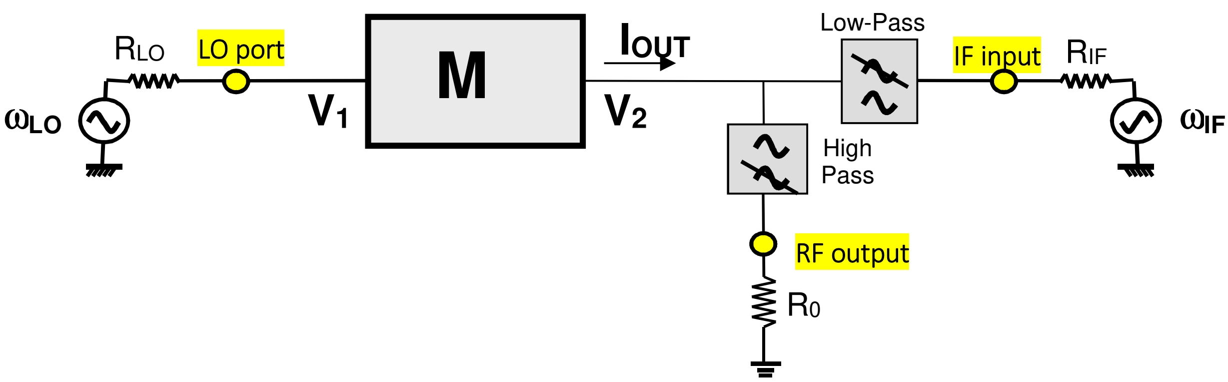
$$I_{OUT} = p\, V_2 - q\, V_2\, V_{GS}^2 + r\, V_1 \quad \textbf{(eq2)}$$ where p , q and r are constants

The SEM cold-FET mixer is shown below and the main frequencies are :

f_{LO}= 9 GHz , f_{IF}= 0.5 GHz et $f_{RF} = f_{LO} + f_{IF}$ = 9.5 GHz ($\omega_{RF} = \omega_{LO} + \omega_{IF}$).

The two control voltages V_1 and V_2 of the FET mixer are :

- LO voltage at gate port : $V_1 = V_{LO} \cos(\omega_{LO} t)$ **(eq3)**
- IF voltage at drain port : $V_2 = V_{IF} \cos(\omega_{IF} t)$ **(eq4)**



1) Using equations 1 to 4, express the output current I_{OUT} as a function of signal magnitudes (V_{LO}, V_{IF}), nonlinearity constants (p, q, r), gate bias V_0 and the mixing frequencies. The following notations can be used for mixing frequencies: $\omega_{IM}=(\omega_{LO} - \omega_{IF})$; $\omega_1=(2\omega_{LO} - \omega_{IF})$; $\omega_2=(2\omega_{LO}+\omega_{IF})$

2) The high-pass filter is designed to reject frequencies lower than 5GHz while the low-pass frequency is designed to cut frequencies greater than 5GHz. Therefore, what are the mixing frequencies at the RF output port?

3) Determine the expression of the voltage conversion gain G_{CV}.

4) If the LO port is assumed to be matched to R_{LO},
   a) express the LO power applied at the LO port
   b) express the LO power at the RF output port
   c) express in dB the LO-to-RF isolation
   d) what is the LO-to-IF isolation ?
   e) express the equivalent impedance Z_{IN} seen by the IF generator @ ω_{IF} at the IF input port