Homework 6
Due 10/21/2016 5pm in the Phillips Hall Dropbox

Reading before homework:
- Lecture summary on Gain Modules, Noises and Nonlinearity
- Egan's book, Chaps 3 and 4.
- Simulink tutorial

1. (**Three modules in cascade for noise figures**) Given three unilateral and impedance-match gain modules: M1 has $g_1 = 10$dB and $F_1 = 3$dB; M2 has $g_2 = 20$dB and $F_2 = 10$dB; M3 has $g_3 = 20$ dB and $F_3 = 20$ dB. Calculate the noise figure in dB for the following cascade when all of the noises are referred (lumped) to the source side. In comparing the cases of (a) and (c), take a note how small the difference of the cascade noise figures.
    - (a) M1-M2-M3 (**5 pts**)
    - (b) M2-M1-M3 (**5 pts**)
    - (c) M1-M3-M2 (**5 pts**)

2. (**Noise sources**) You make noise measurements for a given MOSFET and obtain the following table. What statement(s) are true? (**10 pts**)

Frequency range	1kHz – 2kHz	10kHz – 11kHz	101kHz – 102kHz	1001kHz – 1002kHz
Noise power	−124 dBm	−133 dBm	−145 dBm	−144 dBm

   - (a) Only thermal noise is dominant over the entire range.
   - (b) Shot noise does not exist here.
   - (c) We can use the measurements above 10kHz to estimate the device temperature.
   - (d) The flicker noise has a corner frequency f_c around 1kHz.
   - (e) The flicker noise can be ignored in 100kHz.

3. (**IIP3 calculation**) For a power amplifier with 20dB gain, IIP3(IM) = 30 dBm and $IIP_{H2} = 20$dBm,
   - (a) Give OIP3(IM), IIP_{H3}, OIP_{H3}, OIP_{H2}, IIP_{IM2}, and OIP_{IM2} (**12 pts**)
   - (b) At an input level of $p_{in1} = 10$dBm, give p_{H2}, p_{H3} and p_{IM3}. (**6 pts**)
   - (c) At an input level of $p_{in1} = -10$dBm, give p_{H2}, p_{H3} and p_{IM3}. (**6 pts**)
   - (d) If we need $p_{H2} = 10$dBm out of the power amplifier, what is the input level p_{in1} is needed? What would be the minimal power consumption for the power amplifier assuming 50% output efficiency? (**6 pts**) Output efficiency is defined as the ratio of total output power and total power consumption.

4. (**Simulink**) Follow the Simulink tutorial, build an RFID transmitter as described below. (**45 pts**)
   First model a sine wave source with added phase noise, and view the signal spectrum with a spectrum analyzer module. Requirements: (1) signal source frequency: 915MHz; (2) Amplitude of output signal: 0.1V; (3) Phase noise level -60dBc/Hz @ 100Hz offset. (4) Spectrum frequency resolution: < 1MHz between 890MHz and 940MHz.

   For the PA, model AM to AM and AM to PM nonlinearity. Configure as following. Method: Cubic Polynomial; Linear Gain: 22dB; IIP3: 50dBm; AM/PM: 10 degrees per dB; Lower Input Power Limit for AM/PM Conversion: 20dBm; Upper Input Power Limit for AM/PM Conversion: 50dBm; Noise Figure: 5dB.

   Insert three filters using Digital Filter Design blocks in the library. For the first two filters before PA, use IIR Butterworth filter with the following configurations. Pass Band: 900 to 930 MHz 0dB; Stop band edge 1: 860MHz; Stop band edge 2: 950MHz; Stopband attenuation: 20dB; For the third filter

connected to the PA output, use IIR Elliptic filter and the following configurations. Pass Band: 900 to 930 MHz 0dB; Stop band edge 1: 895MHz; Stop band edge 2: 935MHz; Stopband attenuation: 50dB.

Adjust PA output power to be 30dBm for a 50 Ohms resistor and add a power meter in your system to display the power level (use Display block in Simulink library, you may also need to use dB-Conversion block).

In your homework, submit your system block diagram, the spectrum for the signal at the output of PA and at the output of the filter connecting to the output of the PA. You also need to submit the time domain signal at PA output. (Please remember that you need to simulate the transmitter together with the signal source created in your first homework).

In the signal spectrum at PA output, observe second and third harmonic signal. Reduce IIP3 to 38dBm, compare the third harmonic amplitude with previous simulation results.