Homework 3

ECE 5/413 – Radio Frequency IC Design

Problem 1: Noise Measure

1. Consider an infinite cascade of idential two-ports with individual noise factor F_i and power gain G_i. Show that the overall noise factor F of the inifinite cascade of identical two-ports converges to $F = 1 + \frac{F_i - 1}{1 - \frac{1}{G_i}}$.

2. A quantity **noise measure** M is now defined as $M_i = \frac{F_i - 1}{1 - \frac{1}{G_i}}$.
   Prove that if you have two amplifiers with F_1, G_1 and F_2, G_2, it is always better to put the amplifier with lower noise measure first in a cascade. **Hint:** Start with $M_1 < M_2$ and show that $F_{1-2} < F_{2-1}$.

3. A single-stage LNA has $NF_{min} = 1.4dB$ and $G = 7dB$. By using some circuit tricks the noise figure has improved to $NF_{min} = 1.2dB$ and $G = 5dB$. Show that the noise measure hasn't changed.

4. Repeat **HW2 Problem B1** to find the order of cascade for the least overall noise figure using the noise measure concept (ignore IIP_3 calculations).

Problem 2: Link Budget
A wireless link is to be designed for your future home theatre system operating at 60GHz. The link employs 16-QAM modulation over a line-of-sight distance of 10m and transmits at a rate of 4Gbps occupying a bandwidth of 1GHz. Calculate the minimum transmitter power P_{TX} needed for a link margin of 22dB at the receiver.
The receiver noise figure is $NF = 7dB$, and the transmit and receive antenna gains are $G_{TX} = G_{RX} = 8dBi$ each. The SNR required for the 16-QAM modulator for a BER$= 10^{-6}$ is 21dB.

Problem 3: Calculate the rms noise at room temperature (293K) for :

1. Resistors (a) $R = 50\Omega$ and (b) $R = 10k\Omega$ over a bandwidth of 1 MHz.

2. RC low-pass filters with $R = 1k\Omega$, (a) $C = 0.1pF$ and (b) $C = 10pF$.