ECEG 497 **Wireless System Design** **Spring 2025**

Homework Assignment #7 – due via Moodle at 11:59 pm on Monday, Apr. 14, 2025

***Instructions, notes, and hints*:**

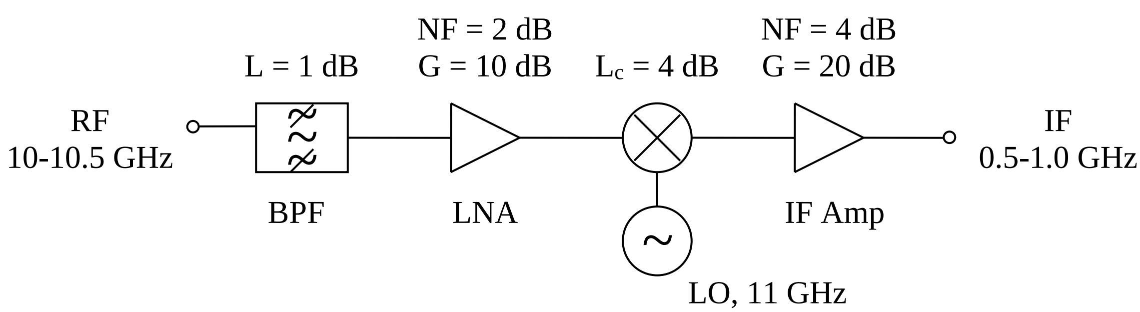
You may make reasonable assumptions and approximations to compensate for missing information, if any. Provide the details of all solutions, including important intermediate steps. You will not receive credit if you do not show your work.

The first set of problems will be graded and the rest will not be graded. Only the graded problems must be submitted by the deadline above. Do not submit the ungraded problems.

***Graded Problems*:**

1. The receiver front end shown below operates at the standard temperature (290 K). Find:

- **a.** The overall noise figure in decibels. Assume that the stages beyond the IF amp contribute little to the total system noise figure.
- **b.** The minimum discernable signal (MDS) in dBm using the standard input noise definition. Assume that an output SNR of 0 dB is required to detect the signal.
- **c.** The spurious-free dynamic range (SFDR), if the input third-order intercept ($IP3_{in}$) is +2.5 dBm and the input 1 dB compression point (P_{1dB}) is –7.0 dBm.



2. Suppose that the LNA is removed from the receiver front end considered in the previous problem. As a result, the value of $IP3_{in}$ rises to +13.2 dBm, and the value of P_{1dB} rises to +3.7 dBm. Repeat the calculations in the previous problem for the new front-end configuration. Identify the parameters that have improved, and those that have degraded. Which changes do you think are significant?

3. An FM broadcast receiver is subjected to a "two-tone" test with two strong equal-amplitude sinusoids at the frequencies f_1 and f_2, where $f_1 < f_2$. The third-order IMD products that are produced appear at the frequencies f_1, f_2, $2f_1 - f_2$, $2f_2 - f_1$, $3f_2$, and $3f_2$ (in increasing value). The FM broadcast band spans 88–108 MHz. If f_1 = 92 MHz, find the value that frequency f_2 must have so that the first four third-order products listed above appear within the FM band.

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4. A certain amplifier has the following specifications, some of which are determined using a two-tone IMD test in a laboratory environment in which external noise has been minimized:

Input and output impedance: 50 Ω
Input and output filter pass-bands: 500–1000 MHz
Gain: 10 dB (assume constant within the filter pass-band)
Noise figure: 5.0 dB
Third-order output intercept point: +40 dBm
1-dB compression point: +30 dBm

- **a.** A minimum output SNR of 0 dB is required for the application in which the amplifier is to be used. Find the spurious-free dynamic range (SFDR) of the amplifier (in dB) under the same conditions as in the two-tone test.
- **b.** Find the blocking dynamic range in dB.
- **c.** Repeat parts a and b for the case when the input and output filter pass-bands are reduced to 800–900 MHz.

Ungraded Problems:

The following problems will not be graded. However, you should attempt to solve them on your own and then check the solutions. You will be responsible for knowing the material referred to in these problems.

1. [partially adapted from a problem in J. F. White, *High Frequency Techniques*, 2004] A new amplifier module that has a 1.0 dB noise figure and 20 dB of gain is being tested. The bandwidth of the amplifier is specified as 800–1000 MHz. A spectrum analyzer is connected to the output of the amplifier and two signal generators to the input through a hybrid combiner in preparation for a two-tone test. With the generators set to 900 and 910 MHz and the same amplitudes, you observe that when the output power of the 900 and 910 MHz signals is 0.1 mW (−10 dBm) each, a new signal appears at 890 MHz that is just at the level of the output noise. Find:

- **a.** The output third-order intercept of the amplifier.
- **b.** The minimum discernable signal (MDS) defined for zero input noise and an output SNR of 0 dB.
- **c.** The spurious-free dynamic range (SFDR).

2. Expand the expression below, and apply trigonometric identities to the result to determine the frequencies and magnitudes of the six third-order IMD products that arise from a "two-tone" test.

$$\left(V_1 \cos \omega_1 t + V_2 \cos \omega_2 t\right)^3$$