ECEG 497 **Wireless System Design** **Spring 2023**

Homework Assignment #8 – due via Moodle at 11:59 pm on Wednesday, Apr. 12, 2023
[assignment revised 4/12/23]

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

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. One graded problem will be randomly selected for detailed evaluation; the others will be evaluated using a coarse rubric. Do not submit the ungraded problems, but review their solutions and make sure that you understand the concepts incorporated into them.

***Graded Problems*:**

1. Below the VHF range (i.e., below 30 MHz or so), anthropogenic noise is usually the more important limiting factor in communication system design than the internally generated noise in the stages that make up a radio/wireless receiver. Using Equation (4.30) of the textbook (Ellingson, 2016) with the appropriate model parameters found in Table 4.2 as a starting point, determine the maximum allowable value of the system noise figure that a receiver located in a typical quiet rural area can have such that the internally generated receiver noise is no worse than that from the surrounding environment at the following frequencies. Equation (4.30) is plotted in Fig. 4.7 of the textbook for the four sets of parameters listed in Table 4.2, but it is easier to use the equation. Assume that a "low-gain omnidirectional antenna at ground level" is used, as specified in the textbook.

  - **a.** 1070 kHz (AM broadcast station WKOK in Sunbury, PA)
  - **b.** 10 MHz (time standard station WWV)
  - **c.** 28 MHz (bottom of amateur radio 10-meter band)

2. **[postponed to HW #9]** Suppose that an 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:

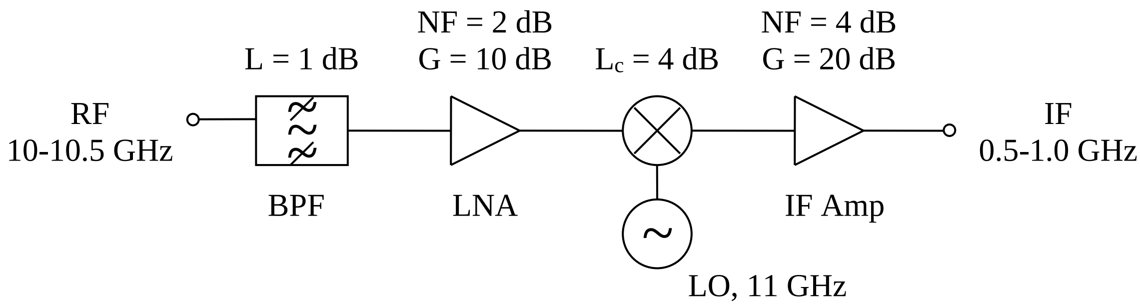
Input and output impedance: 50 Ω
Input and output filter pass-bands: 500–1000 MHz
Gain: 10 dB (neglect roll-off within the filter pass-band)
Noise figure: 5.0 dB
Third-order output intercept point: +40 dBm
1-dB compression point: +30 dBm

  - **a.** Assuming that a minimum output SNR of 0 dB is required for the particular 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 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.

(*continued on next page*)

3. **[postponed to HW #9]** The receiver front end shown below operates at the standard temperature (290 K). Find:

   a. The overall noise figure in decibels, assuming that the IF stages and beyond contribute little to its value.
   b. The minimum discernable signal (MDS) in dBm using the standard input noise definition, assuming 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.



4. **[postponed to HW #9]** 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?

(*continued on next page*)

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. Calculate the difference in decibels between the antenna temperature associated with the "quiet rural" model of anthropogenic noise and that associated with galactic noise at 10 MHz. Repeat the calculation for the case of the "city" model compared to galactic noise.

2. **[postponed to HW #9]** [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).