ECEG 497 Wireless System Design Spring 2023

Homework Assignment #9 – due via Moodle at 11:59 pm on Wednesday, Apr. 26, 2023

***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. 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.

2. The receiver front end shown at the top of the next page 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.

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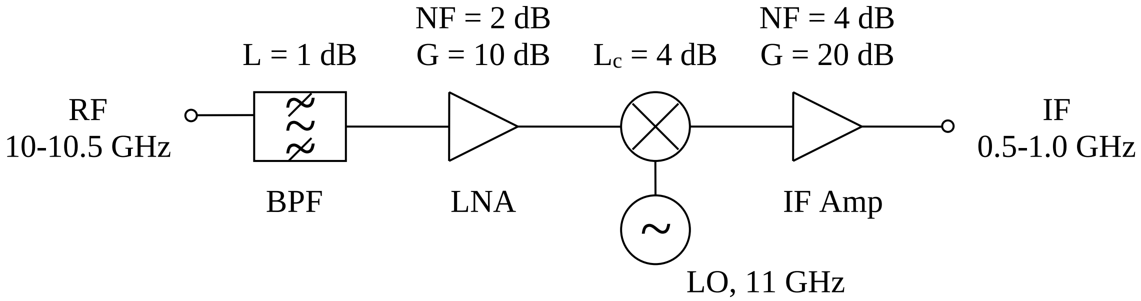

Diagram for Graded Prob. 2.

3. 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?

4. Consider a linear phased array that consists of 12 half-wave dipole antennas spaced along the *z*-axis with the dipoles parallel to the *x*-axis. Neglecting the effects of mutual coupling between the elements, find the interelement phase shift δ in degrees required to steer the main beam in the *yz*-plane to the direction $\theta_0 = 60°$ for the following element spacings:

- **a.** $d = 0.5\,\lambda$
- **b.** $d = 0.8\,\lambda$
- **c.** $d = 1.5\,\lambda$

5. A *grating lobe* is a sidelobe in a radiation pattern that has a maximum value equal to that of the main lobe. Grating lobes are usually undesirable since the typical application of a phased array is to direct all of the radiated energy (or enhance the sensitivity in reception mode) in one direction only. If the interelement phase shift is δ and the element spacing is *d*, grating lobes appear at those angles θ_G that satisfy $\psi = \delta + kd\cos\theta_G = \pm n2\pi$, where $n = 1, 2, 3, \ldots$ (The main beam appears at the angle θ_0 that satisfies $\psi = 0$, which corresponds to $n = 0$.) Physically meaningful angles must fall within the range $0 \le \theta \le 180°$ since θ is not defined outside that range; that is, any θ_G values that fall outside that range are not "visible." Suppose that the main beam of the 12-element array considered in the previous problem is steered to $\theta_0 = 60°$. For the following interelement spacings, determine the number (if any) of grating lobes and the directions in which they appear.

- **a.** $d = 0.5\,\lambda$
- **b.** $d = 0.8\,\lambda$
- **c.** $d = 1.5\,\lambda$

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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 corresponding spurious-free dynamic range (SFDR).

2. Use Matlab to plot the radiation patterns (in dB, array factor only) in the *yz*-plane for the phased arrays considered in Graded Problems 4 and 5 for all three element spacings. The patterns should be normalized to 0 dB. For each pattern, identify the main lobe and the grating lobe(s), if any.