ECEG 497 Wireless System Design Spring 2023

Homework Assignment #6 – due via Moodle at 11:59 pm on Wednesday, Mar. 29, 2023
[Prob. 5 revised 3/28/23]

***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.

It is your responsibility to review the solutions when they are posted (including those for ungraded problems) and to understand and rectify any conceptual errors that you might have. You may contact me at any time for assistance.

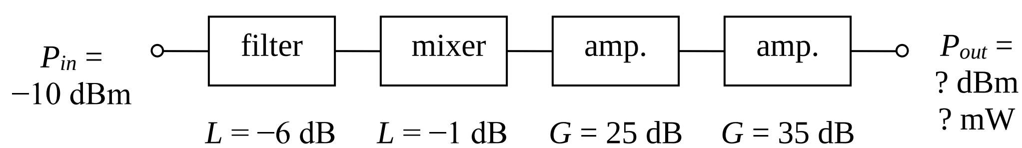
The first set of problems will be graded and the rest will not be graded. Only the graded problems must be submitted by the deadline above. Do not submit the ungraded problems. One graded problem will be randomly selected for detailed evaluation; the others will be evaluated using a coarse rubric.

***Graded Problems*:**

1. Convert the following quantities into dB or dBm, whichever is appropriate:

- **a.** 1.2 nW
- **b.** power ratio (power gain) = 24,000
- **c.** voltage ratio (voltage gain) = 16 (assume $R_L = R_{sig}$)
- **d.** 50 mW
- **e.** 1.5 μW

2. Find the output power (in dBm and in mW) of the system shown in the diagram below. (L = loss; G = gain)



3. *Up-conversion* is a receiver architecture in which the IF is above the frequency range of interest. Suppose that you were to design an up-converting AM broadcast receiver with an IF filter center frequency of 3.9 MHz. The AM broadcast band spans 530–1710 kHz (carrier frequencies). Specify the LO ranges that you would need if you were planning to use (a) the mixer's sum frequency output and (b) the difference frequency output. Also determine which option is most likely to result in the best image rejection performance if the front-end filter is a practical (i.e., not ideal) low-pass type with a cutoff frequency of 1.9 MHz. The front-end filter precedes the mixer in the RF signal path from the antenna.

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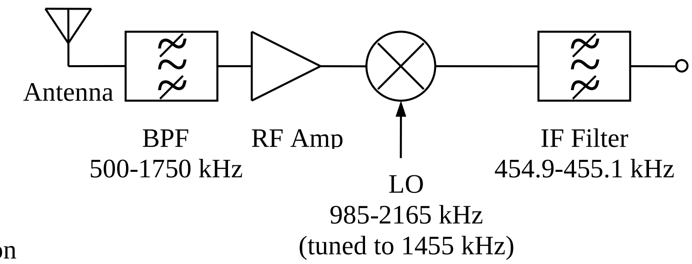
4. The figure below depicts a simplified block diagram of the front end of an AM broadcast receiver. (The AM broadcast band spans 530–1710 kHz in North America.) Currently, the receiver is tuned to pick up station WHAT, which transmits using a carrier frequency of 1000 kHz. The transmitted signal spreads about 12 kHz on either side of the carrier frequency (24 kHz total bandwidth). Several additional stations, some of which are part of other radio services, are also transmitting in the vicinity of the receiver and are listed below. Find the image band that corresponds to the receiver's front end architecture, and determine which of the listed radio stations lie within the potential image band. *Hint*: The image range overlaps the desired RF range. A tunable front-end filter would be required to eliminate image signals in this receiver architecture.

227.5 kHz	WTIC time standard station
480 kHz	WTOC time standard station
960 kHz	WIMP-AM
1000 kHz	WHAT-AM
1020 kHz	KONK-AM
1040 kHz	KUZZ-AM
1365 kHz	WIFF-AM
1810 kHz	Prof. Kelley's ham radio station
3550 kHz	former Prof. Craig's ham radio station



5. **[revisions in boldface]** Consider an upconverting receiver architecture designed to receive the time signal station WWVB (near Fort Collins, Colorado), which transmits a signal centered at 60 kHz. The receiver's IF filter center frequency is 455 kHz, a widely used standard, so the required LO frequency is 395 kHz, and the corresponding image frequency is **850** kHz. A low-pass filter with a cut-off frequency of 420 kHz is used in the receiver for image rejection, but it is not a very good filter. Suppose that a nearby **AM broadcast** station is transmitting at the image frequency of **850** kHz, and it is insufficiently attenuated by the front-end filter. Determine whether the RF (desired) signal and the image signal experience spectral inversion (flipping) in this architecture. Briefly explain your answer either verbally or mathematically.

Ungraded Problems:

The following problems will not be graded. However, you should attempt to solve them on your own and then check the solutions. Try not to give up too quickly if you struggle to solve any of them. Move on to a different problem and then come back to the difficult one after a few hours.

1. [adapted from Prob. 14.1 of Ellingson, *Radio Systems Engineering*, 2016] A cellular base station receiver downconverts the entire block of spectrum (f_{RF}) from 824 MHz to 849 MHz (i.e., B = 25 MHz) to a real-valued signal at an IF centered at 140 MHz. The bandwidth of the IF filter is 25 MHz to match the downconverted spectrum. Specify the LO frequencies and filter requirements for (a) low-side injection and (b) high-side injection. For both (a) and (b), provide equations that indicate the particular IF frequency f_{IF} within the IF bandwidth at which the desired signal will appear, and indicate whether the spectrum of the baseband signal will be flipped.

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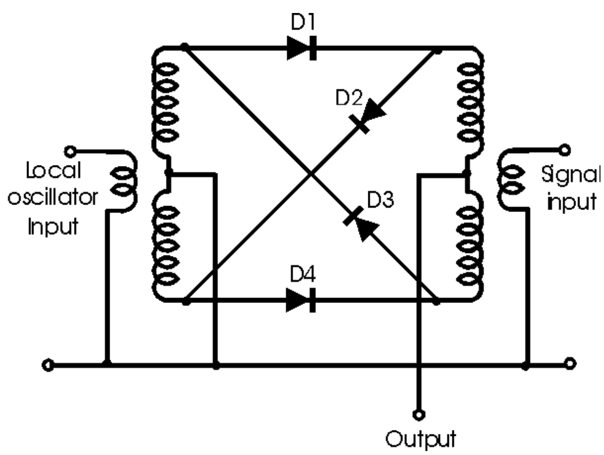
2. [adapted from Prob. 14.5 of Ellingson, *Radio Systems Engineering*, 2016] Diode ring mixers are typically designed to operate with an LO at a specified signal level of at least 7 dBm with respect to 50 Ω, although a mixer designed for a 7 dBm LO might work sufficiently well for an LO level as low as 4 dBm. What makes 7 dBm and 4 dBm the minimum thresholds? (These are not hard limits but rather relatively loose guidelines.) A typical diode ring mixer circuit diagram is shown below. Assume that the center-tapped secondary windings (the ones connected to the diodes) in the circuit have twice as many turns as the primaries; that is, the number of turns between the center tap and one end in the secondary is equal to the number of turns in the primary. Also assume that Schottky diodes are used. That type has a metal-to-*n*-type junction rather than a *pn* junction, which results in fast switching speeds and a turn-on voltage V_F of around 0.3–0.5 V, depending on the specific type. The ports labeled "local oscillator input" and "signal input" each have an input impedance of close to 50 Ω. The horizontal line at the bottom of the diagram is the reference (ground) node. The LO input, signal input, and output voltages are all referenced to that node.



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