ECE 621 (RF IC Design) Winter 2008

Homework #1 (Due January 16)

1. (a) Explain the problem of the image frequency in a superheterodyne receiver architecture.
   (b) Describe two receiver architectures that do not suffer from the image problem and explain why these architectures are not susceptible to the image frequency problem.
   (c) The AM broadcast radio spans 530 kHz to 1610 kHz. What should the IF frequency be to avoid image problems from another AM station?
   (d) Is the image from an FM station a problem for FM broadcast radios? The FM radio spans the 88-108 MHz band and the IF is 10.7MHz.
   (e) For the IS-54 digital cellular phone, the receive band is 869-894 MHz. What should the tunable range of the LO be for a double IF heterodyne receiver? The first IF is at 87 MHz and second is at 455 KHz.

2. For a mixer in a heterodyne receiver there are two possible LO frequency choices $f_{RF} + f_{IF}$ (high-side injection) or $f_{RF} - f_{IF}$ (low-side injection). Using the example of an AM radio (530 kHz to 1610 kHz with an IF of 455 kHZ) explain why high-side injection is preferred.

3. In the heterodyne receiver a fixed f_{IF} (and hence a variable f_{LO}) is used as this allows the use of a fixed frequency bandpass filter which is easier to implement. As outlined in Problem 1 the image can be a problem. A student has suggested that we instead use a variable f_{IF}, fixed f_{LO} scheme, together with a fixed frequency bandpass filter because he believed this would fix the image problem. Is this student correct? Answer parts (a), (b), and (c) below. Assume that the receive band spans from 824 to 894 MHz.
   (a) Assume that we use a fixed f_{IF} of 10 MHz and a variable f_{LO}. Draw the frequency spectrum, including all relevant frequencies, when f_{RF} is 894 and 824 MHz. Repeat the case for f_{IF} of 100 MHz. Assume low-side injection is used for the oscillator.
   (b) Now assume that we use a variable f_{IF} and a f_{LO} of 760 MHz. Again, draw the spectrum when f_{RF} is 894 and 824 MHz. Repeat the case for f_{LO} of 850 MHz.
   (c) Now determine the f_{image} for all the cases in (a) and (b) and comment on whether scheme (b) is better than scheme (a) as far as making it easier to filter out the image.

4. Problem 5.1 of textbook.

5. Problem 5.3 of textbook.

6. Problem 5.4 of textbook.

7. Problem 5.7 of textbook.

8. Problem 5.8 of textbook.

9. An n-channel transistor with $V_T = 0.5V$, $C_{ox} = 36$ fF, $C_{db} = C_{sb} = 8fF$, and $C_{gd\text{-}overlap} = C_{gs\text{-}overlap} = 4fF$ is connected as shown below with the drain open circuited. An ideal current source is tied to the source node of the transistor. $i(t) = 0$ for $t < 0$, and $i(t) = 10\mu A$ for $t > 0$ as shown. The source and the drain are initially ($t \leq 0$) at a voltage of +2.5V. Sketch the voltage at the source and the drain from $t = 0$ until the drain voltage reaches -2.5V. Assume that the capacitances and the threshold voltage are independent of bias and that the V_{dsat} for the transistor with a current of $10\mu A$ is 150mV. Ignore all short geometry effects. *Hint: This problem checks your understanding of the MOSFET capacitances in the different regions of transistor operation.*