ECE 4880 RF Systems Fall 2016
Homework 10
Due on 12/2 5pm in Phillips Dropbox

Reading before homework:

- Chaps. 10 and 11 of lecture notes

1. (**Wi-Fi**) Answer the following questions for Wi-Fi radio networks

   (a) Although Wi-Fi can trace its origin to Alohanet and Ethernet, which country has developed its first prototype according to the IEEE standard? Note that there are some controversies about this issue, so we will go with the patent ruling. (**5 pts**)
   (b) What are the unlicensed bands covered by Wi-Fi as IEEE 802.11b, 802.11a and 802.11g? What interference mitgation (signal unsmearing) techniques were used in each standard? (**5 pts**)
   (c) What are the modulation schemes used in Wi-Fi? What is the TX/RX duplex technique? (**5 pts**)
   (d) For 2.4GHz, US FCC allows 30dBm while EU ETSI only allows 20dBm. We will assume here the modulation scheme is the same. In the line-of-sight model where the power scales with $1/r^2$ (review Chap. 2, i.e., $\gamma = 2$), what is the reduction ratio of distance in EU? For indoors, if the power scales with $1/r^6$ due to channel fading ($\gamma = 6$), what is the reduction ratio of distance in EU? (**10 pts**)
   (e) To support dual-band Wi-Fi transceivers and to minimize oscillator injection, we have chosen to synthesize the frequency between 3.2 – 3.9 GHz. Describe how we can realize both 2.4GHz and 5GHz LO. (**5 pts**)
   (f) What are the major extension of IEEE standards to extend Wi-Fi to MIMO and 60GHz? What are the maximum data rate? (**5 pts**)
   (g) If the Wi-Fi TX has large LO feed through (LOFT), i.e., on top of the desired modulated bandwidth, f_{LO} is an additional component, what will be the homodyne RX concerns for LOFT? (**5 pts**)
   (h) Variable RF gain has been employed to enlarge the dynamic range of the Wi-Fi RX. At the strongest allowable RF_{in}, describe the RF gain and IIP3 need to be at their highest or lowest values? Give one sentence to explain why we need to set a strongest allowable RF_{in}? (**5 pts**)

2. (**Bluetooth**) Bluetooth is a popular "piconet", or wireless personal area network (WPAN)

   (a) Which of the following statement is true for the naming of Bluetooth? (There can be more than one answers) (**5 pts**)
      i. Bluetooth is named as a proposal to unify the protocols in WPAN.
      ii. Bluetooth is the last name of the inventor.
      iii. Bluetooth is meant to describe the blue logo with tooth shape.
      iv. Bluetooth is derived from a Disney movie character name
      v. Bluetooth logo is derived from the combination of Scandinavian alphabet.
   (b) Which one of the following statement is false for the adaptive frequency hopping (AFH) scheme in Bluetooth? (**5 pts**)
      i. 40 channels between 2400MHz and 2483.5MHz are used for channel hopping
      ii. The frequency hopping scheme can effectively spread out the transmission spectrum over a given period of 0.4s.
      iii. Guard bands are inserted between channels to ensure low-cost implementation
      iv. A slave device can occupy any given channel for 0.4s
      v. AFH in general has lower power consumption than OFDM

(c) For a Class 2 (most popular) Bluetooth TX at 0dBm power, an RX 10cm away measures received power at –20dBm. What is the expected power received at 10m if the line-of-sight model can be used with $\gamma = 2$? What is the expected power received at 10m if the indoor fading model is used with $\gamma = 6$? (**10 pts**)

(d) You are a Bluetooth engineer considering the two LNA: (actually now most Bluetooth modules have a single-chip integrated solution all except the LO synthesis)

	Maxim	**Microchip**
Gain	20 dB	14 dB
Noise Figure	2.0 dB	2.0 dB
IIP_{IM3}	0.5 dBm	3 dBm
$P_{1dBcomp}$	–13 dBm	–5.5 dBm
Power Consumption	2.45 mW	6.05 mW

When the RX SNR is most important, which LNA will you choose? When RF_{inmax} needs to be as high as –10dBm, which LNA will you choose? Give one-line explanation. (**10 pts**) Calculate the expected IM3 power for RF_{inmax} = –10dBm in both LNA. (**5 pts**)

(e) Power amplifiers often use EVM (error vector magnitude) at the desirable output power as a measure of linearity. It can be denoted in dB or % by the following definition:

$$EVM\,(dB) = 10\log_{10}\left(\frac{P_{error}}{P_{reference}}\right); \qquad EVM\,(\%) = \sqrt{\frac{P_{error}}{P_{reference}}} \times 100\%$$

For 1dB compression point, the output is 1dB lower than the expected linear output. What is the EVM(%) at 1-dB compression point? (**5 pts**) For a 3% EVM, what is the compression in dB? (**5 pts**)

(f) Bluetooth often uses direct conversion or very low IF to simplify the transceiver structure and avoid the IF generation. Give one-sentence explanation why LNA IIP_{IM2} and LO phase noise become important design considerations. (**10 pts**)