University of California, Berkeley *Fall 2017*
EECS 142/242A *Prof. A. Niknejad*

Problem Set 1
Submit through bcourses

Answer the following questions to the best of your ability. Use any resource (such as texbooks or the Internet/Wikipedia) to answer these questions. Feel free to ask the GSI or instructor for help.

1. Many simple antennas, such as a dipole, are most efficient when they are a significant fraction of the wavelength (quarter or half). (a) For operation at 900 MHz, what is the half-wave dipole length? (b) At 2.4 GHz? (c) At 10 MHz? (d) Explain the choice of carrier frequency based on this information for portable wireless devices. (e) (Bonus) What is the downside of a very short antenna ($\ell \ll \lambda$)?

2. (a) What determines the minimum detectable signal for a receiver? (*Hint*: What do you hear on an analog radio when it's tuned to a channel without a station?) (b) What determines the largest signal? (*Hint:* Consider an audio amplifier that is driven with a signal that is too large for it to handle? Radio receivers also employ amplifiers that exhibit the same behavior.)

3. (a) What's the typical received signal strength of a cellular phone? (b) What voltage does that impart onto the antenna? (c) How about for WLAN (Wi-Fi)? (Hint: Use the signal strength indicator of your WLAN utility or a program such as iStumbler on a Mac. There's also a very nice command line utility called "airport" that provides this information.)

4. (a) What is the typical loss of a coaxial cable at 1 GHz? (b) What determines the maximum power that we may transmit into a cable? (c) Assuming a minimum detectable signal of -90 dBm (75Ω), what is the maximum distance we can communication over a cable? To answer this question, use the results of part (b).

5. How do we increase the communication distance beyond the limits imposed in the previous problem? Why can we not do this indefinitely?

6. Why are cables terminated? Termination is the process of adding a resistance to the end of a cable transmission line equal in value to the characteristic resistance of the line (or designing the input stage of the receiver to have the same impedance as the line).

7. A given communication link is tested over the ocean and found to have a range of 10 km. However when the same link is tested in downtown SF, the range is only 1 km. (a) Why? (Hint: Putting the transmitter at the top of a building helps, but does not completely solve the problem). (b) It is found that the signal quality varies dramatically if one walks a few meters around a given location. Explain.

8. In a quiet cafe in downtown Berkeley your Wi-Fi connection is very strong and you can transmit at maximum throughput. However, as more people come in and turn on their laptops, you find your throughput decreasing. (a) Why? (b) How is the bandwidth shared in this scenario?

9. (*O*ptional) A "jammer" is a device you can buy (illegal) which is used to drop all mobile calls within a certain radius. Can you explain how this device works?

10. (*O*ptional) Suppose that you setup a WiFi network in your house on channel 1 and everything is working great and your maximum throughput is 54 Mbps. A few days later, your neighbor moves in and even though he's on channel 6 (note only 3 WiFi channels are non-overlapping), your throughput has dropped. Why?

11. **242M Required, 142 optional:** Using the Predictive Transistor Model (PTM) (http://ptm.asu.edu/) 7nm MG HPNMOS model, create the following plots. For this technology, $V_{DD} = 0.9$V, $L_{min} = 32$nm. Note these are FinFET devices so that you can specify the number of fins. Select enough fins to realize a device that can deliver a peak current of 100μA. For other fin parameters, use the param.inc file.

    To generate the plots, pick three operating points for V_{gs} and V_{ds}. When sweeping V_{ds}, use three values of V_{gs}, one below "threshold", a little above "threshold", and $V_{gs} = V_{DD}$. For V_{gs} sweeps, pick a V_{ds} point below saturation, around the knee of saturation, and $V_{ds} = V_{DD}$.

    (a) Plot the I-V curves, sweeping both V_{gs} an V_{ds} and plotting the drain current on a linear and log scale. What can you learn from these graphs? How do they deviate from square law?
    (b) Plot g_m versus V_{gs} and V_{ds}. Explain qualitatively the behavior of these plots. Why does g_m increase/decrease as a function of bias?
    (c) Plot r_o versus V_{ds}. Explain qualitatively the behavior of these plots. Why does r_o increase/decrease as a function of bias?
    (d) Plot A_v (maximum voltage gain) versus V_{ds}.
    (e) Plot A_v versus the cannel length L from minimum to 0.25μm. Pick a value of $V_{gs} = V_{ds} = V_{DD}$.
    (f) Plot g_m/I_{ds}, or the transconductor efficiency, versus V_{gs} and V_{ds}. Explain qualitatively the behavior of these plots. Why does g_m/I increase/decrease as a function of bias? What is the optimal bias point in terms of efficiency? What are the downsides to operating at the optimal point? (Hint: See next bullet.)
    (g) Plot C_{gs}, C_{gd}, and C_{ds} while sweeping both V_{gs} and V_{ds}. Normalize the plots to C_{ox}.
    (h) Plot of f_T, or the unity gain frequency, versus V_{gs} and V_{ds}. Explain qualitatively the behavior of these plots. What is the optimal bias point?

    Create a PDF file with your results including your schematic, netlist, and the graphs, and your analysis of the results. *Do not* print out the PDF.