EECS 562
Homework #9

1. A BPSK system needs to transmit 1.5Mbit/sec and provide a 10^{-5} BER. Let N_0=-110 dB_W/Hz. The path loss is 67dB.

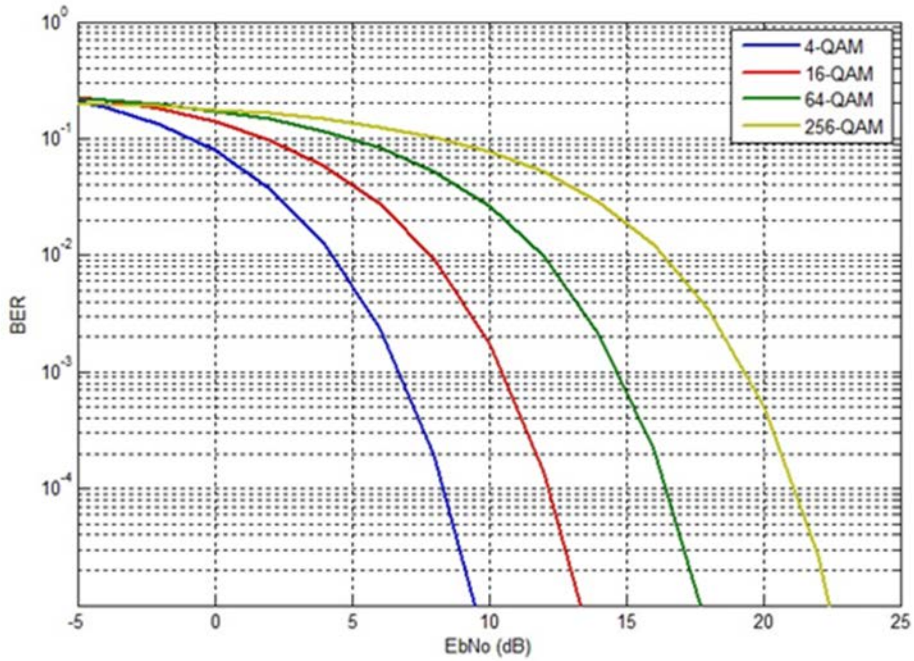
   a. Find the required RF transmission bandwidth, B_{RF}; assume Raised-Cosine pulse shape with a roll off factor α of 1.
   b. Find the required transmitter power.

2. Explore the system trade-off between spectral efficiency and required RF transmission bandwidth for M-QAM. In this case let N_0=-110 dB_W/Hz and assume a required bit rate of 1.5Mbit/sec and Raised-Cosine pulse shape with a roll off factor α of 1.
   a. To provide a 10^{-2} BER find the required E_b and RF transmission bandwidth, $B_{RF,}$ for QPSK, and 64-QAM
   b. To provide a 10^{-3} BER find the required E_b and RF transmission bandwidth, $B_{RF,}$ for QPSK and 64-QAM
   c. To provide a 10^{-4} BER find the required E_b and RF transmission bandwidth, $B_{RF,}$ for QPSK and 64-QAM

That is, fill out the table below and comment on the BER, required E_b and required RF transmission bandwidth trade-offs; specifically discuss the trade-off with respect the spectral efficiency defined as the $S_{eff}=r_b/B_{RF}$ (bits/sec)/Hz).

Use the theoretical BER performance for M-QAM assuming Gray coding given below and at http://www.ittc.ku.edu/~frost/EECS_562/QAM_Theoretical_BER.jpeg (4-QAM=QPSK)

Modulation	BER	E_b	B_{RF}	S_{eff} (bits/sec)/Hz
QPSK	10^{-2}			
QPSK	10^{-3}			
QPSK	10^{-4}			
64-QAM	10^{-2}			
64-QAM	10^{-3}			
64-QAM	10^{-4}			



3. Your company is assigned 1900 to 1920MHz. Explain how you would use this spectrum if
    a. FDD is used
    b. TDD is used.

4. Explain how OFDM helps mitigates multipath fading effects.

5. What is a cyclic prefix and why is it used and what is its cost?

6. What is used in LTE for synchronization?

7. In LTE the OFDM symbol time, T=1/15000 sec = 1/Δf; Δf=15kHz. Here each subcarrier transmits 16-QAM.

$$\text{Bits 1101 so } s_1(t) = 1\cos(2\pi(f_c + \Delta f)t) + 1\sin(2\pi(f_c + \Delta f)t) \text{ for } 0 < t < T$$
$$\text{Bits 0001 so } s_2(t) = -3\cos(2\pi(f_c + 2\Delta f)t) + 1\sin(2\pi(f_c + 2\Delta f)t) \text{ for } 0 < t < T$$
$$s(t) = s_1(t) + s_2(t) \text{ for } 0 < t < T$$

Assume the carrier frequency, f_c = 900 Mhz. Here s(t) is transmitted using two adjacent subcarriers at $f_c + \Delta f$ and $f_c + 2\Delta f$. During one OFDM symbol time, T, the RF signal, s(t), is transmitted.
    a. What is the bit rate of s(t) in b/s.
    b. Show that $s_1(t)$ and $s_2(t)$ are orthogonal over $0<t<T$.
    c. Sketch a receiver structure for $s_2(t)$, what is the receiver output?

8. When an LTE operator uses a 20 MHz channel bandwidth in the downlink there are 1200 occupied subcarriers. In LTE the OFDM symbol time, T=1/15000 sec with a subcarrier separation of 15kHz.

    a. If all 1200 subcarriers use 8-QAM what is the total bit rate of in b/s.
    b. If all 1200 subcarriers use 16-QAM what is the total bit rate of in b/s.