EECS 562
Homework 5

1. Let z_i be a complex symbol for i=1...4

In[ ]:= **z1 = 3 + j * 3; z2 = 3 − j * 3; z3 = − 3 + j * 3; z4 = − 3 − j * 3;**

In a stream of bits to be transmitted each pair of bits (2 bits) is mapped into one complex symbol, here,

$(0,0) \longrightarrow z_1$,

$(0,1) \longrightarrow z_2$,

$(1,0) \longrightarrow z_3$,

$(1,1) \longrightarrow z_4$.

The stream of information bits is thus mapped into a sequence of complex symbols. The modulated RF signal $y_i(t) = \text{Re}[z_i e^{-j2\pi f_c t}]$ transmitted one symbol time. Here a complex symbol is transmitted every symbol time of T_s=1 ms. The modulated RF signal $y_i(t)$ is processed by a quadrature receiver.

    a. Find $y_2(t) = \text{Re}[z_2 * e^{-j2\pi f_c t}]$

    b. What is the transmission bit rate? [Hint: the units of bit rate is bits/sec.]

    c. For a bit sequence = {1,1,0,0,0,0,1,0,0,1} list the transmitted complex symbols.

    d. For a bit sequence = {1,1,0,0,0,0,1,0,0,1} plot the RF signal, assume a convenient f_c;   note $f_c > \frac{10}{T_s}$.

    e. Does the RF signal have a constant envelope?

    f. Let g(t) = $\text{Re}[z_1 e^{-j2\pi f_c t}]\cos(2\pi f_c t)$. Find x(t) where x(t) = $h_{ILPF}(t) * g(t)$ (where $*$ means convolution), that is, g(t) is input to a ILPF with bandwidth $\frac{1}{T_s}$.

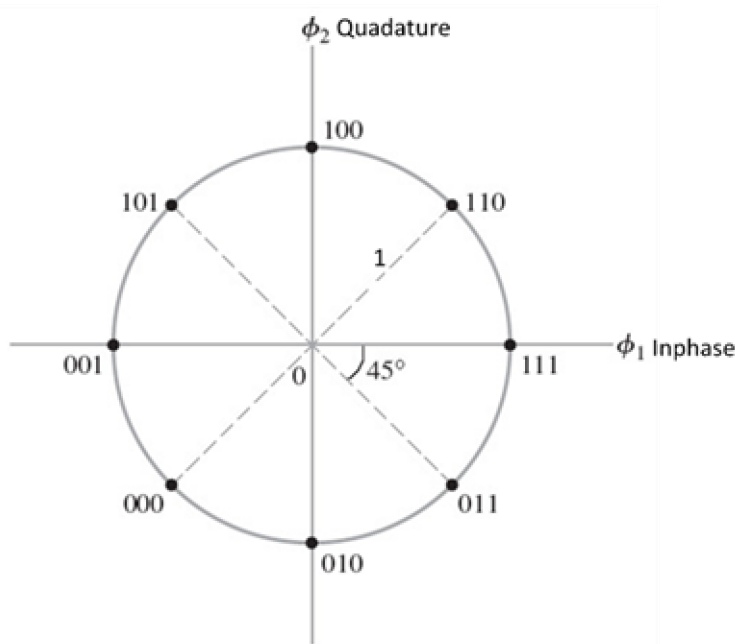**2.** What is the transmitted (RF) signal for each QPSK symbol with a bit time = T_b=5 μs and f_c=10MHz and the energy per symbol E_s= 3x10^{-6}.

3. Draw a QPSK receiver using a LPF followed by a sampler and a QPSK receiver using an integrate-and-dump in the in-phase and quadrature channels respectively. Explain why these provide the same functionality.

4. A signal space diagram (constellation) is given below:

Quadrature
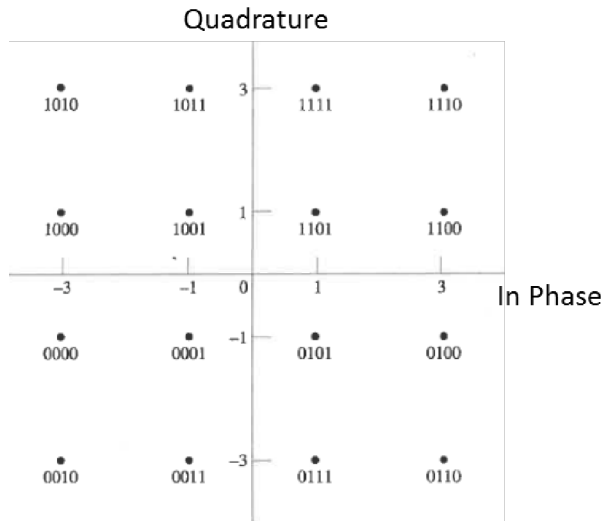
a. For this constellation what is M in M-QAM?

b. If the T_S = symbol time = 1ms what is the bit rate?

c. What is the minimum RF bandwidth?

d. With raised cosine pulse shaping with α=0.75 what is the required RF bandwidth?

e. For detection what is the required integration time.

f. What is the RF signal for the symbol 0101, let f_c=10MHz?

g. Does the RF signal have a constant envelope?

h. A QAM coherent detector uses and integrate and dump in the in-phase and quadrature channels respectively at the end of an integration time the I channel sample is -3.1 and Q channel sample is +0.9 what are the output bits?

i. A QAM coherent detector uses and integrate and dump in the in-phase and quadrature channels respectively at the end of an integration time the I channel sample is 3.1 and Q channel sample is 0.9 what are the output bits?

5. The signal space diagram (constellation) for a digital RF signal is given below. The symbol time is 0.1 ms and the carrier frequency = f_c=10MHz.

a. What is the transmitted bit rate?
b. With raised cosine pulse shaping with $\alpha=0.5$ what is the required RF bandwidth?
c. What is the transmitted RF signal for the symbol 000?
d. What is the Energy/symbol?
e. What is the Energy/bit?
f. Does the RF signal have a constant envelope?
g. What is the received symbol if the recovered complex signal is z=1.1+j0.05?
h. A synchronous (or coherent) detector is required in this case. TRUE or FALSE.

6. Using
Digital Modulation: Quadrature Phase-Shift Keying (QPSK) Signal Constellation and Eye Diagrams
Explain the impact in terms of the eye diagram, transmission bandwidth, and signal quality of the following parameter changes:
a. Changing the raised cosine roll-off factor from .1 to 0.9.
b. Changing the I/Q phase error from 0 to 25^0.
c. Explain what happened when you click on the trajectory.

7. What is the advantage of a constant envelope RF signal?

8. Fill out the table below assuming a bit rate of 1 Mb/s.
Define the spectral efficiency as η_{eff} = (bits/sec)/(RF bandwidth Hz)

Modulation	B_{RF} (MHz) with $\alpha = 0$	η_{eff} with $\alpha = 0$	B_{RF} (MHz) with $\alpha = 0.5$	η_{eff} with $\alpha = 0.5$	B_{RF} (MHz) with $\alpha = 1$	η_{eff} with $\alpha = 1$
ASK	☐	☐	☐	☐	☐	☐
BPSK	☐	☐	☐	☐	☐	☐
QPSK	☐	☐	☐	☐	☐	☐
8 – PSK	☐	☐	☐	☐	☐	☐
16 – QAM	☐	☐	☐	☐	☐	☐
64 – QAM	☐	☐	☐	☐	☐	☐
256 – QAM	☐	☐	☐	☐	☐	☐
1024 – QAM	☐	☐	☐	☐	☐	☐
4096 – QAM	☐	☐	☐	☐	☐	☐

9. A digital RF system uses the constellation shown below. Given a sequence of information bits 100111001 arrive at the transmitter at a rate of 10 Mbits/sec.

Constellation
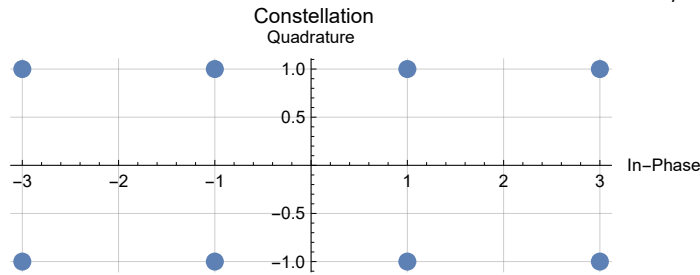
a. What is the symbol rate?

b. Is the energy/symbol the same for all symbols?

c. Define a mapping of bits to symbols for these information bits information bits 100111001 and plot the RF signal, assume a convenient f_c

d. Specify the integration time (in μs) QAM coherent detector used in the integrate-and-dump in the receiver.

e. Does the RF signal have a constant envelope?