EECS 562

Homework 5

1. (Concept: QPSK)

Let z_i be a complex symbol for i=1…4

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In[∘]:= z1 = 1 + j; z2 = 1 - j; z3 = -1 + j; z4 = -1 - j;
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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) = Re[$z_i e^{-j2\pi f_c t}$] transmitted one symbol time. A complex symbol is transmitted every symbol time of T_s=1 μs. The modulated RF signal y_i(t) is processed by a quadrature receiver.

a. Find y_3(t) = Re[$z_3 * e^{-j2\pi f_c t}$]

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) = Re[$z_3 e^{-j2\pi f_c t}$])(2cos(2 πf_c t)). Find x(t) where x(t) = $h_{\text{ILPF}}(t) * g(t)$ (where $*$ means convolution), that is, g(t) is input to a ILPF with bandwidth $\frac{1}{T_s}$.

2. (Concept: For QPSK energy per symbol and RF bandwidth)

Given the complex symbols defined in Problem 1,

a. 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= 2x10^{-6}?

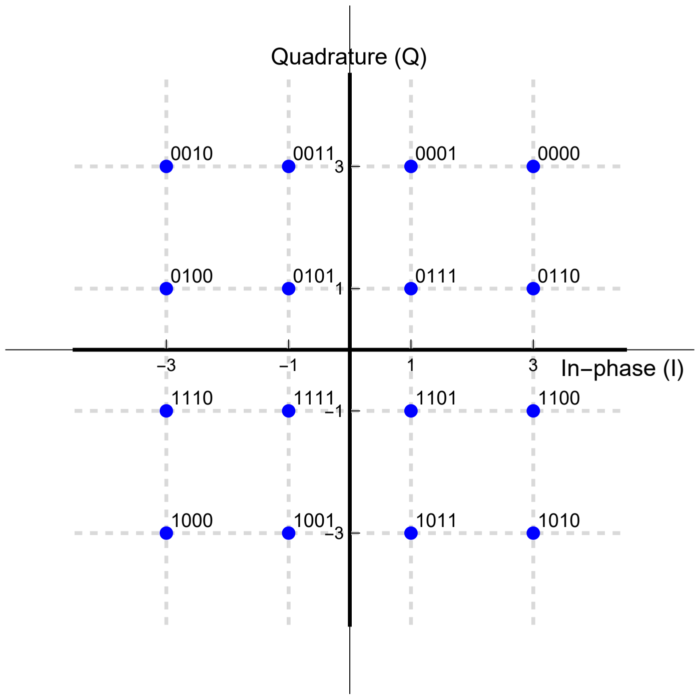
b. What is the RF bandwidth of this QPSK signal?

3. (Concept: QPSK receiver structure)

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. (Concept: Properties of 16-QAM)

A signal space diagram (constellation) is given below:



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

b. If the T_S = symbol time = 100μs what is the bit rate?

c. Using raised cosine pulse shaping with α=0.5 what is the required RF bandwidth?

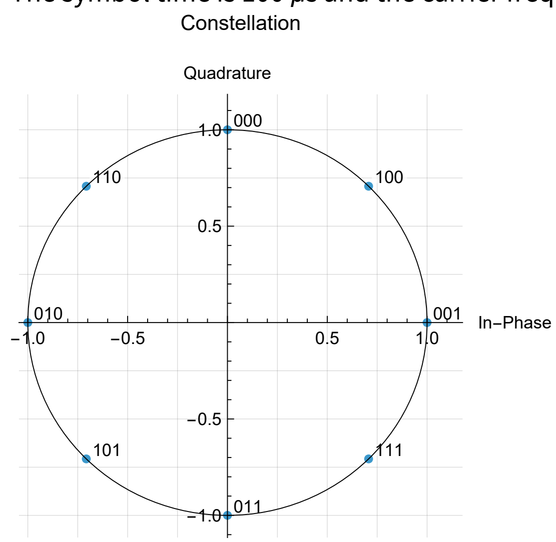
d. For detection what is the required integration time.

e. What is the RF signal for the symbol 1101, let f_c=10MHz?

f. Does the RF signal have a constant envelope, yes or no?

g. A QAM coherent detector uses an integrate and dump; at the end of an integration time the in-phase sample is -3.1 and quadrature Q channel sample is -0.9.
What are the output bits?

5. (Concept: Properties of 8-PSK)
The signal space diagram (constellation) for a digital RF signal is given below.
The symbol time is 100 μs and the carrier frequency = f_c=20MHz.



a. What is the transmitted bit rate?

b. Using raised cosine pulse shaping with α=0.75 what is the required RF bandwidth?
c. What is the transmitted RF signal for the symbol 100?
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. An envelope detector can be used in this case. TRUE or FALSE.

6. (Concept: QPSK with phase error and amplitude imbalance)
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:

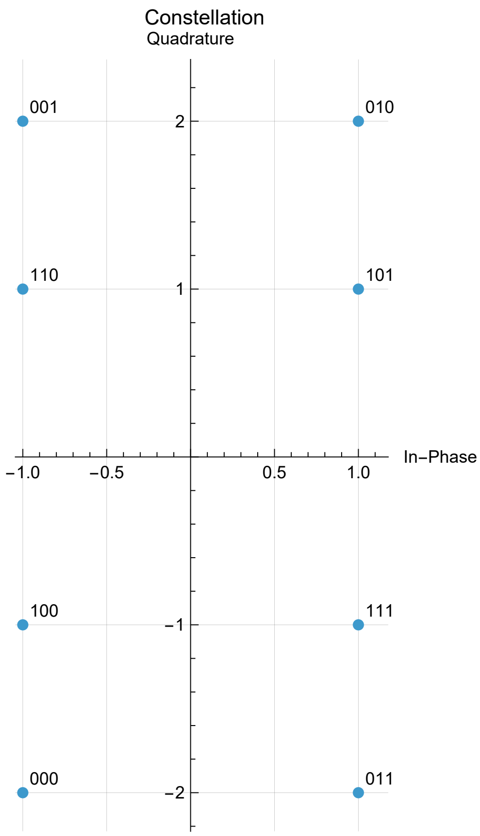
a. Changing the raised cosine roll-off factor from .1 to 0.9.
b. With raised cosine roll-off factor of 0.1 changing the I/Q phase error from 0 to 25^0.
c. With raised cosine roll-off factor of 0.1 and I/Q phase error of 0 changing the I/Q amplitude imbalance from 0 to 0.5.
d. Explain what happened when you click on the trajectory.

7. (Concept: Non-linear amplifiers can be used with constant envelope RF signals)
What is the advantage of a constant envelope RF signal?

8. (Concept: Bit rate-RF bandwidth trade-offs with digital modulation)
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. (Concept: QAM with a general signal constellation)
A digital RF system uses the constellation shown below. Given a sequence of information bits 100101001 arrive at the transmitter at a rate of 30 Mbits/sec.



a. What is the symbol rate?

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

c. Using the the mapping of bits to symbols given above and information bits 100101001 and find and plot the RF signal, assume f_c=100 MHz.

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?