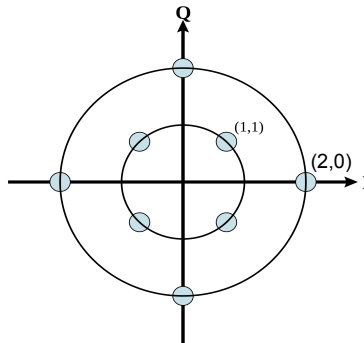


# ECE 440 – Spring 2018

## Homework 7

Due in class or office hours on Wednesday April 3

1. (Exam 2, Spring 16) In order to build a two dimensional modulation, we need pairs of orthogonal functions (they can then be scaled to become orthonormal). Specify conditions on the parameter  $A$  so that the following pairs of functions are orthogonal in the interval  $[0, T]$ . If it is not possible or they are orthogonal regardless of  $A$ , say so.
  - (a)  $\cos(2\pi At)$  and  $\sin(2\pi At)$ .
  - (b)  $\cos(2\pi f_c t)$  and  $\cos(2\pi(f_c + A)t)$ .
  - (c)  $\Pi(At)$  and  $-\Pi(t/A)$  (square pulses, see definition in formula page).
  - (d)  $\Pi(\frac{t}{T} - 0.5)$  and  $\Pi(\frac{t}{T} - 0.5) * \text{sign}(t - A)$ .
  - (e)  $\Lambda(\frac{4t}{T} - 1)$  and  $\Lambda(\frac{4t}{T} - A)$ .
2. (Final, Spring 18) An amplitude and phase-shift keying (APSK) has the constellation below, where the basis functions for the horizontal and vertical axis are  $\phi_1(t) = \sqrt{2/T} \cos(2\pi f_0 t)$  and  $\phi_2(t) = \sqrt{2/T} \sin(2\pi f_0 t)$  for  $0 < t < T$ , respectively.



- (a) Assuming that all symbols are equally likely to be transmitted, what is the average transmit power of this modulation?
  - (b) Would all the symbols in the constellation suffer the same probability of error in an AWGN channel? Otherwise, which ones would have lowest probability of error? Why?
  - (c) If the demodulator were to receive the signal  $x_r(t) = 1.5\sqrt{2/T} \cos(2\pi f_0 t) + 1.5\sqrt{2/T} \sin(2\pi f_0 t)$ , what symbol would it return? Re-draw the constellation and mark your answer graphically.
  - (d) If a channel is able to transmit this constellation without error, what is the capacity of that channel?
3. (Problem 10.6 in 7th edition)

- (a) A BPSK and QPSK system transmit at equal rates; that is, two bits are transmitted in the BPSK system for each symbol (phase) in the QPSK system. Compare their symbol error probabilities versus  $E_s/N_0$  (note that  $E_s$  for BPSK is  $2E_b$ )
- (b) A BPSK and QPSK system have equal bandwidth. Compare their symbol error rates versus SNR (note that for this to be the case, the symbol durations must be the same)
- (c) On the basis of parts (a) and (b), what do you conclude about the deciding factors in choosing BPSK vs QPSK?