

# EE 484

## Homework 4

Due Monday, February 12, 2018

**Problem 1.** A BPSK signal is utilized at 10,000 bits/sec. The equally likely waveforms are  $s_1(t) = A \cos(\omega_0 t)$  and  $s_2(t) = -A \cos(\omega_0 t)$ , where  $A = 1$  mV and the single-sided noise density  $N_0 = 5 \times 10^{-12}$  W/Hz. Assume the signal power and energy per bit are normalized to a  $1\text{-}\Omega$  resistive load. Find the expected number of bit errors made in one hour at the receiver.

**Problem 2.** Suppose we have BPSK modulation and we implement an error correction code, say, a (15,5) BCH code ( $n = 15$ ,  $k = 5$ ). This code can correct 3 bit errors in a block of size 15 bits. Plot on the same graph  $P_b$  vs.  $E_b/N_0$  for both the uncoded and coded waveform. Your  $E_b/N_0$  values should be in dB on the plot. Your plot should be done using a software package such as Excel or Matlab.

**Problem 3.** Suppose we have a QPSK constellation where each point (or symbol) is at a radius of  $r_1$  from the origin. The performance of this system depends on the distance between the constellation points and is mostly determined by the distance between adjacent points,  $d$ . It is a simple application of the Pythagorean theorem to show that  $r_1 = d/\sqrt{2}$  (verify this). With this system we transmit 2 bits per constellation symbol. Suppose now we consider an 8PSK constellation where we transmit 3 bits per symbol. If we used the same radius for the points as was used for the QPSK system the points would be closer to each other in distance since we now have 8 points on the ring instead of 4. Thus, the probability of a symbol decision error at the receiver is higher for this design. Therefore, if we wish to maintain the same probability of symbol error for the 8PSK system that we had for the QPSK system we have to increase the radius of the ring to some value  $r_2$  so that the distance between adjacent constellation symbols for the 8PSK system is also  $d$ .

- a. Find the required value of the radius  $r_2$  in terms of  $d$ .
- b. How much more power is required for the 8PSK system with a radius of  $r_2$  to achieve the same symbol error performance as the QPSK system when just considering adjacent symbol errors, that is, errors caused by transmitted symbols received closer to adjacent symbols?