

## CES 544 Project 2

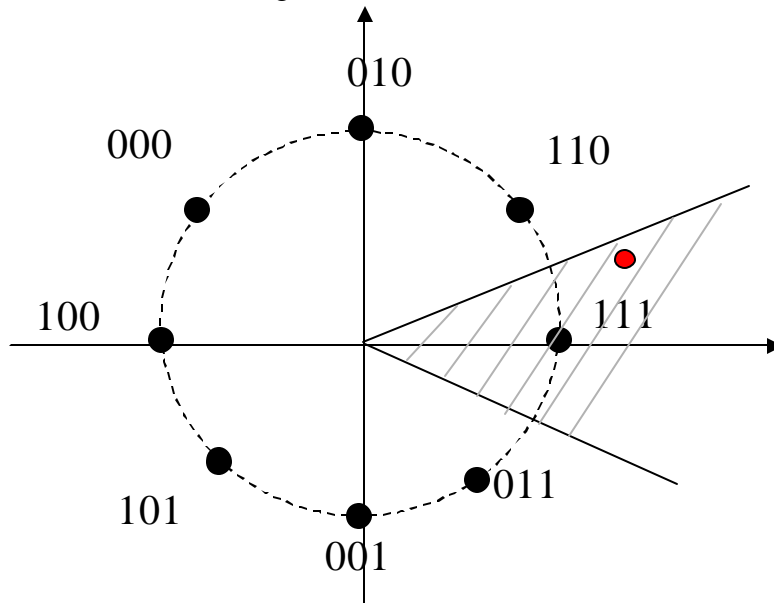
### 8PSK Modulation and Demodulation

#### I. Objectives

1. Understand the concepts of baseband complex modulation.
2. Understand the process of modulation and demodulation in complex baseband.
3. Learn to simulate communication system with flat Rayleigh fading and AWGN.

#### II. Theories

The constellation diagram of 8PSK modulation is shown in the following figure.



In 8PSK modulator, every 3 bits are mapped to one complex-valued 8PSK symbol. The transmitted symbols are corrupted by both Rayleigh flat fading and additive white Gaussian noise.

$$r_k = h_k x_k + n_k \quad (1)$$

where  $x_k$  is the 8PSK modulated information symbol,  $h_k$  is the impulse response of the flat Rayleigh fading,  $r_k$  is the symbol at receiver, and  $n_k$  is AWGN.

In this project, we assume that the receiver can perfectly estimate the fading response  $h_k$ . Then, at the receiver, we can compensate the received symbol by the estimated fading

$$y_k = r_k / h_k \quad (2)$$

After fading compensation, we perform demodulation on the fading compensated symbol  $y_k$ . The demodulated process is performed by finding one of the eight constellation symbols that has the smallest Euclidean distance with  $y_k$ .

For 8PSK modulation, the entire coordinate system can be equally divided into 8 angle sectors, with each angle sector corresponding to one of the 8 constellation symbols. The demodulation process can be performed by using the angle sectors. For example, the angle sector defined by  $[-\mathbf{p}/8, \mathbf{p}/8]$  corresponds to the 8PSK symbol  $\sqrt{E_s}e^{j0}$ . If  $y_k$  falls in the angle sector of  $[-\mathbf{p}/8, \mathbf{p}/8]$ , then the demodulated symbol is  $\sqrt{E_s}e^{j0}$ , which means the output of the demodulator is (1, 1, 1) based on the constellation diagram.

### III. Procedures

1. Write a function, EightPSK\_mod.m, to perform baseband 8PSK modulation. The input of the function is a vector containing binary '0's and '1's, the output of the function is a vector containing the baseband complex 8PSK symbols. The energy of the output symbols is 1.
2. Write a function, EightPSK\_demod.m, to perform baseband 8PSK demodulation. The input of the function is a vector containing baseband complex 8PSK symbols, the output of the function is a vector containing the binary sequence.
3. Test your modulator and demodulator by passing a short binary sequence through the modulator, and then pass the output of the modulator to the demodulator. Compare the original binary sequence and the output of the demodulator to make sure they are working properly.
4. In the simulation, we are going to use a slot structure similar to the second generation cellular standard IS-136. The symbols are transmitted in slots (bursts). Each slot has 162 symbols, with the symbol rate being 24.3ksym/s. We are going to find the BER at  $E_b/N_0 = [0:5:25]$ dB. Step 5 through 12 describes how to find out the BER at  $E_b/N_0 = 0$ dB.
5. Generate a random binary sequence corresponding to the length of slot. The '1's and '0's are equi-probable. (How many bits need to be generated for a slot with 162 symbols and 8PSK modulation?)  
**Hint:**  $A = (\text{rand}(1, 1) > 0.5)$  will give us a random variable A with equiprobable '0' or '1'.
6. Pass the binary sequence through 8PSK modulator by using the EightPSK\_mod.m.
7. The modulated symbols are passed through Rayleigh fading.
  - a) Using your Rayleigh.m function from Project 1 to generate 162 fading samples. The sampling period is equal to the system symbol period. Calculate the maximum Doppler shift for a system operating at 1800 MHz, and the mobile speed is 120km/hr.
  - b) Multiply the modulated symbol vector with the Rayleigh fading vector by using the dot operator "x.\*h" in Matlab.
8. Generate zero-mean AWGN. In Matlab, AWGN can be generated with the function randn(m, n). Since both the inphase component and quadrature

component of the signals are going to be corrupted by AWGN, the AWGN sequence should have complex-values.

- a) Generate the complex valued AWGN sequence by using the following command  

$$\text{noise} = \text{noise\_amplitude} * (\text{randn}(1, N) + j * \text{randn}(1, N));$$
 where N is the number of symbols per block. noise\_amplitude depends on  $E_b/N_0$ . What is the variance of the noise in terms of noise\_amplitude?
- b) The relationship between noise variance and  $E_b/N_0$  can be expressed by the following equation

$$E_b / N_0 = \frac{E_s}{\text{noise\_variance} \times \log_2 M}$$

where  $E_s$  the energy of one symbol, and M is the modulation constellation size. What should be the noise\_amplitude for  $E_s = 1$ ,  $M = 8$ , and  $E_b / N_0 = 0 \text{ dB}$  ?

- c) Generate the noise component by using the noise\_amplitude calculated from the previous step. Add the noise vector to the fading corrupted signal vector.
9. After fading and AWGN, the signals are received by the receiver. Compensate the received signal vector by using fading vector (using the operator dot divide “./”). Assume the receiver has perfect knowledge of fading.
  10. Pass the fading compensated signal vector through the 8PSK demodulator. The output of the demodulator is the binary information recovered at receiver.
  11. Compare the recovered binary sequence with the original binary sequence, and record the # of error bits. (**Hint**: `sum(recovered_bin ~= original_bin)`)
  12. Use a “for” loop to simulate 200 independent slots at  $E_b/N_0 = 0 \text{ dB}$ . Find the bit error rate at 0 dB by using  

$$\text{BER} = \# \text{ of total error bits} / \# \text{ of total bits}$$
 The # of bits should be accumulated from all 200 slots.
  13. Use an outer for loop, repeat step 5 through 12 for  $E_b/N_0 = [5, 10, 15, 20, 25]$ .
  14. Using the function `semilogy( )` plot BER v.s.  $E_b/N_0$ . The x-axis,  $E_b/N_0$ , should be in unit of dB. The function `semilogy` will set the y-axis in log-domain.

#### IV. Questions

1. Write the equation describing the relationship between  $E_b/N_0$  (dB) and noise\_amplitude used to generate AWGN as described in step 8.