ECE5884 Wireless Communications – Quiz 6 **29 August 2022**

1. The constellation for M-PAM is $A_i = (2i-1-M)d$ for $i = 1, 2, \cdots, M$. A wireless communication system uses the 4-PAM constellation signalling, where 4-PAM can be represented as in Figure 1. We have equiprobable signaling.

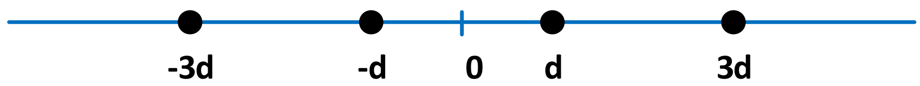

Figure 1: 4-PAM constellation diagram.

(a) The constellation mapping is usually done by Gray encoding. Propose a suitable Gray encoding for the above 4-PAM constellation.

(b) What is the minimum distance, d_{min}, between constellation points?

(c) If the average energy of the 4-PAM constellation is E_s, write d_{min} in terms of E_s.

(d) Draw decision boundaries.

(e) By assuming the additive white Gaussian noise (AWGN) channel, write down a set of equations for the received signal at time t for all possible A_is of the 4-PAM constellation. The AWGN, $n(t)$, follows a circularly symmetric complex Gaussian distribution, i.e., $n(t) \sim \mathcal{CN}(0, N_0)$, where N_0 is the average noise power. (See Slides#10-11 of the lecture note) . You may write the set of equations as follows:

$$r(t) = \begin{cases} \cdots + n(t), & \text{for } A_1. \\ \cdots + n(t), & \text{for } A_2 \\ \cdots + n(t), & \text{for } A_3. \\ \cdots + n(t), & \text{for } A_4 \end{cases} \tag{1}$$

(f) Derive an expression for the symbol error rate (SER) in terms of E_s and N_0. Please provide all important steps in the derivation.

(g) (**MATLAB**) We define the average symbol SNR as $\gamma_s = \frac{E_s}{N_0}$. Based on the Maximum Likelihood (ML) decoding criteria, verify the SER expression derived in (f) by using a MATLAB simulation program. You may plot SER vs γ_s where γ_s varies from -10 dB to 16 dB. You may generate an SER vs γ_s plot as in Figure 2 ☺.

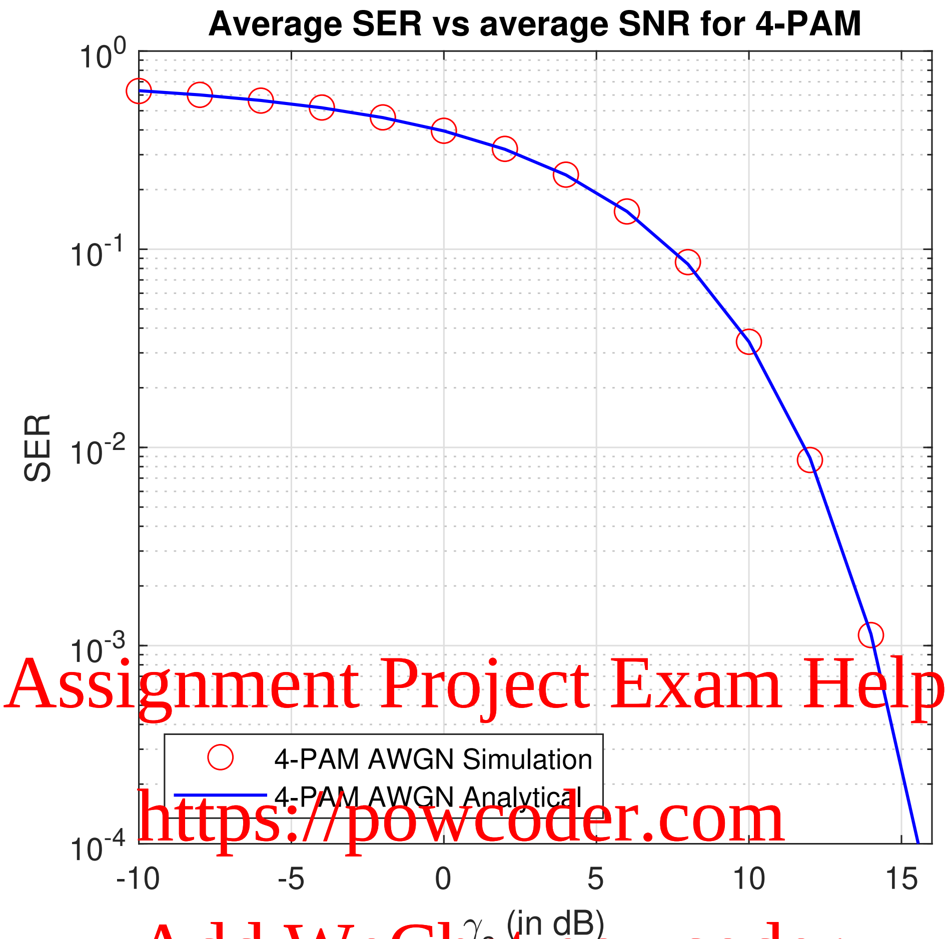

Figure 2: SER vs γ_s for 4-PPAM.