

EE3101 Communication Engineering

Tutorial 8

- (1) Assume that there is no ISI in the signal detection under perfect timing and demodulation process.
 - (a) Drive the minimum Nyquist passband transmission bandwidth of a 90Mb/s 16QAM system
 - (b) If (i) the maximum available passband transmission bandwidth is 25MHz, (ii) the data rate of the system is 135Mb/s, and (iii) minimum Nyquist bandwidth is used; suggest a suitable modulation scheme.

- (2) Consider an ideal M-ASK coherent demodulator is used for the following received signal, (refer to lecture notes for the receiver block diagram),

$$r(t) = E_i \sqrt{\frac{2}{T}} \cos(\omega_c t) + n(t) \quad E_i = E_1 + 2(i-1)E$$

where E_i is the signal level of the signal point i , E is a constant, T is the symbol duration, ω_c is the carrier angular frequency, and $n(t)$ is the Additive White Gaussian Noise (AWGN) with double-sided power spectral density of $N_0/2$. Assuming that Gray coding is used and with optimum detection and large $\frac{E^2}{N_0}$ value is used.

- (a) Show that the probability of bit error can be approximated as:

$$P_B = \frac{2(M-1)}{M \log_2 M} Q\left[\sqrt{\frac{2E^2}{N_0}}\right]$$

- (b) Show that the average bit energy can be expressed as:

$$E_b = \frac{1}{\log_2 M} \left[E_1^2 + 2E_1 E(M-1) + \frac{2(M-1)(2M-1)}{3} E^2 \right]$$

- (c) For a given error performance in (a), show that the transmission power can be minimized by setting

(i) $E_1 = -E(M-1)$; and

(ii) the corresponding average bit error can be approximated as:

$$P_B = \frac{2(M-1)}{M \log_2 M} Q\left[\sqrt{\frac{6E_b \log_2 M}{N_0(M^2-1)}}\right]$$

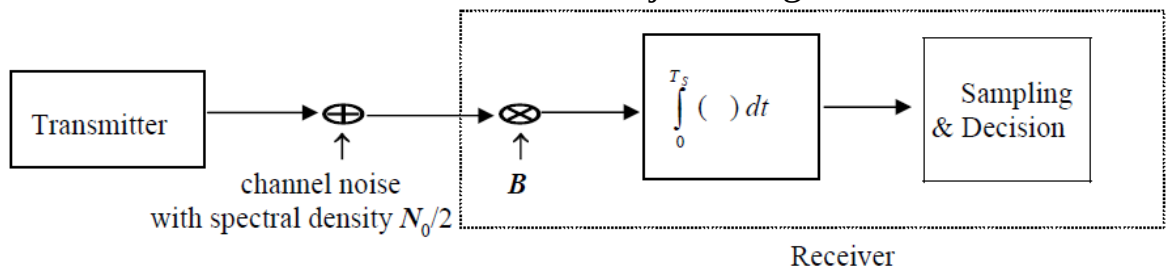
- (3) Consider the performance of M -QAM, M -PSK and M -ASK (use the result in (2) for optimum M -ASK) systems for a given bit rate and same symbol error probability P_S . Assume that $M \geq 16$ and $P_S \leq 10^{-2}$, show that the required transmission power is:

(a) $P_{MPSK}(dB) \sim P_{MQAM}(dB) + 10 \log\left(\frac{3M}{2\pi^2}\right) dB$

(b) $P_{MASK}(dB) \sim P_{MPSK}(dB) + 5dB$

Note: $\sin\theta \approx \theta$ for small θ

- (4) A random data sequence is applied to the 16QAM modulator. The four signal levels at both I and Q channels of the modulator are $-2.8A$, $-A$, $+A$, and $+2.8A$. Derive the unfiltered power spectrum density at the modulator output in terms of A , the carrier angular frequency ω_c and bit duration T_b .
- (5) A 1.544Mb/s random binary signal is converted into a 4-level NRZ signal. The output levels are: $-3.4A$, $-A$, A and $3.4A$. Consider the receiver as shown below is used for signal detection. Assume that (i) the channel is AWGN with double-sided power spectral density of $N_0/2$; (ii) perfect timing is used at the receiver; and (iii) the decision levels are set at the middle of the two adjacent signal levels.



- (a) What is the symbol duration T_S ;
- (b) What are the four output signal levels at the integrator output?
- (c) Determine the noise power σ^2 at the integrator output in terms of N_0 , B and T_S .
- (d) Determine the 3 threshold levels and then derive the symbol error probability P_S in terms of A , T_S and N_0 .