1. (8%) Given a bandpass signal \( x(t) \), whose spectrum is shown below. Here, we assume \( f_m << f_c \). If \( x(t) = m(t) \cos(2\pi f_c t) + n(t) \sin(2\pi f_c t) \), find \( m(t) \) and \( n(t) \), respectively.

\[ X(f) = \begin{cases} A & -f_c - f_m < f < -f_c - f_m \\ A & f_c + f_m < f < f_c + f_m \\ 0 & \text{otherwise} \end{cases} \]

2. (10%) Assume the magnitude response of a causal and stable LTI system is expressed as

\[ |H(j\omega)| = \frac{9 + \omega^2}{\omega^4 - 6\omega^2 + 25} \cdot \alpha \]

(a) (5%) Find the impulse response of this system.
(b) (5%) Is this impulse response unique? If yes, state your reasons. If no, find another impulse response that has the same magnitude response.

3. (7%) Assume \( x(t) = \sum_{k=-\infty}^{\infty} A(\frac{t-10k}{2}) \), where \( A(\frac{t}{\tau}) = \begin{cases} 1 & |t| < \tau \\ 0 & \text{otherwise} \end{cases} \).

If this signal passes through a lowpass filter with the impulse response \( h(t) = \text{sinc}(\frac{t}{4}) \), find the filtered output signal.

4. (15%) An AM modulator has output:

\[ X_c(t) = 40\cos(2\pi(200)t + 40\cos(2\pi(180)t + 4\cos(2\pi(220)t) \]

(a) (5%) Determine the modulation index.
(b) (5%) Determine the efficiency.
(c) (5%) With coherent detection, consider the channel noise as AWGN with power spectral density \( N_0/2 \). Please compute the detection gain.
5. (10%) In DSB transmission, consider the channel noise as AWGN with power spectral density $N_0/2$ and use the analysis model below. Assume $x_c(t) = A_c m(t) \cos(\omega_c t + \theta) + n(t)$.

(a) (5%) Please give the predetection SNR $\gamma$.

(b) (5%) Let $\gamma$ be the SNR of the "equivalent" baseband system: $\gamma = \frac{P_r}{N_0 \omega} = \frac{A_c^2 m^2}{2N_0 \omega}$; express the postdetection SNR $\Delta$ with $\gamma$.

![Diagram of predetection and postdetection systems]

6. (20%) Consider digital modulation. Answer the following questions.

(a) (3%) What is the key difference between coherent demodulation and differentially coherent demodulation in the operating principles? You may use diagrams to help the explanation, but the key points should be explained clearly in words.

(b) (3%) What is the key difference between coherent demodulation and noncoherent demodulation in the operating principles? You may use diagrams to help the explanation, but the key points should be explained clearly in words.

(c) (6%) Can binary ASK (that maps binary 0 to $A_c \cos(\omega_c t)$ and binary 1 to null waveform) be demodulated coherently? Can it be demodulated differentially coherently? And can it be demodulated noncoherently? Note that you should give reasons for each answer.

(d) (3%) What does “M” stands for in “MSK”? What does it mean?

(e) (5%) In analyzing the noise performance of coherent demodulation, the “union bound” is frequently a useful tool. Explain what “union” means and what “bound” means here. You may use diagrams to help the explanation, but the key points should be made clear in words.

7. (5%) Give a quantitative comparison of the spectral efficiency of the following three digital modulation schemes: 16-QAM, 8-FSK, and orthogonal 4-FSK. Show clearly how you obtain your conclusion.
8. (10%) Figure (a) shows the magnitude of a channel's frequency response. Assume the channel noise is AWGN and the transmitted signal is confined within the band [-0.9, 0.9] Hz.

Figure (b), (c), and (d) show the frequency magnitude responses of three filters. Two of them are a zero-forcing equalizer and an MMSE equalizer, respectively, designed for the channel shown in (a).

(a) (5%) Which one of Figure (b), (c), or (d) possibly represents the frequency magnitude response of a zero-forcing equalizer? Why?

(b) (5%) Which one possibly represents an MMSE equalizer? Why?

9. (15%) Consider the following constellation plots for 4-QAM and 8-QAM.

(a) (4%) For both schemes, make bit assignment to each constellation point such that the bit error rate is minimized when symbol errors occur.

(b) (3%) A channel-coded 8-QAM is constructed by cascading a channel-encoder and an 8-QAM modulator. Let the channel-coded 8-QAM system has the same information data rate and same symbol rate as an un-coded 4-QAM system does. What should be the code rate of the channel encoder?

(c) (8%) Roughly estimate the requirement on the coding gain of the channel code such that the channel-coded 8-QAM system has a better BER performance than the un-coded 4-QAM system.