Assignment 1: Physical Layer

1) Suppose a signal is to be transmitted at a data rate of B bits/second. Calculate the minimum bandwidth required to achieve this if the signal is transmitted using:
   (i) NRZ
   (ii) HDB3
   (iii) Manchester Encoding
   Explain your answer in each case.

2) Given the narrow (usable) audio bandwidth of a telephone transmission facility, a nominal SNR_{db} of 56dB (400,000), and a distortion level of <0.2%,
   a. What is the theoretical maximum channel capacity (kbps) of traditional telephone lines?
   b. What is the actual maximum channel capacity?

3) Decompose the signal (1 + 0.1 cos 5t) cos 100t into a linear combination of sinusoidal functions, and find the amplitude, frequency, and phase of each component.

4) What is the channel capacity for a teleprinter channel with a 300-Hz bandwidth and a signal-to-noise ratio of 3 dB, where the noise is white thermal noise?

5) A modified NRZ code known as enhanced-NRZ (E-NRZ) is sometimes used for high-density magnetic tape recording. E-NRZ encoding entails separating the NRZ-L data stream into 7-bit words; inverting bits 2, 3, 6, and 7; and adding one parity bit to each word. The parity bit is chosen to make the total number of 1s in the 8-bit word an odd count. What are the advantages of E-NRZ over NRZ-L? Are there any disadvantages?

6) A sine wave is to be used for two different signaling schemes: (a) PSK; (b) QPSK. The duration of a signal element is 10^{-5} s. If the received signal is of the following form:

$$s(t) = 0.005 \sin (2\pi\, 10^6\, t + \theta) \text{ volts}$$

and if the measured noise power at the receiver is 2.5×10^{-8} watts, determine the E_b/N_0 (in dB) for each case.

7) Let $m_1(t)$ and $m_2(t)$ be message signals and let $s_1(t)$ and $s_2(t)$ be the corresponding modulated signals using a carrier frequency of f_c.
   a. Show that if simple AM modulation is used, then $m_1(t) + m_2(t)$ produces a modulated signal that is a linear combination of $s_1(t)$ and $s_2(t)$.
   b. Show that if simple PM modulation is used, then $m_1(t) + m_2(t)$ produces a signal that is not a linear combination of $s_1(t)$ and $s_2(t)$.

8) Assume that a telephone line channel is equalized to allow bandpass data transmission over a frequency range of 600 to 3000 Hz. The available bandwidth is 2400 Hz. For r = 1, evaluate the required bandwidth for 2400 bps QPSK and 4800-bps, eight-level multilevel signaling. Is the bandwidth adequate? Why?

9) Consider an audio signal with spectral components in the range 300 to 3000 Hz. Assume that a sampling rate of 7000 samples per second will be used to generate a PCM signal.
   a. For SNR = 30 dB, what is the number of uniform quantization levels needed?
   b. What data rate is required?

10) An NRZ-L signal is passed through a filter with r = 0.5 and then modulated onto a carrier. The data rate is 2400 bps. Evaluate the bandwidth for ASK and FSK. For FSK, assume that the two frequencies used are 50 kHz and 55 kHz.