Credit Hours System
Communications and Computer Engineering
Communications I (ELCN 306)
Problem Set 3 - Pulse Code Modulation

Question 1

In a PCM system, an input signal $m(t) = 8\cos(2\pi t)$ volts. It is required to design a uniform quantizer with a maximum quantization error of 0.4 volts.

1) What is the minimum number of bits required to characterize the output levels?
2) What is the **actual** maximum quantization error if that minimum number of bits are fully utilized?
3) Assume that the zero volt value is a mid-point between two levels. Assume also a sampling rate that is double the Nyquist rate, with the first samples taken at $t = 0$ seconds.
   Sketch the quantizer output waveform for one complete cycle of the input.

Question 2

Four telemetry signals of bandwidths 0.5 KHz, 1 KHz, 2 KHz and 4 KHz. TDM is used and these signals are transmitted simultaneously by binary PCM.
Each signal must be sampled at least 25% above the Nyquist rate.
The maximum tolerable error in sample amplitudes is 0.5% of the peak signal amplitude.

1) What is the sampling rate of each signal?
2) What is the minimum number of levels of the Quantizer?
3) What is the minimum possible data rate of the multiplexed signal?
4) What is the minimum bandwidth required for transmission? (Assume channel efficiency of 1.5 bps/Hz)

Question 3

A signal band-limited to 4 KHz, whose power is 10 Watts, is transmitted using a binary companded PCM with $\mu = 100$. The number of levels of the compander is 256.
Note: For the μ-Law compander,

$$y = \frac{\ln(1+\mu\hat{m})}{\ln(1+\mu)}, \qquad \text{SNR} \simeq \frac{3L^2}{[\ln(1+\mu)]^2}$$

1) Find the transmission bandwidth assuming the signal is sampled at rate 25% higher than the Nyquist rate, and that the channel efficiency is 2 bps/Hz.
2) Find the output signal-to-noise ratio (SNR), in dB, of the compander
3) It is required to increase the SNR obtained in part (2) by 12.04 dB while maintaining the same transmission bandwidth.
   What can be changed to achieve such requirement?
   What is the value of such change?
4) The compander is replaced by a uniform quantizer, such that the system has the same transmission bandwidth and the same output SNR as in parts (1) and (2), respectively.
   What will be the maximum quantization error of this uniform equalizer?
5) The signal power is increased by 50%.
   What will be the output SNR of the compander?
   What will be the output SNR of the uniform quantizer?

Question 4

A message signal $m(t)$ is transmitted using binary PCM without compression. If the SNR required to be at least 47 dB, determine the minimum number of levels for the system's quantizer, assuming that $m(t)$ is sinusoidal.
Determine the actual SNR obtained using that minimum number of levels.
Repeat for a μ-law quantizer with $\mu = 100$.

A. Question 5

For the data stream **011100101**, sketch the transmitted sequence of pulses for each of the following line codes:

1) Manchester Code
2) Polar NRZ signaling
3) Bipolar NRZ signaling
4) Alternate Mark Inversion
5) Unipolar RZ signaling