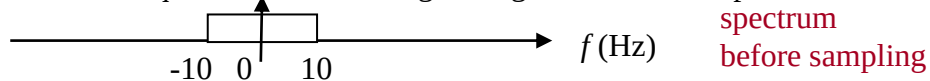


EE 3008. Chapter 6 Tutorial Questions

Q1) Consider a multi-user PCM system. For circuit speed limitation, a pulse requires a minimum duration of $1\mu\text{s}$. If the input bandwidth of each user (before sampling) is 3kHz and the quantization level is 16, calculate the approximate number of users that can be supported simultaneously. (**Notes:** This is called a time division multiplexing (TDM) system, in which multiple users share a channel by transmitting pulses at different time slots.)

Q2) Sampling is applied to a low-pass signal with bandwidth of 10Hz shown below.

- Determine the minimum sampling rate that can avoid aliasing.
- Show the spectrum after impulse sampling. (Read “Extra Reading” to answer this question.)
- Describe a technique to restore the original signal from its sampled version.



Q3) The signal $m(t) = 6\sin(2\pi t)$ volts is transmitted in a 4-bit PCM system. The quantizer is linear as shown in the lecturer notes, with a step size $a = 1\text{V}$. Sketch the resulting sequence of quantized samples for one cycle of the input. Assume sampling is taken 4 samples per second at $t = \pm 1/8\text{s}, \pm 3/8\text{s}, \pm 5/8\text{s}, \pm 7/8\text{s} \dots$. Use the following codebook

0.5 → 0000	1.5 → 0001	2.5 → 0010	3.5 → 0011	4.5 → 0100	5.5 → 0101 ...
-0.5 → 1000	-1.5 → 1001	-2.5 → 1010	-3.5 → 1011	-4.5 → 1100	-5.5 → 1101 ...

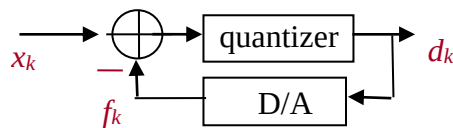
Q4) Determine the dynamic range capability of an 8-bit linear PCM system. (**Note:** Dynamic range is defined as $(Q_{\max}/Q_{\min})^2$, where $Q_{\max}$ and $Q_{\min}$ are, respectively, the maximum and minimum amplitudes of the quantization levels. Normally it is expressed in dB. For evaluating dynamic range, in engineering, we usually assume that $Q_{\max} \approx A/2$ for input range $[-A/2, +A/2]$.)

Q5) Consider uniform quantization. The input signal amplitude is limited within $[-2, 2]$.

- What is the maximum quantization error if the number of quantization bits is 4.
- How much reduction (in dB) of quantization error power can be achieved by increasing the number of quantization bits from 4 to 7?

Q6) Let the input signal be limited to $(-2\text{V}, +2\text{V})$. Let $Q_{\min} = 2/15\text{V}$ be the minimum quantization value of a μ -law signal. Determine the bit number required by the μ -law quantization with $\mu = 15$.

Q7) Find the accumulated error in the DPCM with the following two choices of f_k .



- $f_k = x_{k-1}$ and
- $f_k = \sum_{i=1}^{k-1} d_i$ where $d_k = A_k + \varepsilon_k$.

Discuss your observation.

- Comment the advantages of differential pulse-code modulation (DPCM) compared to PCM.

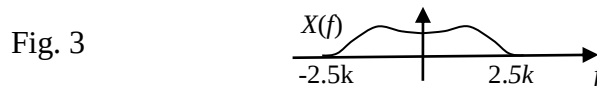
Q8) An analog signal has a bandwidth of 3 kHz ($f_m=3$ kHz) and is converted into a discrete signal. The quantization error is specified not to exceed $\pm 1\%$ of the peak-to-peak analog signal. The carrier frequency is denoted by f_c .

- What is the minimum number of bits per sample that should be used in digitizing the analog waveform using uniform quantization?
- Determine the minimum sampling rate?
- Assume that BPSK is used. Determine the bandwidth of the transmitted signal. (Assume that the envelope of the transmitted symbol is rectangular. The first zeros in the spectrum are used to estimate the bandwidth.)
- Assume that 8PSK is used. Determine the bandwidth of the transmitted signal. (Assume the same conditions as for (c).)

Q9) A communication system is based on BPSK with bit rate 32 kb/s.

- Assume that the input analogue signal has bandwidth 4kHz and is sampled at Nyquist rate. Determine the number of bits for quantization.
- Find the transmission symbol rate and the related bandwidth. Assume 90% in-band power.
- Assume that modulation is changed to QPSK. Solve (a) and (b) again.

Q10) Let $x(t)$ be an analogue signal with its spectrum shown in Fig.3. It is sampled at Nyquist rate. Each sampled signal $x(i)$ is quantized into 256 levels and then represented by a PCM scheme using rectangular pulses



- Determine the Nyquist sampling rate for $x(t)$.
- Determine the bit rate at the output of the PCM scheme.
- Determine the required bandwidth for the PCM signals. Assume that the bandwidth is determined using the first zero in the spectrum.

Q11) (a) Consider a PCM scheme for a signal uniformly distributed in $[-1V, +1V]$. A linear quantizer with quantized values $(-3/4, -1/4, +1/4, +3/4)$ is used. Determine the quantization SNR.

(b) Continue from (a). Assume that the bandwidth of the input signal is 5 kHz. Determine the minimum bit rate of the PCM output signal. Find the minimum bandwidth of the transmitted signal when a QPSK modulation is used. Use the 90% power criterion.

(c) What are the quantized values for a linear quantizer if the input is distributed in $[-2V, +2V]$?

Q12) (a) Explain the advantages of non-uniform quantization.

(b) Consider a 4-bit non-linear PCM system based on μ -law with $\mu = 10$. Let the input signal be uniformly distributed in $[-1V, +1V]$. Find the maximum amplitude of the quantized values.

(c) Repeat (b) if the input signal is uniformly distributed in $[-3V, +3V]$.

Q13) Consider a uniform quantization scheme over input range $[-0.5A, +0.5A]$ using $n=2^k$ levels. Find (a) average signal power, (b) average quantization error power and (c) average signal to quantization noise ratio.