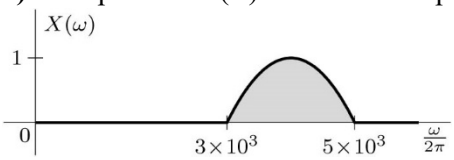
ENGR 4333/5333: Digital Signal Processing

HW 2: Ch 3

1) Consider the following specifications for bandpass signals. For each case, find the minimum permissible sampling rate and the ranges of sampling frequency that will allow reconstruction of the bandpass signal from its uniform samples.

a) $f_1 = 50$ kHz and $f_2 = 70$ kHz
b) $f_1 = 17.5$ kHz and $f_2 = 22.5$ kHz
c) $f_2 = 25$ kHz and $B = 10$ kHz
d) $f_1 = 4$ kHz and $B = 6$ kHz

2) The spectrum $X(\omega)$ for a real bandpass signal $x(t)$ is shown in Figure below:



a) Determine the permissible ranges of the sampling frequency F_s that allow the original signal to be recovered from its samples.
b) Sketch $X_{\tilde{\delta}}(\omega)$, the spectrum of the sampled signal, for the sampling frequencies $F_s = 5$ and 10 kHz. Can we reconstruct $x(t)$ using these sampling rates? How?
c) What happens if the sampling rate $F_s = 7$ kHz?
d) Consider the sampling rates $F_s = 5.5$ and 11 kHz. Determine what happens for both sampling rates, and state, with reasons, which rate is preferable.

3) A TV signal (video and audio) has a bandwidth of 4.5 MHz. This signal is sampled, quantized, and binary coded.

a. Determine the sampling rate if the signal is to be sampled at a rate 20% above the Nyquist rate.
b. If the samples are quantized into 1024 levels, determine the number of binary pulses required to encode each sample.
c. Determine the binary pulse rate (bits/s) of the binary coded signal.

4) A digital communication channel is capable of transmitting 56600 bits per second, about the rate of a high-speed dial-up modem at the turn of the century. We want to use this channel to transmit a single analog signal $x(t)$ with lowpass content. The signal magnitude is limited to $|x(t)| \leq x_{max}$. System specifications require that the error between the digitized signal and $x(t)$ must not exceed $\pm 10^{-3} x_{max}$.

a) What is the required number of bits B of the ADC?
b) What is the maximum bandwidth of the analog input for which the channel can be reliably used without aliasing errors?
c) Suppose that our desired message $x(t)$ is streamed audio, which has a maximum frequency content of around 3500 Hz. Will the system work? If yes, justify how. If not, explain what you might do to best accommodate this particular message signal so that the channel can be used.

5) A signal $x(t)$ is converted to a binary signal. If the signal-to-quantization-noise ratio (SQNR) is required to be at least 47 dB, determine the minimum number of quantization levels L required, assuming that $x(t) = 3\cos(2\pi 5t)$ is a sinusoid. Determine the actual SQNR obtained with this minimum L.

6) An audio signal $x(t)$ with amplitude in the range [-5 to 5] volt is sampled, and each sample is represented by 4 bits.
a) What is the maximum quantization error
b) What is the quantized value x_q for a sample value 3.723 V if rounding asymmetric converter is used.
c) What is the two's complement code word for the quantized level found in part b?
d) If the received code word is 1101, what is the quantized value of the sample x_q?