Advanced Theory of Communication

University of Tehran

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Homework 7

Due : 1403/3/6

Problem 1

A band-limited signal having bandwidth W can be represented as

$$x(t) = \sum_{n=-\infty}^{\infty} x_n \frac{sin(2\pi W(t - n/2W))}{2\pi W(t - n/2W)}$$

a) Determine the spectrum $X(f)$ and plot $|X(f)|$ for the following cases:

$$x_0 = 2 \quad x_1 = 1 \quad x_2 = -1 \quad x_n = 0 \quad n \neq 0, 1, 2 \tag{1}$$
$$x_0 = -1 \quad x_0 = 2 \quad x_1 = -1 \quad x_n = 0 \quad n \neq -1, 0, 1 \tag{2}$$

b) Plot $x(t)$ for these two cases.

c) If these signals are used for binary signal transmission, determine the number of received levels possible at the sampling instants $t = nT = n/2W$ and the probabilities of occurrence of the received levels. Assume that the binary digits at the transmitter are equally probable.

Problem 2

A 4-kHz bandpass channel is to be used for transmission of data at a rate of 9600 bits/s. If $N_0/2 = 10^{-10}$ W/Hz is the spectral density of the additive zero-mean Gaussian noise in the channel, design a QAM modulation and determine the average power that achieves a bit error probability of 10^{-6}. Use a signal pulse with a raised cosine spectrum having a roll-off factor of at least 50 percent.

Problem 3

An ideal voice-band telephone line channel has a band-pass frequency-response characteristic spanning the frequency range 600–3000 Hz.

a) Design an M = 4 PSK (quadrature PSK or QPSK) system for transmitting data at a rate of 2400 bits/s and a carrier frequency $f_c = 1800Hz$. For spectral shaping, use a raised cosine frequency-response characteristic. Sketch a block diagram of the system and describe the functional operation of each block.

b) Repeat (a) for a bit rate $R = 4800$ bits/s and a 8-QAM signal

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Problem 4

A voice-band telephone channel passes the frequencies in the band from 300 to 3300 Hz. It is desired to design a modem that transmits at a symbol rate of 2400 symbols/s, with the objective of achieving 9600 bits/s. Select an appropriate QAM signal constellation, carrier frequency, and the roll-off factor of a pulse with a raised cosine spectrum that utilizes the entire frequency band. Sketch the spectrum of the transmitted signal pulse and indicate the important frequencies.

Problem 5

Design an M-ary PAMsystem that transmits digital information over an ideal channel with bandwidth W = 2400 Hz. The bit rate is 14,400 bits/s. Specify the number of transmitted points, the number of received signal points using a duobinary signal pulse, and the required Eb to achieve an error probability of 10^{-6}. The additive noise is zero-mean Gaussian with a power spectral density of 10^{-4} W/Hz.

Problem 6 Simulation Problem

Suppose we have bandpass BPSK modulation with central frequency f_0 and equivalent lowpass pulse shape $g(t)$.

$$g(t) = \begin{cases} \frac{1}{\sqrt{T}} & 0 \leq t \leq T \\ 0 & otherwise \end{cases}$$

The signal is passed through the channel with a lowpass impulse response $c(t)$.

$$c(t) = \begin{cases} \sqrt{\frac{3}{2T}}(1 - \frac{t}{2T}) & 0 \leq t \leq 2T \\ 0 & otherwise \end{cases}$$

After adding white noise with density $\frac{N_0}{2}$ to the received signal, the low pass equivalent signal is passed through the match filter $h^*(-t)$ (where $h(t) = g(t) * c(t)$) , and output of filter $y(t)$ is sampled at $t = nT$ denoted by $y_n = y(nT)$. Assume $T = 1$.

a. Derive the discrete model of this system shown in the figure 2.

b. Calculate the SNR at the input of the Viterbi algorithm (MLSE). (After the filter $h^*(-t)$ in the following figure)

c. Generate the sequence y_n in Figure 2 using the discrete model described in Part 1. Create an $i.i.d$ sequence with equal probability and random variable $I_n \in \{\pm 1\}$ and a suitable Gaussian noise. Use the results of part b, to adjust the noise variance in order to produce the desired SNR.

d. Simulate the optimal receiver based on the 6L depth Viterbi algorithm for the data generated in part c for different values of SNR in the interval $[0dB - 20dB]$ and plot the error probability curve.

e. If QPSK modulation is used $I_n \in \{\pm\frac{1}{\sqrt{2}} \pm j\frac{1}{\sqrt{2}}\}$, repeat part d using the corresponding optimal receiver structure.

Note: This problem must be simulated in the **MATLAB** environment.

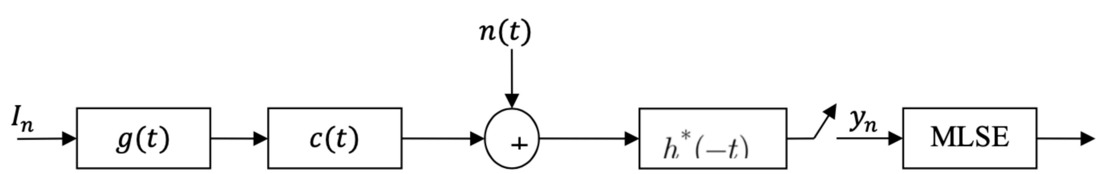

Figure 1