EE 3640 Communication Systems I — Chi-chao Chao
Spring 2023

Homework Assignment No. 6
Due 1:20pm, June 8, 2023

Reading: Haykin & Moher, Chapter 7.

Problems for Solution:

1. Specify the Nyquist rate and the Nyquist interval for each of the following signals:

   (a) $g(t) = \text{sinc}(200t)$.

   (b) $g(t) = \text{sinc}^2(200t)$.

2. Twenty-four voice signals are sampled uniformly and then time-division multiplexed. The sampling operation uses flat-top samples with 1 μs duration. The multiplexing operation includes provision for synchronization by adding an extra pulse of sufficient amplitude and also 1 μs duration. The highest frequency component of each voice signal is 3.4 kHz.

   (a) Assuming a sampling rate of 8 kHz, calculate the spacing between successive pulses of the multiplexed signal.

   (b) Repeat your calculation assuming the use of Nyquist rate sampling.

3. Given the data stream $\{a_n\}_{n=1}^{10} = 1110010100$, assume the use of differential encoding:

$$b_n = b_{n-1} \oplus \bar{a}_n, \quad \text{for } n \geq 1$$

   where $\oplus$ is the XOR (exclusive or) operation and $b_0 = 1$. Note that $\bar{a}_n = 1$ if $a_n = 0$ and $\bar{a}_n = 0$ if $a_n = 1$. Sketch the transmitted sequence of pulses for $\{b_n\}_{n=1}^{10}$ with each of the following line codes:

   (a) Polar nonreturn-to-zero.

   (b) Bipolar return-to-zero.

   (c) Manchester code.

4. A PCM system uses a uniform quantizer followed by a 7-bit binary encoder. The bit rate of the system is equal to 50×10^6 b/s.

   (a) What is the maximum message bandwidth for which the system operates satisfactorily?

   (b) Determine the output sinal-to-(quantization) noise ratio when a full-load sinusoidal modulating wave of frequency 1 MHz is applied to the input.

5. Consider a chain of $n-1$ regenerative repeaters, with a total of n sequential decisions made on a binary PCM wave, including the final decision made at the receiver. Assume that any binary symbol transmitted through the system has an independent probability p_1 of being inverted by any repeater. Let p_n represent the probability that a binary symbol is in error after transmission through the complete system.

   (a) Show that for $n \geq 1$,

   $$p_{n+1} = p_n(1 - p_1) + (1 - p_n)p_1.$$

   (b) Use (a) to show that for $n \geq 1$,

   $$p_n = (1/2)[1 - (1 - 2p_1)^n].$$

   (c) If p_1 is small and n is not too large, what is the corresponding approximate value of p_n? (*Hint:* $(1 + x)^n \approx 1 + nx$ for small x.)

6. Consider a sinusoidal wave of frequency f_m and amplitude A_m, which is applied to a delta modulator of step size Δ and sampling period T_s. Determine the maximum amplitude of this modulating signal required to avoid slope overload.

Homework Collaboration Policy: I allow and encourage discussion or collaboration on the homework. However, you are expected to write up your own solution and understand what you turn in. Late homework is subject to a penalty of 5% to 40% of your total points.