# ELEC 470 Communication and Information Systems Fall 2014

**Homework Assignment #5 – due in BRKI 369 at 5:00 pm Tuesday, Dec. 9, 2014**
**(revised 7:00 pm Dec. 8, 2014)**

***Instructions, notes, and hints*:**

You may make reasonable assumptions and approximations in order to compensate for missing information, if any. Provide the details of all solutions, including important intermediate steps. You will not receive credit if you do not show your work.

***Assignment*:**

Probs. 6.2-4 and 6.2-7, plus the following additional problems:

1. A binary channel that can accommodate a bit rate of up to 36,000 bps (bits per second) is available for use with a PCM-encoded voice signal that is bandlimited to 3.2 kHz. If the signal is to be sampled at a rate 10% above the Nyquist limit, how many bits (and therefore how many quantization levels) are necessary to encode the signal using uncompressed PCM?

2. An analog signal is quantized and transmitted using a PCM system. If each sample at the receiving end of the system must be known to within ±0.5% of the peak-to-peak full-scale value (i.e., the full range of the receiver's digital-to-analog converter), how many binary digits must each sample contain?

3. A compact disc (CD) recording system samples each channel of a stereo signal using a 16-bit analog-to-digital converter (ADC) operating at a sample rate of 44.1 kHz. Note that a stereo recording system has two independent channels.

    a. Determine the output SQNR (signal-to-quantization noise ratio) for a full-scale sinusoid, that is, one whose amplitude variation extends over the full range of the ADC.
    b. The digital bit stream produced by the recording system is augmented by error correction and other control data so that the information overhead is 100%. That is, for every bit of digital music data, there is one bit of error correction and control data. Find the output bit rate of the recording system.
    c. The CD can record roughly an hour's worth of music. Find the number of bits stored on a full CD.

4. **[clarification added 12/8/14]** An audio signal is processed by a band-pass filter with cut-off frequencies of 300 Hz and 3000 Hz. The signal is sampled at a rate of 8 kHz to generate a PCM signal. The application requires that the SQNR (signal-to-quantization noise ratio) be 30 dB or greater for a full-scale signal (i.e., one with a mean squared amplitude equal to $m_p^2$).

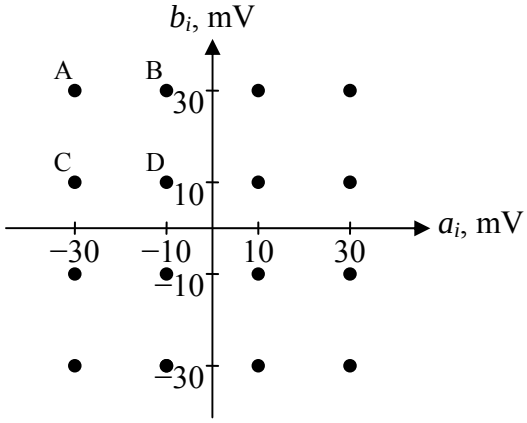
    a. What is the required minimum number of quantization levels, assuming uniform quantization?
    b. Calculate the minimum required system bandwidth.
    c. If mu-law companding is used with $\mu = 255$, what is the SQNR?

(*continued on next page*)

5. A mathematical expression for a 16-QAM signal is given by

$$\phi_{16-QAM}(\omega) = a_i\, p(t)\cos\omega_c t + b_i\, p(t)\sin\omega_c t, \qquad i = 1, 2, 3, 4,$$

where the constants $\{a_i\}$ and $\{b_i\}$ each have the four different possible values given in the constellation diagram shown below; $p(t)$ is the pulse shape in the time domain (with a peak value of 1); and $\omega_c$ is the RF carrier frequency. What is the amplitude and phase of the 16-QAM signal for each of the four states in the constellation diagram labeled A through D?




Note: Some problems have been adapted from a published source. The source is not cited here to preserve the integrity of the assignment. Source information is available from the course instructor.