Homework #2: Chapter 2 (due Sep. 14, 2012)

Preliminary

- All problems are worth +10 points unless otherwise noted.
- Download the CompanionFiles2.zip file
  http://www.ece.nmsu.edu/~pdeleon/Teaching/EE395/Homework/CompanionFiles2.zip
- Code the following tools from *DSP Software Toolkit* Chapter 4: **requantize.m** (given on p. 112).
- Please attach at the *end* of your assignment printouts of **main1.m** (code to solve software problem 1), **main2.m** (code to solve software problem 2), etc....

Software Problems

Use your software tools to solve the following problems.

1. Explain in detail the operation of requantize.m. Consider using examples to clarify your explanation.
2. Generate a 10 s ($f_s = 8000$), uniformly-distributed (-1.0 to $+1.0$) random process input, x (rand in MATLAB). Requantize the signal with 3, 5, and 8 bits/sample (three separate signals), x_Q. Compute the SNR for each requantized signal:

   ```
   x_Q = requantize(x,5); % quantize signal with 5 bits
   e = x - x_Q; % compute quantization error
   sigma_x2 = cov(x); % compute signal power
   sigma_e2 = cov(e); % compute quantization error (noise) power
   SNR_dB = 10*log10(sigma_x2 / sigma_e2) % compute SNR
   ```

   How do your SNR values compare with the "6dB-per-bit rule"? Explain why the variance (cov in MATLAB) for a zero-mean signal is the same as the power.
3. Generate a 10 s ($f_s = 8000$), cosinusoid x with amplitude 1.0 and frequency 440 Hz. Requantize the signal with 3, 5, and 8 bits/sample (three separate signals), x_Q. Compute the SNR for each requantized signal. Repeat but with amplitudes 0.5 and 0.25. Explain why changing the amplitude of the cosinusoids, results in sub- "6dB-per-bit rule" performance.
4. Load and listen to the TIMIT speech signal by typing in the MATLAB command window:

   ```
   [x,fs,bits] = wavread('dr1-fvmh0.wav');
   sound(x,fs);
   ```

   a What is the sampling rate and resolution (bits/sample) of the speech signal?

   b Requantize the speech signal with 3, 5, and 8 bits per sample. Listen to the three requantized signals–you should hear a definite difference in SNR. Of course the noise is solely due to the requantization. Comment.

   c Plot the original signal as well as each signal in (b). Note the quantizer levels.

   d Plot histograms of the quantization error for each resolution. Comment.

Textbook Problems

1.15, 1.21, 1.22, 2.3

Bonus Problem (+5 points)

In most classes (including EE395), the assignment of the course letter grade is a quantization of the total points earned in the course. Furthermore, NMSU awards grade points based on the quantized letter grade. This information is summarized in Table **??**.

Table 1: Quantizer mapping

Total points	Letter Grade	Grade Points
90 – 100	A	4.0
80 – 89	B	3.0
70 – 79	C	2.0
60 – 69	D	1.0
0 – 59	F	0.0

We assume that with five uniform[1] quantization levels, the letter grade can be represented with $\log_2(5) = 2.32$ bits (don't think too hard about fractional bits!). Assuming uniform distribution of grades[2] (equal numbers in each grade band), the SNR of the grading process is approximately 6 dB/bit × 2.32 bits = 14 dB.

Recently, a new grade-point awarding scheme has been adopted and is summarized in Table **??**.

Table 2: Quantizer mapping

Total points	Letter Grade	Grade Points
97 – 100	A+	4.0
93 – 96	A	4.0
90 – 92	A-	3.7
87 – 89	B+	3.3
83 – 86	B	3.0
80 – 82	B-	2.7
77 – 79	C+	2.3
73 – 76	C	2.0
70 – 72	C-	1.7
67 – 69	D+	1.3
63 – 66	D	1.0
60 – 62	D-	0.7
0 – 59	F	0.0

(a) Determine the SNR of the proposed grading scheme under the assumption of a uniform quantizer and a uniform distribution of grades. Compare your result to the old scheme and comment.

(b) Since a more precise measurement, i.e. higher SNR, results from more bits in the quantizer, argue that the proposed grading scheme is a good thing (at least as far as signal processing engineers are concerned!).

[1] To make the point quantizer uniform, we would have to change the range for the F to 50 – 59 from 0 – 59.
[2] This assumption is not generally true in upper division or graduate courses.