EE521 Analog and Digital Communications

Quiz 1 Rules

Please work alone

Please work alone, although you may ask me questions by email. I will reply when appropriate by email to all so that everyone has the same clarifications (and to avoid redundant questions by clarifying just once when needed).

Open Book, Open Notes, Computer Allowed

Use of the text, *Digital Communications*, Second Edition, by Bernard Sklar, and the course handouts, including updates posted on http://temple.jkbeard.com, is encouraged as references while working this quiz. Also, use of notes taken by yourself during class and while studying, and your homework and other notes by yourself are OK to use while working this quiz. You are encouraged to use your computer to help with problems or to work this quiz.

Turning In the Quiz

The quiz is due at 6:00 PM on Wednesday, March 1, 2006. You may

- Turn it in to Dr. Beard at the beginning of EE521 class,
- Send a file by email to jkbeard@temple.edu or jkbeard@comcast.net or
- FAX it to (609) 654-8751

Format of your Work

Your work must be legible and your reasoning must be clear. Use complete sentences in any explanations when you write out an answer or explanation. References to Sklar must include page numbers, heading numbers, and, if relevant, equation numbers. Additional information such as "third paragraph" and a quote of a word or two such as "that begins with 'For the random variable *z(T)*…'" will help me to locate your reference.

If you use handwriting, please scan to a GIF, TIFF, JPG, or PDF file (**PDF preferred**) and e-mail me that file, or use FAX to the number I gave above.

Percentage Credit

There are four questions, each with 25% credit. Each has two or three parts. Credit for each part is given on the question.

Question 1

Part A (50%)

Section 1.2.4, pages 14-16, defines an energy signal as a signal of finite total energy, and it defines a power signal as a signal that has infinite duration that has nonzero but finite average power. If a signal is denoted by *x(t)*, it is an energy signal if

$$E_x = \lim_{T \to \infty} \int_{-\frac{T}{2}}^{\frac{T}{2}} x^2(t) \cdot dt = \int_{-\infty}^{\infty} x^2(t) \cdot dt \tag{1.1}$$

is finite and nonzero. If a signal is denoted by *y(t)*, it is a power signal if

$$P_y = \lim_{T \to \infty} \frac{1}{T} \int_{-\frac{T}{2}}^{\frac{T}{2}} y^2(t) \cdot dt \tag{1.2}$$

is finite and nonzero. If the autocorrelation of a signal *z(t)* as given in Section 1.4, page 19, as

$$R_z(\tau) = \int_{-\infty}^{\infty} z(t) \cdot z(t+\tau) \cdot dt \tag{1.3}$$

exists and is nonzero, is *z(t)* a power signal or an energy signal?

Part B (50%)

Section 1.7, pages 45-50 discusses bandwidths of digital signals. The mixing operation and the trapezoidal bandwidth occupancy of band limited signals are show in Figure 1.18 on page 46. Section 1.7.2 pages 47-50 discusses “The Bandwidth Dilemma,” the fact that signals of finite duration have energy spectra that is not strictly bounded in frequency, and strictly band-limited signals are not strictly limited in their time extent. Figure 1.20 on page 48 shows the common ways of specifying effective or equivalent bandwidth for the energy spectrum of square pulses.

Determine the energy spectral density of a square pulse that is given by

$$x(t) \begin{cases} = 1, & |t| \le \dfrac{T}{2} \\ = 0, & |t| > \dfrac{T}{2} \end{cases} \tag{1.4}$$

Calculate the normalized energy E_x for this pulse.

Question 2

Part A (40%)

Our requirement is 1000 characters per second. Our character is encoded as 7-bit ASCI, a parity bit, and two overhead bits for synchronization. Our symbols that are transmitted over the data link have 16 levels.

a) How many bits do we have per symbol?
b) What is the effective transmitted bit rate?
c) What is the symbol rate?

Part B (20%)

Suppose that we change the transmitted signal of Part A from a 16-level signal to a binary signal. What is the transmitted symbol rate?

Part C (40%)

We have a hypothetical signal

$$x(t) = \frac{\sin(2\pi \cdot f_0 \cdot t)}{2\pi \cdot f_0 \cdot t} \tag{2.1}$$

a) Using the Nyquist criteria, what is the minimum samping rate for this signal, if we want to perfectly reconstruct it from the sampled data?
b) If the frequency f_0 is 100 Hz, what is the engineering sample rate for this signal?

Question 3

Part A (50%)

We have a voice signal and will transmit the band 300 Hz to 3000 Hz. This is a bipolar signal, and can be represented by test signals that are sine waves with a center frequency that slowly varies from 300 Hz to 3000 Hz.

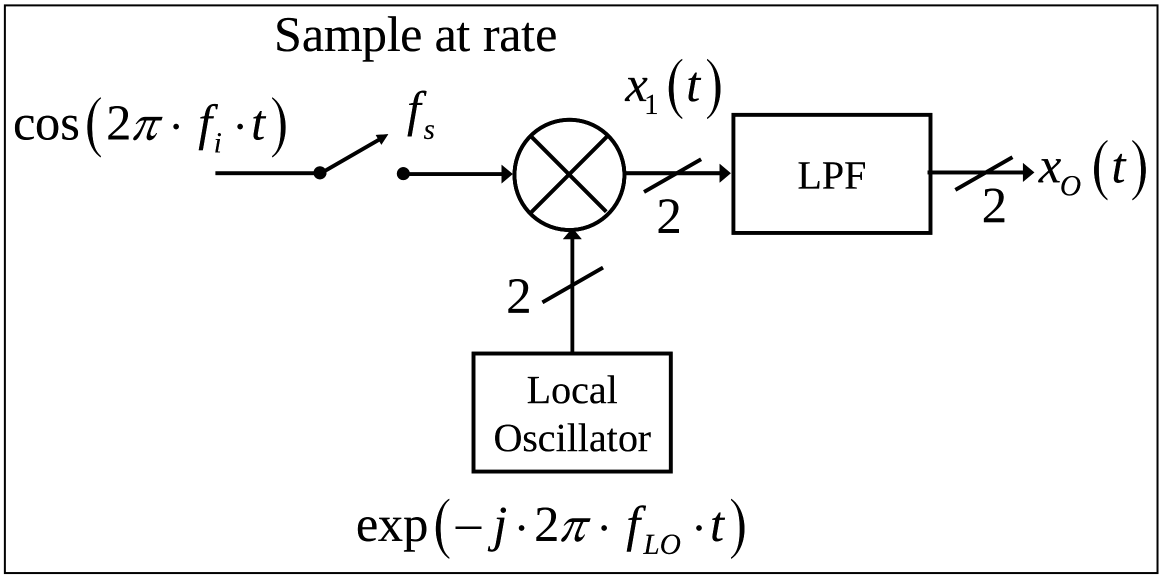
a) How many bits do we need, at a minimum, so that peak quantization error is 0.4% of the peak signal?
b) Using the engineering approximation to the Nyquist sampling requirement, and not taking advantage of the unused band below 300 Hz (i.e. transmitting 0 to 3000 Hz), what is the minimum practical sample rate to transmit this signal?
c) How many bits per character do we have?
d) What is the bit rate, neglecting overhead bits such as parity bits?

Part B (50%)

We are transmitting the signal from Part A using a QPSK waveform and matched filtering.

a) How many bits per symbol do we have?
b) What is the symbol rate? What is the bit rate?
c) For an E_b/N_0 of 10 dB, what is the probability of bit error per symbol?
d) What is the bit error rate in errors per second?

Question 4



Part A (60%)

The figure shows a simple tone being fed into a digital quadrature demodulator. The input frequency is of the form $f_i = f_0 + \Delta f$ where f_0 is a constant center frequency, Δf is the deviation of the signal from the center frequency, and the sample rate f_s is determined by the engineering Nyquist criteria for the bandwidth, i.e. $|\Delta f| < \frac{B}{2}$ where B is the bandwidth. The local oscillator (LO) frequency is four times the center frequency divided by an odd number, i.e. $\frac{4 \cdot f_0}{2 \cdot k + 1}$.

a) Using simple trigonometry, find the equation for the positive frequency component of the input signal propagated through the block diagram to $x_o(t)$. Assume that the mixer is a perfect two-channel multiplier.
b) What is the minimum engineering sample rate if the bandwidth B is 3000 Hz?
c) Assume that the value of k in the divisor $2 \cdot k+1$ for the LO frequency is 29. What is the sample rate? Does it satisfy the engineering Nyquist criterion?
d) At what fraction of the sample rate between -0.5 and +0.5 does the center frequency alias?

Part B (40%)

We have BPSK and two demodulators, one coherent and one incoherent. What is the difference in $\frac{E_b}{N_0}$ between them? Why?