COMP3721 – Introduction to Data Communications
Assignment One – Fall 2008

General Instructions

- You may work with one partner for this assignment. Your partner may be from your set or another full-time CST set.
- You and your partner may discuss any and all details of each question freely. You may also discuss questions in broad terms with others, particularly in lab, but ultimately your answers should show sufficient individuation from others' answers reflecting your work in answering the questions.
- All work submitted is subject to the standards of conduct as specified in BCIT Policy 5002.

Submissions

- This assignment is due October 6, 2008 by 1630 hrs at the latest. Late assignments will not be accepted.
- Submit you assignment to your **lab instructor's** assignment box in the SW2 connector.
- Your submissions must include a cover page clearly specifying your name, student number and set. If working with a partner, this information should be provided for each partner.

Marking

The assignment consists of 7 questions totaling 39 marks.

Questions

1. Two blue armies are strategically camped on opposite hills preparing to attack a single red army in the valley. The read army can defeat either of the blue armies separately but will fail to defeat both blue armies if they attack simultaneously. The blue armies communicate using an "unreliable" communication system (a foot soldier).

   The commander with one of the blue armies would like to attack at noon. His problem is this: if he sends a message to the other blue army, ordering the attack, he cannot be sure it will get through. He could ask for an acknowledgement, but that might not get through either. Is there a protocol that the two blue armies can use to synchronize their attacks and avoid defeat? [2 marks]

   No. There is no way to be assured that the last message gets through, except by acknowledging it. Thus, either the acknowledgment process continues indefinitely, or one army has to send the last message and then act with uncertainty.

2. Decompose the signal (1 + 0.1cos5t)cos100t into a linear combination of three sinusoidal functions. Find the amplitude, frequency and phase of each component. Plot each component, then sum the components over time to produce the composite signal. Hint: use the identity for cos(a) cos(b). [5 marks]

   First, expand the equation:

   $(1 + 0.1 \cos 5t) \cos 100t = (\cos 100t) + (0.1 \cos 5t)(\cos 100t)$

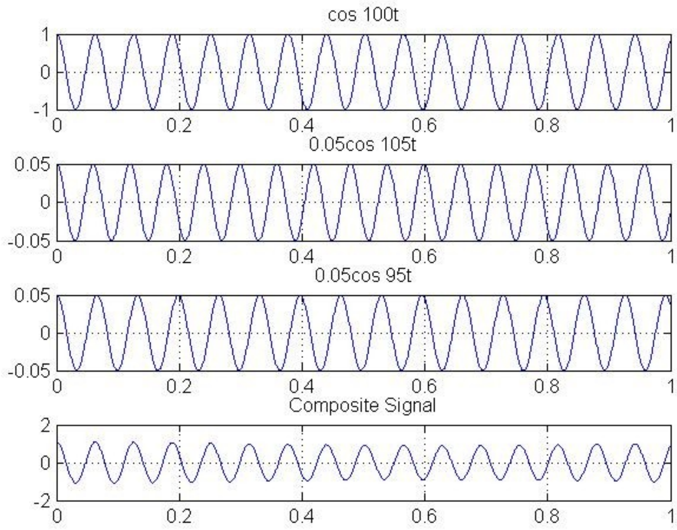
   Then apply the trigonometric identity:

   $\cos a \cos b = (1/2)(\cos(a + b) + \cos(a - b))$

   The signal equation can now be rewritten as the linear combination of three sinusoids:

   $(\cos 100t) + (0.05 \cos 105t) + (0.05 \cos 95t)$

   The composite signal can be plotted as shown:



3. What is the minimum signal-to-noise ratio, in decibels, required to place a T1 signal (1.544 Mbps) on a 1 MHz line? *[5 marks]*

   Using Shannon:

   $\boldsymbol{1.544 * 10^6 = 1 * 10^6 * \log_2(1 + SNR)}$
   $\boldsymbol{\log_2(1 + SNR) = 1.544}$
   $\boldsymbol{SNR = 2^{1.544} – 1 = 2.91601875763315791357647512683 26 – 1 \approx 1.92}$
   $\boldsymbol{SNR_{DB} = 10\log_{10}(2^{1.544} – 1) \approx 2.82 \text{ dB}}$

4. A 10 kHz baseband channel is used by a digital transmission system. Ideal pulses are sent at the Nyquist rate, and the pulses can take 16 levels. What is the bit rate of this system? *[5 marks]*

   A baseband channel has a minimum frequency of 0 Hz, thus the highest frequency this channel will propagate must be 10 kHz. That is, the bandwidth of the channel is 10 kHz and

   $\boldsymbol{B = BW_{channel} = F_{max\_channel} – F_{min\_channel}}$
   $\boldsymbol{H = F_{max\_channel} = BW_{channel} + F_{min\_channel} = 10 \text{ kHz} - 0 \text{ kHz} = 10 \text{ kHz}}$

   Using Nyquist:

DTR (bps) = 2 * H * $\log_2 V$ = 2 * $(10 * 10^3)$ * $\log_2 16$ = 20000 * 4 = 80 kbps

5. A digital transmission system has a bit rate of 45 Megabits/second. How many PCM voice calls can be carried by the system? *[5 marks]*

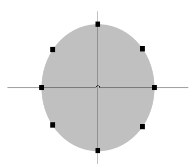
   A PCM channel is sampled at 8 kHz using 256 sampling levels, thus the PCM channel data rate is:

   DTR_{pcm} = 8000 samples / second * $\log_2 256$ bits / sample = 64 kbps

   Then a 45 Mbps channel can carry:

   45 Mbps / 64 kbps/channel ≈ 703 channels

6. Does the following constellation diagram represent ASK, PSK, FSK or QAM modulation? How many levels does this system have? Given bandwidth *H*, what is the maximum data transfer rate possible using this modulation scheme? *[5 marks]*

   The constellation diagram contains 8 points. Each point has the same distance from the origin, thus amplitude is not being varied. Each point is at a unique angle from the positive x-axis, thus there are 8 unique phase shifts. The system illustrated is 8-PSK.

   Given eight possible ways to modulate the carrier for each baud, 8-PSK can encode $\log_2 8 = 3$ bits/baud. Assuming a maximum frequency of H, then the maximum baud rate is 2H (by Nyquist) and the maximum data transfer rate is:

   Using Nyquist:

   $2H * \log_2 V = 2H * \log_2 8 = 2H * 3 = 6H$ bits/second

   where H is specified in Hertz.

7. Suppose a storage device has a capacity of 1 gigabyte. How many one-minute songs can the device hold using conventional CD format? *[5 marks]*

Conventional CD format encodes two signals, a left and a right channel, each sampled at 44.1 kHz using 16-bits/sample. The audio CD data rate is then:

2 channels * 44100 samples/sec/channel * 16 bits/sample = 1.4112 Mbps
1.4112 MBps / 8 bits/byte = 176.4 kBps

A 1 GB storage device can then hold:

10^9 bytes / (176.4 * 10^3 bytes/sec) ≈ 5669 seconds
5669 seconds / 60 second/minute ≈ 94.5 minutes

8. Suppose that a digitized TV picture is to be transmitted from a source that uses a matrix of 480 by 500 picture elements (pixels), where each pixel can take on one of 32 intensity values. Assume that 30 pictures are sent per second.

(a). Find the source data rate, R. [2 marks]

(30 pictures/s) (480 $\times$ 500 pixels/picture) = 7.2 $\times$ 10^6 pixels/s

Each pixel can take on one of 32 values and can therefore be represented by 5 bits:

R = 7.2 $\times$ 10^6 pixels/s $\times$ 5 bits/pixel = 36 Mbps

(b). Assume that the TV picture is to be transmitted over a channel with a 4.5-MHz bandwidth and a 35-dB signal-to-noise ratio. Find the capacity of the channel (in bps). [3 marks]

Using Shannon: $C = B \log_2 (1 + SNR)$
$B = 4.5 \times 10^6$ MHz = bandwidth

and,
$SNR_{dB} = 35 = 10 \log_{10} (SNR)$

hence,
$SNR = 10^{35/10} = 10^{3.5}$

therefore,

$$C = 4.5 \times 10^6 \log_2 (1 + 10^{3.5}) = 4.5 \times 10^6 \times \log_2 (3163)$$

$$C = (4.5 \times 10^6 \times 11.63) = 52.335 \times 10^6 \text{ bps}$$

(c). Discuss how the parameters given above could be modified to allow transmission of color TV signals without increasing the value of R. [2 marks]

Allow each pixel to have one of ten intensity levels and let each pixel be one of three colors (red, blue, green) for a total of $10 \times 3 = 30$ levels for each pixel element.