EE450, Homework #3, Solutions

1. If we want to send data at a speed of 3000 bps through a channel of bandwidth 1000 Hz, what is the minimum S/N ratio required?

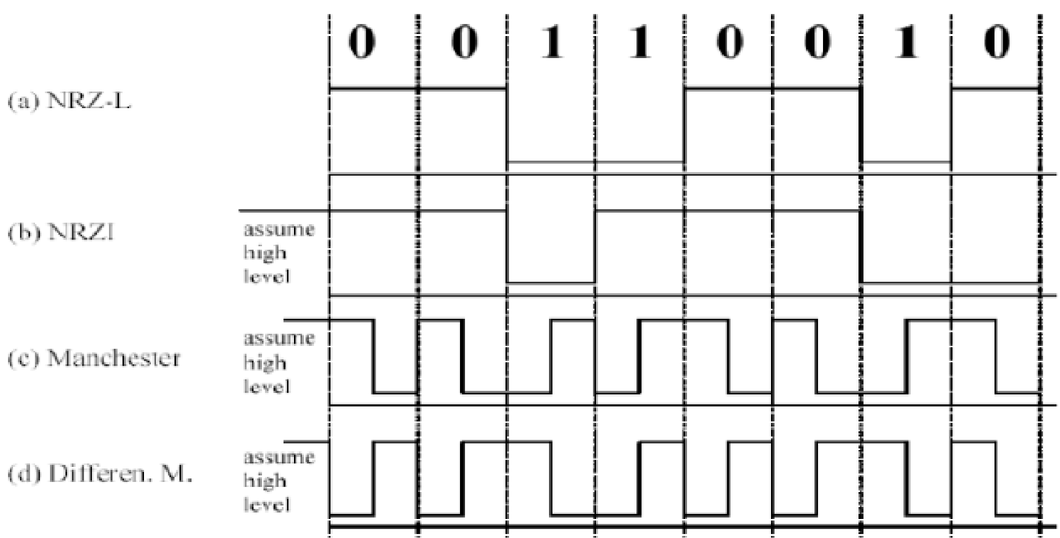
   $C = W \log_2 (1 + S/N)$
   C = capacity of channel
   B = bandwidth in Hz
   S/N = Signal to noise ratio
   $C/B = 3000/1000 = 3$
   $2^{C/B} = 2^3 = 8 = (1 + S/N)$
   $S/N = 7$
   [It's Ok if the students provide the SNR in dB as their final answer].

2. What is the maximum bit rate that can be transmitted over a channel with bandwidth of 500 Hz and a signal to noise ratio of 5 dB?

   $C = W \log_2 (1 + S/N)$
   $S/N \text{ dB} = 5 \text{ dB} = 10 \log (S/N) => S/N = 3.162$
   $C = 500 \log_2 (1 + 3.162) = 1028.7$ bps

3. Encode 00110010 by (a) NRZ-L, (b) NRZI, (c) Manchester, and (d) Differential Manchester.

   [It doesn't matter if the students start from low or high, both are correct].



4. Calculate the signaling rate for the following modulation schemes and bit rates:

   a) 36Kbps, 4-QAM

   b) 8Kbps, 32-QAM

   c) 3Kbps, 8-PSK

   Bit rate = signaling (or baud) rate * bits per baud. Solving for baud rate we get:
   a) 36000/2 = 18000 Bd
   b) 8000/5 = 1600 Bd
   c) 3000/3 = 1000 Bd

5. Calculate the bit rate for the following modulation schemes and signaling rates

   a) 1Kbaud, 32-QAM

   b) 2Kbaud, BASK

   c) 5Kbaud, BFSK

   Just like problem 4, with the only difference that it is the bit rate that we need to find.
   Hence:
   a) 1000 * 5= 5000 bps
   b) 2000 * 1 = 2000 bps
   c) 5000 * 1 = 5000 bps

6. Assume that you are to design a synchronous TDM carrier to support 30 voice channels using 6-bit samples and a structure similar to T1. Determine the required bit rate.

   Synchronous TDM carrier supporting 30 voice channels of bandwidth 4000 Hz each with 8000 samples/sec to be quantized into 6 bits/sample:
   30 x 8000 samples/sec x 6 bits/sample = 1.44 Mbps is the required min. bit rate.
   It's Ok if the students include the synchronization overhead].

7. Find the number of the following devices that could be accommodated by a T1-type synchronous TDM line if 1% of the line capacity is reserved for synchronization purposes.

   a) 110-bps teleprinter terminals,
   b) 300-bps computer terminals,
   c) 1200-bps computer terminals,
   d) 9600-bps computer output ports,
   e) 64-kbps PCM voice frequency lines.

   How would these numbers change if each of the sources were operational an average of 10% of the time? In this case, there will be statistical TDM usage and the line should be utilized at most up to 80% of its capacity.

T1 line : 1.544 Mbps, and 1% is used for synchronization purposes, remaining is 1.544 Mbps x 0.99 = 1,528,560 bps

(a) N = 1,528,560 bps/110 bps = 13,896
(b) N = 1,528,560 bps/300 bps = 5,095
(c) N = 1,528,560 bps/1200 bps = 1,273
(d) N = 1,528,560 bps/9600 bps = 159
(e) N = 1,528,560 bps/64 Kbps = 23

[In the following part it's ok if the students provide a numerical answer instead of just the qualitative argument.]

If the sources are operational 10% of the time, then, we can connect 10 times more of those devices to the T1 line

If we are further required to have only 80% utilization of the link, then we can increase the number of devices to 8 times more, rather than 10 times.

8. Four 1 Kbps devices are to be multiplexed using synchronous TDM. The multiplexor will take one bit from each source during each cycle. Find

   a) The duration of the bit before multiplexing
   b) The duration of the bit after multiplexing
   c) The duration of the multiplexed frame
   d) The multiplexer bit rate
   e) The multiplexer frame rate.

   Duration of bit before MUX = 1/1K = 1 msec
   Multiplexer bit rate is 4x1K = 4Kbps and hence the bit duration at output of MUX is 1/4K = 0.25 msec
   Duration of multiplexed frame is 4x0.25msec = 1msec
   Frame rate is 1/1msec = 1000 frames/sec

9. We have 14 sources, each creating 500 8-bit characters per second. Since only some of these devices are active at any moment, a statistical TDM, using <u>character interleaving</u>, is used to aggregate these sources. Each frame consists of 6 time slots (each time slot will support a character). Four bits of overhead (address) are added to each character in each time slot.

   a) The number of bits in the multiplexed frame
   b) The multiplexer frame rate
   c) The duration of the multiplexed frame
   d) The multiplexer bit rate

   a. Frame size = $6 \times (8 + 4)$ = **72 bits.**
   b. We can assume that we have only 6 input lines. Each frame needs to carry one character from each of these lines. This means that the frame rate is **500 frames/s.**
   c. Frame duration = 1 /(frame rate) = 1 /500 = **2 ms**.
   d. Data rate = (500 frames/s) $\times$ (72 bits/frame) = **36 kbps**.