Data Communications Midterm Solutions

2016.10.25

☞ You can answer either **in English or in 한글**.

☞ Specify **correct units (e.g. bps, baud, bits, dB)** for full credits. (부정확한 단위는 감점요인임)

Student ID: _____ Name: _____

1. In principle, frequency-division multiplexing is unfit to multiplex digital signal streams. Briefly explain the reason. **(5pts)**

FDM that splits bandwidth cannot carry digital signals that require infinite bandwidth.

2. A fan has 5 blades. The fan rotates at *x* revolutions per second. It is illuminated by fluorescent light that flickers at 60 Hz. In case you see an illusion that the blades slowly rotate in the opposite direction of the real movement, what condition do you have for *x*? [Hint: give an inequality in *x*.] Show your derivation. **(5pts)**

Condition for undersampling: $60 \leq 2 \cdot 5 \cdot x \Rightarrow x \geq 6$.

3. An engineer is using a very short communication link that connects two devices. A measurement shows that the link is subject to noise whose power is 3 dBm, and its bandwidth is 10 MHz. Show your derivation for each answer to the following questions.

   A. The engineer can use a transmitter whose transmission power is 27 dBm. What is the maximum bit rate that the line can provide? [Hint: You can use approximation for simpler calculation.] **(10pts)**

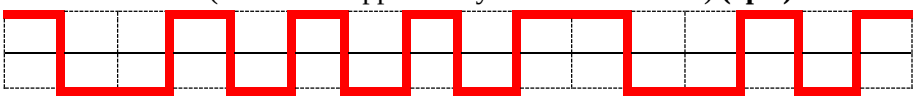
SNR_{dB} = (27 – 3) dB = 24 dB. Max bit rate $C \approx B \cdot \frac{SNR_{dB}}{3} = 10 \times 10^6 \times \frac{24}{3} = 80\ M(bps)$.

   B. If the engineer aims at 3/4 of the maximum bit rate for practical reasons, what is the number of signal levels that he should use? **(5pts)**

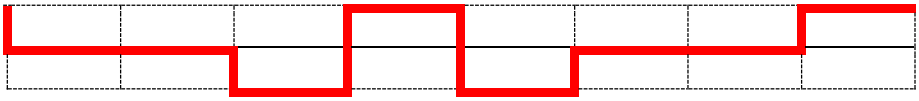
To achieve 60 Mbps, we need $2 \times 10 \times 10^6 \log_2 L = 60 \times 10^6 \Rightarrow \log_2 L = 3 \Rightarrow L = 2^3 = 8$.

4. In each of the line coding scheme below, draw the signal movement for the bits 00111001. Each column represents a single bit time. If necessary, assume that the last signal was positive.

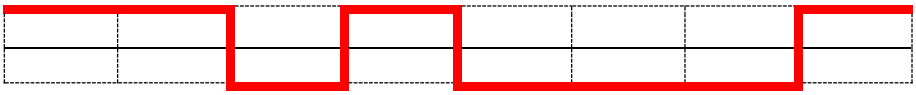
   A. Differential Manchester (inversion happens only if the next bit is 1) **(5pts)**



   B. AMI **(5pts)**



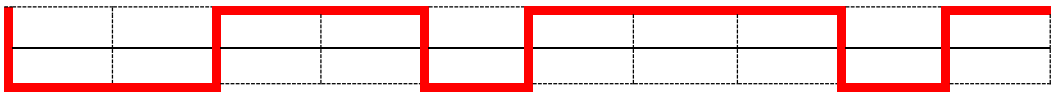
   C. NRZ-I (inversion happens only if the next bit is 1) **(5pts)**



5. Suppose the 4B/5B mapping codes are as given in the following table.

   A. If it is used in combination with NRZ-I (inversion happens only if the next bit is 1; the last signal level was positive), depict the signal movement for the bit pattern in Problem 4. **(5pts)**

Data Sequence	*Encoded Sequence*	*Control Sequence*	*Encoded Sequence*
0000	11110	Q (Quiet)	00000
0001	01001	I (Idle)	11111
0010	10100	H (Halt)	00100
0011	10101	J (Start delimiter)	11000
0100	01010	K (Start delimiter)	10001
0101	01011	T (End delimiter)	01101
0110	01110	S (Set)	11001
0111	01111	R (Reset)	00111
1000	10010		
1001	10011		
1010	10110		
1011	10111		
1100	11010		
1101	11011		
1110	11100		
1111	11101		



   B. What problem of NRZ-I does the 4B/5B solve? Give a brief explanation to your answer. **(5pts)**

Lack of self-synchronization. 4B/5B prevents more than three 0s from being given to the NRZ-I line coder even if contiguous 0s need to be transmitted.

6. An analog signal has a bandwidth of 20 KHz, where the band starts at 30 KHz. We sample this signal at Nyquist rate. If the communication channel carries the digitized signals at 400 Kbps, what is the SNR_{dB}? [Hint: for quantization error, use $SNR_{dB} = 6.02n_b + 1.76$ dB]. Show your derivation. **(5pts)**

Nyquist rate is $2 \times (30 + 20) = 100\ K(Hz)$. So, each sample is represented by 4 bits. $\therefore SNR_{dB} = 6.02 \times 4 + 1.76 = 25.84\ (dB)$.

7. What is the functional difference between line coding and block coding although they are both called "coding"? [Hint: mapping between what entities?] **(5pts)**

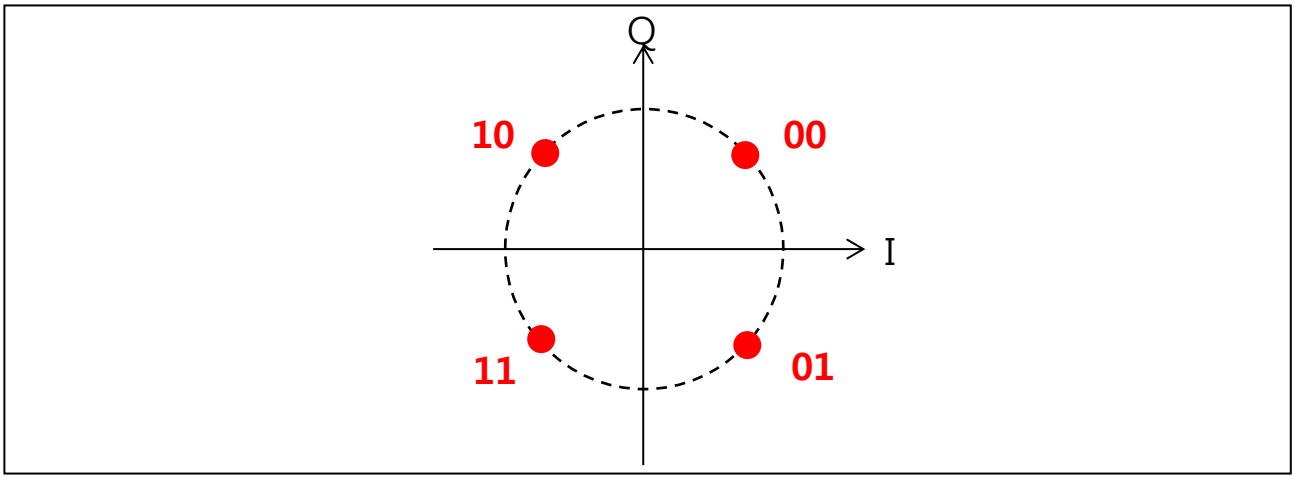
Line coding maps digital information to digital signal. Block coding maps digital information to another digital information.

8. Suppose you are given a channel through which you transmit digital signals using QPSK. The bit rate is 12 Mbps.

   A. If the digital signals come from a Nyquist sampling module, what is the rightmost frequency of the channel? Assume d=0. Show your derivation. **(10pts)**

$S = 12 \times \frac{10^6}{2} = 6M\ (\text{baud})$, so $B = (1 + d)S = 6M\ (\text{Hz})$. Nyquist sampling tells us that the rightmost frequency is $\frac{6 \times 10^6}{2} = 3M\ (\text{Hz})$.

B. If we use the input bits alternatingly for the in-phase (I) and quadrature (Q) carriers, say IQIQIQIQ…., and 0 value for no phase shift and 1 value for 180° phase shift, draw the constellation diagram. Mark each point in the constellation diagram with the corresponding 2-bit pattern. **(5pts)**



9. T-1 line can be used to implement DS-1 service, and has 1.544 Mbps capacity. **(5*1pts)**
   A. How many voice channels (namely DS-0) can this line support? _____**24**_____
   B. What is the bandwidth of the human voice that is sampled in each voice channel? _____**4 KHz**_____
   C. How much overhead (for synchronization) is included in the capacity? ____**8 Kbps**_____
   D. How much overhead is included in each T-1 frame? _____**1 bit** _____
   E. How much voice data is carried by each T-1 frame? __ **192 bits**_____ (errata: 1.536 Mbits → 192 bits)

10. Spread spectrum is not good for bandwidth efficiency.
    A. What is the reason that it is used despite the inefficiency? **(4pts)**

security

    B. How can we mitigate the inefficiency problem? [Hint: what is the technique that we can use to cope with it?] **(4pts)**

multiplexing

11. Calculate the baud rate for the given bit rate and type of modulation. **(4*2pt)**
    A. 3000 bps, binary FSK, no guard band _____**3000 baud**_____
    B. 2000 bps, binary ASK _____**2000 baud**_____
    C. 4000 bps, QPSK _____**2000 baud**_____
    D. 36,000 bps, 64-QAM ____**6000 baud** _____

12. For AM and FM, give the audio signal bandwidth (B) and the channel bandwidth (B_{AM} or B_{FM}). **(4*1pt)**
    A. AM: B= _____**5 KHz**_____ and B_{AM} =_____**10 KHz**_____
    B. FM: B= _____**15 KHz**_____ and B_{FM} =_____**200 KHz**_____