| Subject : | SEHH2238 : Computer Networking |
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| Lab/Tutorial : | Session 3 : PCM and Error Detection (Solution) |

## 1) PCM

1. We have sampled a low-pass signal with a bandwidth of 200 kHz using 1024 levels of quantization.

   a. Calculate the number of bits per sample.

   no. of bits per sample ($n_b$) $= Log_2 L$
   $= Log_2 1024$
   $= 10$ bits

   b. Calculate the bit rate of the digitized signal

   Sampling frequency = 2 x highest frequency component
   = 2 x 200 kHz
   = 400 kHz

   Bit rate = Sampling freq. x no. of bits per sample
   = 400 x 10
   = 4 Mbps

   c. Calculate the $SNR_{dB}$ for this signal.

   $SNR_{dB} = 6.02\,(n_b) + 1.76$
   $= 6.02 \times 10 + 1.76$
   $= 61.96$

2. An analog signal has voltage level in the range of 0 to 5 V. The signal is digitized using PCM with the signal-to-noise ratio due to quantization confined to 55 dB.

   a. Determine the minimum number of bits required.

   $SNR_{dB} = 6.02\,(n_b) + 1.76$
   $55 \leq 6.02\,(n_b) + 1.76$
   $nb \geq 8.84$

   Therefore 9 bits are required.

   b. Suppose that all "0"s represents the lowest signal voltage level and all "1"s represents the highest signal voltage. If the quantization value is round-up and assigned linearly to each signal level, what is the binary code for 1.75 V?

   $111111111_2 = 511_{10}$ represents 5V

   For 1.75V, the value $= \lceil 511 \times 1.75 / 5 \rceil$
   $= \lceil 178.85 \rceil$
   $= 179$

   The binary code is 010110011

## 2) <u>Error Detection</u>

1. What is the maximum effect of a 2-ms burst of noise on data transmitted at the following rates?

   a. 1500 bps

   no. of affected bits = Data rate x burst duration
   = $1500 \times 2 \times 10^{-3}$
   = 3 bits

   b. 100 kbps

   no. of affected bits = Data rate x burst duration
   = $100 \times 10^{3} \times 2 \times 10^{-3}$
   = 200 bits

2. Assuming even parity, find the parity bit for each of the following data units.

   a. 1011011

   1011011 **1**

   b. 0001100

   0001100 **0**

3. 01001 01101 11000 10001 00101 is received using two dimensional even parity bit. The first 4 blocks are data with the parity bit in the rightmost bit, while the last block is all parity. Assume that no more than 2 bits contain error. Find the error bit(s).

0 1 0 0 1
0 1 1 0 1
1 1 0 0 0
1 0 0 0 1
0 0 1 0 1

4. Given the dataword 1010011110 and the polynomial $x^4 + x^2 + x + 1$.

   a. Show the generation steps of the codeword at the sender site.

   $x^4 + x^2 + x + 1$ (degree 4) represents the divisor 10111 (5 bits).
   Append 4 "0"s at the end of the dataword, i.e. 10100111100000
   ** Division Step **
   Get the reminder 1010
   Final codeword transmitted is 10100111101010

   b. Assuming no error, show the checking of the codeword at the receiver site.

   Use the same divisor 10111 with the received codeword
   ** Division Step **
   If no error, the reminder should be 0.