EE5837 : Principles of Digital Communication
Assignment 3 Solutions

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1. Total number of characters = 50
   Total time to transmit entire message T_0=0.5 sec
   Number of bits per character = 8
   Total number of bits to be transmitted = 400

   (a) If 32-PAM is used for baseband transmission, number of bits required are $n = log_2 M$= 5 bits. Therefore the entire message is divided into 80 symbols of 5 bits each. Since 80 symbols are transmitted in 0.5 seconds f_{sym}= 160 symbols/sec.
   $\implies \quad R_b$ = nf_{sym}=5 $\times$ 160 = 800bps

   (b) i. If 16-PAM is used for baseband transmission, number of bits required are $n = log_2 M$= 4 bits. Therefore the entire message is divided into 100 symbols of 4 bits each. Since 100 symbols are transmitted in 0.5 seconds f_{sym}= 200 symbols/sec.
   $\implies \quad R_b$ = nf_{sym}=4 $\times$ 200 = 800bps

   ii. If 8-PAM is used for baseband transmission, number of bits required are $n = log_2 M$= 3 bits. Therefore the entire message is divided into 133 symbols of 3 bits and 1 symbol of 1 bit. Since 134 symbols (133+1) are transmitted in 0.5 seconds f_{sym}= 268 symbols/sec.
   $\implies \quad R_b$ = nf_{sym}=3 $\times$ 266 + 1$\times$2 = 800bps

   iii. If 4-PAM is used for baseband transmission, number of bits required are $n = log_2 M$= 2 bits. Therefore the entire message is divided into 200 symbols of 2 bits each. Since 200 symbols are transmitted in 0.5 seconds f_{sym}= 400 symbols/sec.
   $\implies \quad R_b$ = nf_{sym}=2 $\times$ 400 = 800bps

   iv. If 2-PAM is used for baseband transmission, number of bits required are $n = log_2 M$= 1 bit. Therefore the entire message is divided into 400 symbols of 1 bit each. Since 400 symbols are transmitted in 0.5 seconds f_{sym}= 800 symbols/sec.
   $\implies \quad R_b$ = nf_{sym}=1 $\times$ 800 = 800bps

2. (a) The output response of the above system can be written as

$$Y(f) = H_n(f)X(f)$$
$$\implies \quad \frac{X(f)}{\sqrt{1+(\frac{f}{f_o})^{2n}}}$$

   Aliased signal can be represented as

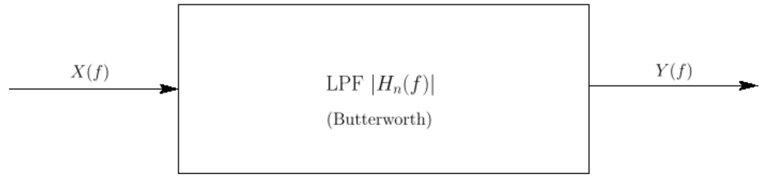

Figure 1:

$$E(f) = X(f) - Y(f)$$
$$E(f) = X(f)\{1 - \frac{1}{\sqrt{1 + (\frac{f}{f_o})^{2n}}}\}$$
$$E(f)_{db} = X(f)_{db} + 20\log\{1 - \frac{1}{\sqrt{1 + (\frac{f}{f_o})^{2n}}}\}$$
$$\implies -50 = 20\log\{1 - \frac{1}{\sqrt{1 + (\frac{f}{f_o})^{2n}}}\}$$
$$\implies f = f_o(0.006)^{\frac{1}{2n}}$$

For f_o = 4000 Hz and n = 5, f = 2411.9 Hz

(b) For n = 10, f = 3106 Hz

3. Given data:
f_m = 4 kHz
M = 4

$$\mathbf{\frac{q}{2} \leq \frac{A_m}{100}}$$

where A_m is maximum amplitude of the analog signal.

But, $$q = \frac{2A}{L}$$

$$\implies \qquad \frac{2A}{2L} \leq \frac{A}{100} \qquad \implies \qquad L \geq 100 \quad \textbf{or} \quad n \geq log_2 100$$

$$\implies \qquad n = 6, \qquad L = 64$$

(a) Since 64 level quantizer is used, number of bits per sample (level) are 6.

(b) To avoid aliasing minimum sampling rate required is f_s = Nyquist Rate = $2f_m$ = 8 kHz.
Each sample is encoded using 6 bits. Thus, the bit rate $R_b = 6f_s$ =48 kbps. In a 4-PAM transmission system symbols are formed using 2 bits each. Therefore symbol rate is $f_{sym} = \frac{R_b}{2}$ = 24k symbols/sec.

4. The MATLAB (.m) files are submitted alongwith the folders which comprise of:

   (a) DC_A3.m (main file)
   (b) Function files
      (i) uniquan.m

(ii) encode.m
(iii) pam4.m
(iv) decision_metric.m
(v) BER.m
(vi) decode_pcm.m