FORMATTING AND BASEBAND MODULATION

Lecture 12

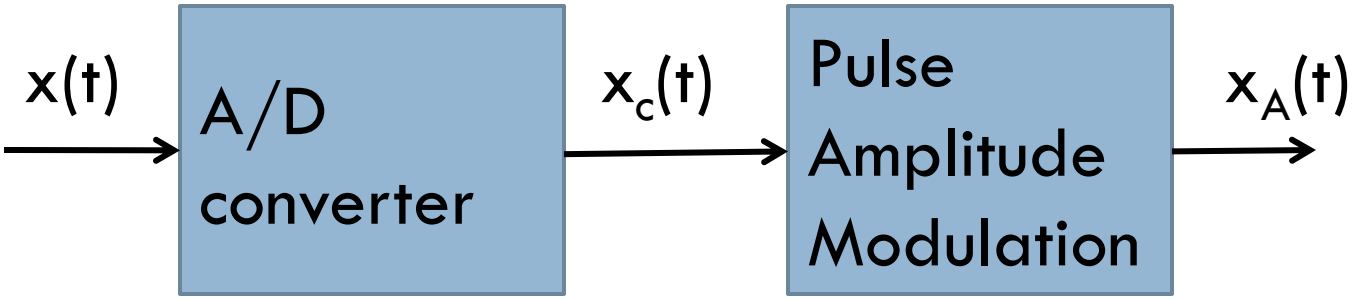
Pulse shaping filters

- These are used to reduce the bandwidth
- We have seen that bandwidth ranges from R to 2 R Hz where R is the bit rate and pulses are rectangular
- With pulse shaping filters the bandwidth requirement can be calculated from the following formula

$$BW = \frac{R(1+r)}{2} \quad where \;\; 0 \le r \le 1 \;\; for \;\; binary$$

$$BW = \frac{R_s(1+r)}{2} \quad for \;\; M-ary \;\; system$$

M'ary pulse modulation waveforms



$x(t)$: Analog Signal

$x_c(t)$: Binary Output

$x_A(t)$: M'ary Signal

PCM-PAM signalling

Analog signal : -0.5 to 0.5 volt. And 6 bit PCM

PCM output	010000	000100	001000	000110	011110
8'ary values	2 0	0 4	1 0	0 6	3 6

Example

Analog signal fm = 3.5 kHz

Sampling frequency : 8 kHz

PCM bit rate (6 bits /sample) R = 48 kbits/sec

Bandwidth requirement : 2 R = 96 Khz

(On-Off signalling)

For PAM signalling Symbols/sec = 48/3 = 16 Ksymbols/sec

Bandwidth requirement = 16x2 = 32 KHz.

Trade –off of Power and bandwidth

- Previous example

  PAM transmission

    Bandwidth reduced

    Noise performance same as the difference in consecutive levels is same.

    Larger power as the amplitude increases.

  PCM transmission

    More bandwidth : Less power

Problem

- A PCM system uses a sampling rate of 8000 samples per second

  Peak signal power to average quantization noise power is to be 30 dB

  Find the minimum quantization levels needed and the minimum number of bits per sample needed

  Find the system bandwidth assuming bipolar signalling

Solution

$$10\log 3L^2 = 30$$

$$3L^2 = 10^3$$

$$L = 18.257$$

$$We\ chose\ L = 32$$

$$l = 5$$

$$Bit\ time\ T = \frac{T_s}{l} = \frac{1}{8000 \times 5} = 25\mu s$$

$$Bandwidth\ W = \frac{1}{T} = 40\ \ kHz$$

Problem

- A waveform $x(t) = 10\cos\left(1000t + \frac{\pi}{3}\right) + 20\cos\left(2000t + \frac{\pi}{6}\right)$ is to be uniformly sampled for digital transmission

  (a) What is the maximum allowable time interval between sample values?

  (b) If we want to reproduce one hour of this waveform how many sample values need to be stored?

Solution

$$\omega_m = 2\pi\ f_m = 2000$$

$$(a)\quad f_m = \frac{2000}{2\pi} = 318.3\,Hz$$

$$f_s \geq 2\,f_m = 636.6\ samples\ \ per\ \sec$$

$$T_s = \frac{1}{f_s} \leq 0.00157\ \ s$$

$$(b)\ Number\ of\ \ samples = f_s \times Total\ \ time$$

$$= 636.6 \times 3600$$

$$= 2.29 \times 10^6$$

Problem

- An analog waveform whose maximum frequency is 4000 Hz is to be transmitted using 16 level PAM system. The quantization distortion must not exceed 1 % of the peak to peak analog signal

  (a) What is the minimum number of bits per sample that must be used

  (b) What is the minimum required sampling rate and the resulting bit rate?

  © What is the 16-ary PAM symbol transmission rate?

Solution

$$(a)\ L \geq \frac{1}{2p} = \frac{1}{0.02} = 50\ levels$$

$$We\ use\ the\ next\ integer\ \ power\ of\ \ 2\ i.e.64$$

$$Number\ of\ \ bits/sample = 6$$

$$(b)\ \ f_s \geq 2f_m = 2 \times 4000 = 8000\ \ samples/Second$$

$$Bit\ \ \ rate\ \ 6 \times 8000 = 48000\ \ bits/s$$

$$(c)\ 16\ level\ \ pulses : k = 4\ \ bits/\ pulse$$

$$Symbol\ \ rate\ \ R_s = \frac{R}{4} = \frac{48000}{4} = 12000\ \ symbols/s$$

Problem

- A signal is sampled at 8000 samples/s and the samples are quantized to 64 evenly spaced levels.Calculate and compare the bandwidths and ratio of peak signal power to rms quantization noise for binary and 4 level pulses
- Assume bandwidths to be 1/R and 1/Rs respectively for binary and 4 level signalling

Solution

$$Bit\ rate = R = 8000 \times 6 = 48000\ bits/s$$

$$Bandwidth\ = R = 48000\ Hz$$

$$\frac{S}{N} = 3L^2 = 3 \times (64)^2 = 12288$$

$$For\ \ 4\ level\ case$$

$$Symbol\ Rate\ = \frac{R}{k} = \frac{48000}{2} = 24000\ symbols/s$$

$$Bandwidth\ = 24000\ Hz$$

$$\frac{S}{N} ratio\ \ is\ \ same$$

Problem

- In a compact disc (CD) audio system an analog signal is digitized so that the ratio of peak signal power to peak quantization noise power is at least 96 dB.The sampling rate is 44.1 kilosamples/s

  (a) How many quantization levels are needed ?

  (b) How many bits/sample are needed ?

  © What is the data rate in bits/s ?

Solution

$$\left(\frac{S}{N}\right)_{peak} = \frac{V_p^2}{\left(\frac{q}{2}\right)^2} = \frac{4V_p^2}{q^2}$$

$$\frac{2V_p}{q} = L \;:\; \frac{4V_p^2}{q^2} = L^2$$

$$10\log L^2 = 96 \quad : L = 63096 \;\; so\ we\ take\ L = 65536$$

$$l = 16 \quad bits / sample$$

$$R = 16 \times 44100 = 705600\ bits / s$$