3-3.

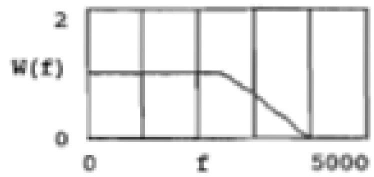
$A := 1 \qquad f1 := 2500 \qquad f2 := 4000$

$f := 0, 200 \,..\, 5000$

$W1(x) := \mathrm{if}(|x| < f1, A, 0)$

$$W2(x) := \left[\frac{-A}{f2 - f1}\right] \cdot (|x| - f2) \cdot (\Phi(|x| - f1) - \Phi(|x| - f2))$$

$W(x) := W1(x) + W2(x)$



$fs := 10000 \qquad \tau := 50 \; 10^{-6} \qquad Ts := \dfrac{1}{fs} \qquad d := \dfrac{\tau}{Ts}$

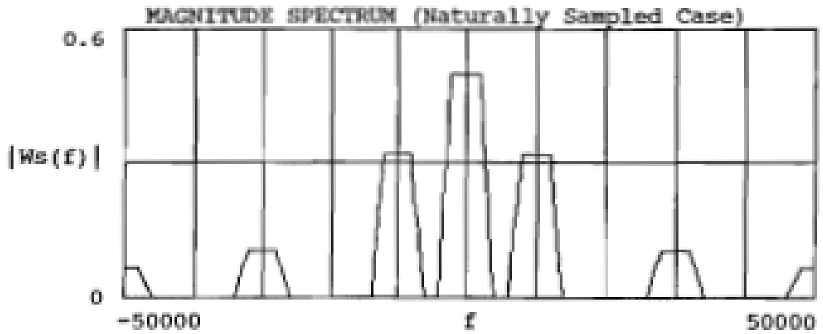
(a) Naturally-sampled PAM

$n := -5, -4 \,..\, 5 \qquad Sa(x) := \mathrm{if}\left[x \neq 0, \dfrac{\sin(x)}{x}, 1\right]$

$f := -50000, -48000 \,..\, 50000$

$$Ws(f) := d \cdot \sum_{n} (Sa(\pi \; n \; d)) \cdot W(f - n \cdot fs)$$

3-3 Cont'd.

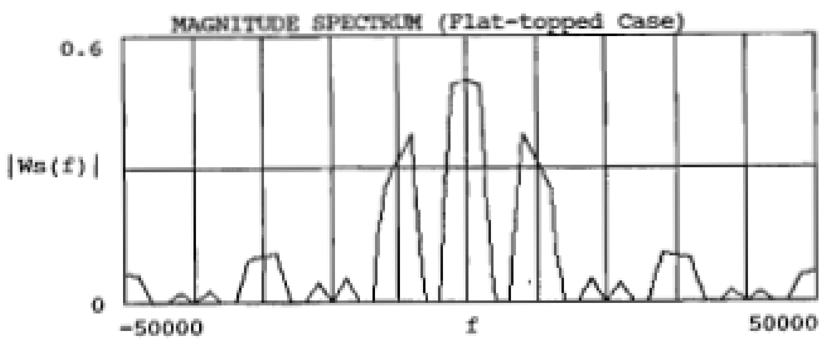


(b) Flat-topped PAM

$$H(f) := \tau\ Sa(\pi \cdot \tau\ f)$$

$$Ws(f) := \left[\frac{1}{Ts}\right] \cdot H(f) \cdot \sum_{n} W(f - n\ fs)$$

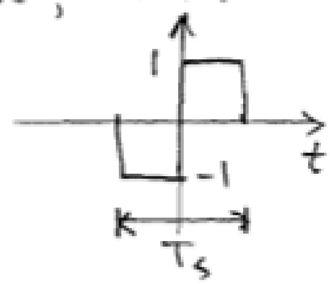
See next screen for plot



3-6. using (3-10)

$$W_s(f) = \frac{H(f)}{T_s} \sum_{k=-\infty}^{\infty} W(f - kf_s)$$

where $H(f)$ is the spectrum of the Manchester encoded pulse, $h(t)$.



Thus

$$H(f) = \int_{-\infty}^{\infty} h(t) e^{-j\omega t} dt$$

$$= \int_{-T_s/2}^{0} (-1) e^{-j\omega t} dt + \int_{0}^{T_s/2} (1) e^{-j\omega t} dt$$

$$= \frac{j}{\omega} \left[-e^{-j\omega t} \Big|_{-T_s/2}^{0} + e^{-j\omega t} \Big|_{0}^{T_s/2} \right]$$

$$= \frac{-j}{\omega} \left\{ 2 - 2 \left(\frac{e^{j\omega T_s/2} + e^{-j\omega T_s/2}}{2} \right) \right\} \rightarrow \cos \frac{\omega T_s}{2}$$

$$H(f) = -j T_s \frac{\left(1 - \cos \omega T_s/2\right)}{\omega T_s/2}$$

3-6 Cont'd.

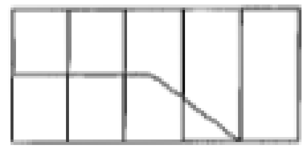
$A := 1 \quad f1 := 2500 \quad f2 := 4000$

$f := 0, 200 .. 5000$

$W1(x) := \mathrm{if}(|x| < f1, A, 0)$

$$W2(x) := \left[\frac{-A}{f2 - f1}\right] (|x| - f2)\,(\Phi(|x| - f1) - \Phi(|x| - f2))$$

$W(x) := W1(x) + W2(x)$



$fs := 10000$

$$Ts := \frac{1}{fs}$$

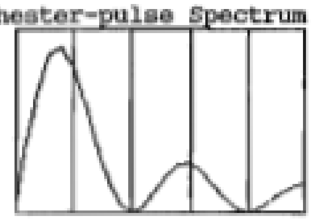
$j := \sqrt{-1}$

$n := -5, -4 .. 5$

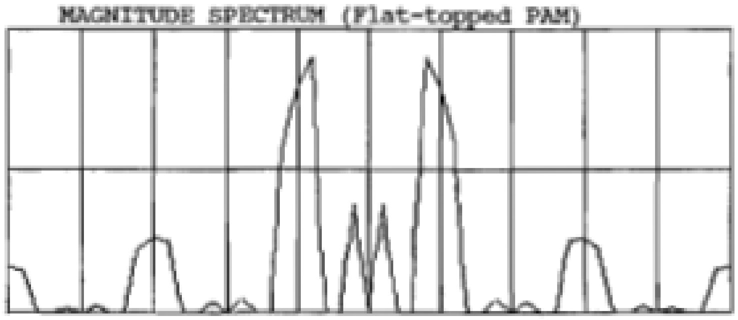
$$Sa(x) := \mathrm{if}\left[x \neq 0, \frac{\sin(x)}{x}, 1\right]$$

$f := -50000, -48000 .. 50000$

$$H(f) := j \cdot Ts \cdot Sa\left[\pi \cdot f \frac{Ts}{2}\right] \cdot \sin\left[2\,\pi \cdot f \cdot \frac{Ts}{4}\right]$$



$$Ws(f) := \left[\frac{1}{Ts}\right] \cdot H(f) \cdot \sum_{n} W(f - n\,fs)$$



3-11.

(a.) $f_s \geq 2 B_{analog} = 2(20\ kHz) = 40\ \frac{k\,samples}{sec}$

For 8X oversampling of the recovered PCM signal
(used to increase f_s 8X and simplify LPF requirements)

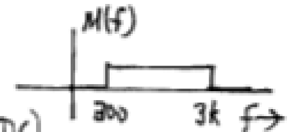
$\Rightarrow f_{8x} = 8 f_s = 320$ k samples/sec

$$B_{null} = R = n f_{8x} = \left(16 \frac{bits}{sample}\right)\left(320 \frac{k\,samples}{sec}\right) = \underline{\underline{5.12\ MHz}}$$

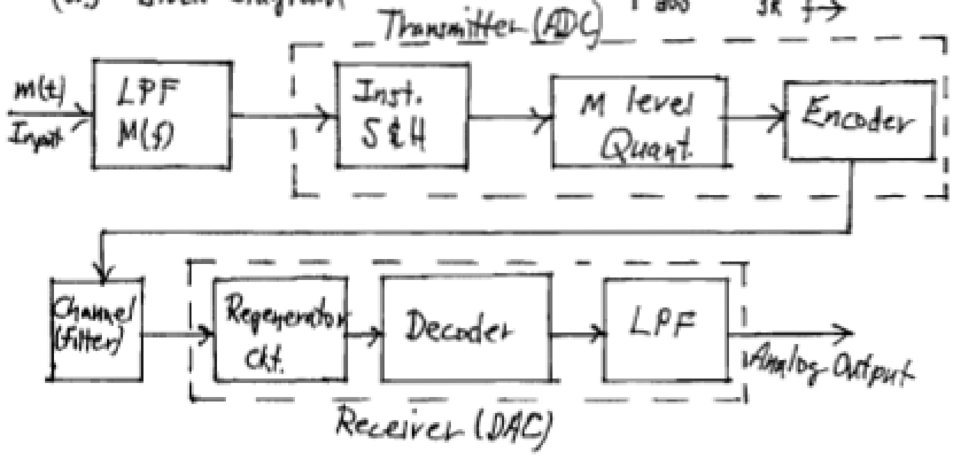
(b) Using (3-18)

$$\left(\frac{S}{N}\right)_{peak} = 6.02n + 4.77\,dB = 6.02(15) + 4.77 = \underline{\underline{94.77\,dB}}$$

3-12. PCM system



(a.) Block Diagram



(b.) Assume $P_e = 0 \Rightarrow$ Use (3-18).

$$\left(\frac{S}{N}\right)_{dB\ peak} = 6.02n + 4.77 = 30\,dB \Rightarrow n = 4.19$$

$\Rightarrow$ Use $n = 5 + \text{parity} = \underline{\underline{6}}$ (If no parity, $n = 5$ bits)

$$\Rightarrow B_{null} = R = n f_s = (6)\left(7k\ \frac{\text{samples}}{\text{sec}}\right) = \underline{\underline{42\ kHz}}\ \text{(with parity)}$$

$$B_{null} = (5)(7) = \underline{\underline{35\ kHz}}\ \text{(No parity)}$$

(c.) If the audio signal is a <u>voice</u> signal it is likely to have a large peak-to-average voltage ratio. Therefore, a non-uniform quantizer with smaller step sizes near the zero level will reduce the quantizing noise. A $\mu = 255$ non-uniform characteristic is typically used in the U.S. See the textbook for further discussion.

3-18.

dB := -30,-29 ..-5   M := 256 $n := \frac{\log(M)}{\log(2)}$

μ := 255   n = 8

$SNRa := 6.02\ n + 4.77 - 20\ \log(\ln(1 + \mu))$