S7

7.2-2

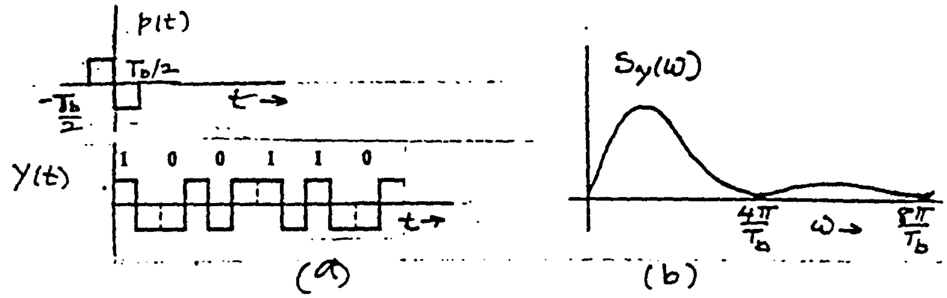

Fig. S 7.2-2

$$p(t) = \text{rect}\left(\frac{t+\frac{T_b}{4}}{T_b/2}\right) - \text{rect}\left(\frac{t-\frac{T_b}{4}}{T_b/2}\right)$$

and

$$P(\omega) = \frac{T_b}{2}\,\text{sinc}\left(\frac{\omega T_b}{4}\right)e^{j\omega T_b/4} + \frac{T_b}{2}\,\text{sinc}\left(\frac{\omega T_b}{4}\right)e^{-j\omega T_b/4}$$

$$= jT_b\,\text{sinc}\left(\frac{\omega T_b}{4}\right)\sin\left(\frac{\omega T_b}{4}\right)$$

$$S_y(\omega) = \frac{|P(\omega)|^2}{T_b} = T_b\,\text{sinc}^2\left(\frac{\omega T_b}{4}\right)\sin^2\left(\frac{\omega T_b}{4}\right)$$

From Fig. S7.2-2, it is clear that the bandwidth is $4\pi/T_b$ rad/s or $2R_b$ Hz.

8-9

andwidth is

7.3-1 From Eq. (7.32)

$$4000 = \frac{(1+r)6000}{2} \Rightarrow r = \frac{1}{3}$$

7.3-2 Quantization error $\frac{\Delta V}{2} = \frac{m_p}{L} \leq 0.01\, m_p \Rightarrow L \geq 1($

(a) Because L is a power of 2, we select $L = 128 = 2^7$

(b) This requires 7 bit code per sample.

Nyquist rate $= 2 \times 2000 = 4$ kHz for each signal.

The sampling rate $f_s = 1.25 \times 4000 = 5$ kHz.

Eight signals require $8 \times 5000 = 40{,}000$ samples/s.

Bit rate $= 40{,}000 \times 7 = 280$ kbits/s. From Eq. (7.32)

$$B_T = \frac{(1+r)R_b}{2} = \frac{1.2 \times 280 \times 10^3}{2} = 168 \text{ kHz}$$

7.3-3 (a) $B_T = 2R_b \Rightarrow R_b = 1.5$ kbits/s.

(b) $B_T = R_b \Rightarrow R_b = 3$ kbits/s.

(c) $B_T = \frac{1+r}{2} R_b$. Hence $3000 = \frac{1.25}{2} R_b \Rightarrow R_b = 4.8$ kbits/s.

(d) $B_T = R_b \Rightarrow R_b = 3$ kbits/s.

(e) $B_T = R_b \Rightarrow R_b = 3$ kbits/s.

7.3-4 (a) Comparison of $P(\omega)$ with that in Fig. 7.12 shows that this $P(\omega)$ does satisfy the Nyquist criterion with $\omega_b = 2\pi \times 10^6$ and $r = 1$. The excess bandwidth $\omega_x = \pi \times 10^6$.

(b) From Table 3.1, we find

$$p(t) = \text{sinc}^2(\pi \times 10^6 t)$$

From part (a), we have $\omega_b = 2\pi \times 10^6$ and $R_b = 10^6$. Hence $T_b = 10^{-6}$. Observe that

$$p(nT_b) = \begin{cases} 1 & n = 0 \\ 0 & n \neq 0 \end{cases}$$

Hence $p(t)$ satisfies Eq. (7.36).

(c) The pulse transmission rate is $1/T_b = R_b = 10^6$ bits/s

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7.3-5 In this case $R_b/2 = 1$ MHz. Hence we can transmit data at a rate $R_b = 2$ MHz. Also $B_T = 1.2$ MHz. Hence, from Eq. (7.32)

$$1.2 \times 10^6 = \frac{1+r}{2}(2 \times 10^6) \Rightarrow r = 0.2$$

7.3-6 $f_2 = 700$ kHz. Also $R_b/2 = 500$ kHz and $f_x = 700 - 500 = 200$k

Hence $r = \frac{f_x}{R_b/2} = 0.4$ and $f_1 = \frac{R_b}{2} - f_x = 500 - 200 = 300$ kHz.

(a)
7.7-3 Each 8-ary pulse carries $\log_2 8 = 3$ bits of information. Hence the bandwidth is reduced by a factor of 3

(b) The amplitudes of the 8 pulses used in this 8-ary scheme are $\pm A/2$, $\pm 3A/2$, $\pm 5A/2$ and $\pm 7A/2$. Consider binary case using pulses $\pm A/2$. Let the energy of each of these pulses (of amplitude $\pm A/2$) be E_b. The power of this binary case is

$$P_{binary} = E_b R_b$$

Because the pulse energy is proportional to the square of the amplitude, the energy of a pulse $\pm kA/2$ is $k^2 E_b$. Hence the average energy of the 8 pulse in the 8-ary case above is

$$E_{av} = \frac{E_b\left[2(\pm 1)^2 + 2\left(\pm\frac{3}{2}\right)^2 + 2\left(\pm\frac{5}{2}\right)^2 + 2\left(\pm\frac{7}{2}\right)^2\right]}{8} = 21E$$

Hence

$$P_{8\text{-}ary} = E_{av} \times \text{pulse rate} = 21\,E_b \times \frac{R_b}{3} = 7\,E_b R_b$$

Therefore $$P_{8\text{-}ary} = 7\,P_{binary}$$

7.7-1 (a) $M = 16$. Each 16-ary pulse conveys the information of $\log_2 16 = 4$ bits. Hence, we need

$$\frac{12000}{4} = 3000 \text{ 16-ary pulses/sec.}$$

Minimum transmission bandwidth $= \frac{3000}{2} = 1500$ Hz.

(b) From Eq. (7.32), we have $R_b = \frac{2}{1+r} B_T$. Hence

$$3000 = \frac{2}{1.2} B_T \Rightarrow B_T = 1800 \text{ Hz}.$$

7.7-4 (a) For polar signaling, R_b bits/sec requires a bandwidth of R_b Hz. The half-width rectangular pulse of amplitude $A/2$ has energy

$$E_b = \left(\frac{A}{2}\right)^2 \frac{T_b}{2} = \frac{A^2 T_b}{8}$$

The power P is given by

$$P = E_b R_b = \frac{A^2 T_b}{8} R_b = \frac{A^2}{8}$$

(b) The energy of a pulse $\pm k\frac{A}{2}$ is $k^2 E_b$. Hence the average energy of the M-ary pulse is

$$E_M = \frac{1}{M}\left[2E_b + 2(\pm 3)^2 E_b + 2(\pm 5)^2 E_b + \cdots + 2[\pm(M-1)]^2 E_b\right]$$

$$= \frac{2E_b}{M} \sum_{k=0}^{\frac{M-2}{2}} (2k+1)^2$$

$$= \frac{M^2-1}{3} E_b$$

Each M-ary pulse conveys the information of $\log_2 M$ bits. Hence, we require only $R_b/\log_2 M$ M-ary pulses/second. The power P_M is given by

$$P_M = \frac{E_M R_b}{\log_2 M} = \frac{M^2-1}{3\log_2 M} E_b = \frac{(M^2-1)A^2}{24 \log_2 M} \simeq \frac{M^2 A^2}{24 \log_2 M}$$