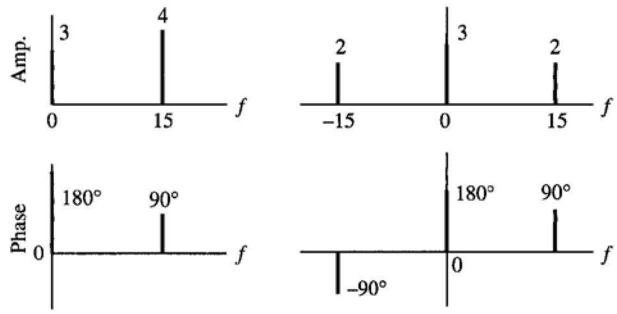
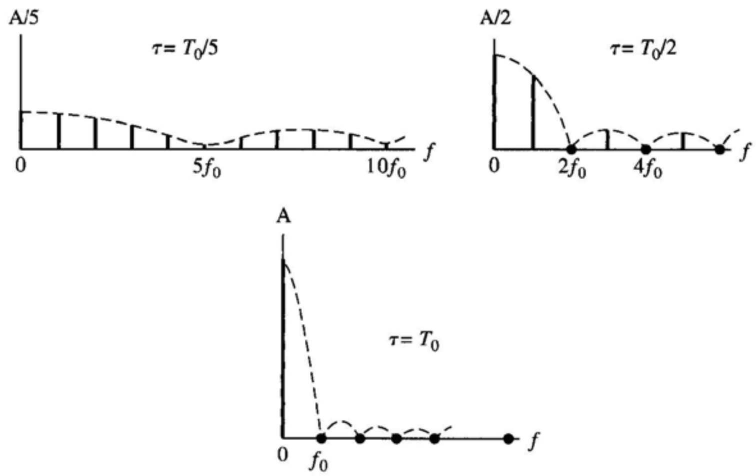
حل تمرینات

۲-۱-۱ .

$$v(t) = 3\cos(2\pi 0t \pm 180°) + 4\cos(2\pi 15t - 90° \pm 180°)$$



۲-۱-۲.



۲-۱-۳.

$$P = 7^2 + 2 \times 5^2 + 2 \times 2^2 = 107$$

۲-۲-۱.

$$V(f) = 2\int_0^{\infty} Ae^{-bt}\cos\omega t\,dt = \frac{2A}{\omega}\,\frac{b/\omega}{1 + (b/\omega)^2} = \frac{2Ab}{b^2 + (2\pi f)^2}$$

$$|V(f)| \geq \frac{1}{2}\left(\frac{2A}{b}\right) \Rightarrow |f| \leq \frac{b}{2\pi}$$

۲-۲-۲.

$$\int_{-\infty}^{\infty} |V(f)|^2\,df = \frac{2A^2}{b^2}\int_0^{\infty} \frac{df}{1 + (2\pi f/b)^2} = \frac{A^2}{\pi b}\,\frac{\pi/2}{\sin \pi/2} = \frac{A^2}{2b}$$

$$\int_{-\infty}^{\infty} |v(t)|^2\,dt = A^2\int_0^{\infty} e^{-2bt}\,dt = \frac{A^2}{2b}$$

۲-۲-۳.

$z(t) = V(t)$ with $b = 1$ and $2A = B$

پس ،

$$Z(f) = Ae^{-b|-f|} = \frac{B}{2}e^{-|f|}$$

.۲-۳-۱

$$\mathcal{F}[v(-t)] = \frac{1}{|-1|}[V_e(-f) + jV_o(-f)] = V_e(f) - jV_o(f)$$

$$\begin{aligned} Z(f) &= a_1[V_e(f) + jV_o(f)] + a_2[V_e(f) - jV_o(f)] \\ &= (a_1 + a_2)V_e(f) + j(a_1 - a_2)V_o(f) \end{aligned}$$

.۲-۳-۲

$$\frac{d}{df}\left[\int_{-\infty}^{\infty} v(t)e^{-j2\pi ft}\,dt\right] = \int_{-\infty}^{\infty} v(t)(-j2\pi t)e^{-j2\pi ft}\,dt = -j2\pi\mathcal{F}[tv(t)]$$

$$tv(t) \leftrightarrow \frac{1}{-j2\pi}\frac{d}{df}V(f)$$

.۲-۴-۱

$$(A \operatorname{sinc} 2Wt)^2 \leftrightarrow \frac{A}{2W}\Pi\left(\frac{f}{2W}\right) * \frac{A}{2W}\Pi\left(\frac{f}{2W}\right) = \begin{cases} \dfrac{A^2}{2W}\Lambda\left(\dfrac{f}{2W}\right) \\ 0 \qquad |f| > 2W \end{cases}$$

.۲-۵-۱

الف.

$$\int_{-\infty}^{\infty} v(t)\delta(t+4)\,dt = v(-4) = 49$$

ب.

$$v(t) * \delta(t+4) = v(t+4) = (t+1)^2$$

پ.

$$v(t)\delta(t+4) = v(-4)\delta(t+4) = 49\delta(t+4)$$

ت.

$$v(t) * \delta(-t/4) = |-4|v(t) * \delta(t) = 4(t-3)^2$$

.۲-۵-۲

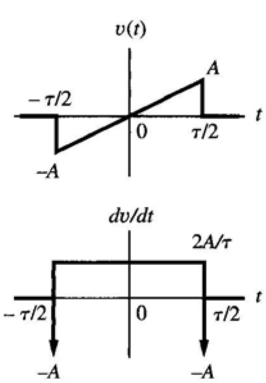
$$\begin{aligned} \mathcal{F}[Au(t)\cos\omega_c t] = \frac{A}{2}&\left[\frac{1}{j2\pi(f-f_c)} + \tfrac{1}{2}\delta(f-f_c)\right. \\ &\left. + \frac{1}{j2\pi(f+f_c)} + \tfrac{1}{2}\delta(f+f_c)\right] \end{aligned}$$

.۲-۵-۳

$$\frac{dv(t)}{dt} = \frac{2A}{\tau}\Pi\left(\frac{t}{\tau}\right) - A\delta\left(t+\frac{\tau}{2}\right) - A\delta\left(t-\frac{\tau}{2}\right)$$

$$j2\pi fV(f) = 2A \operatorname{sinc} f\tau - Ae^{j\pi f\tau} - Ae^{-j\pi f\tau}$$

$$V(f) = \frac{jA}{\pi f}(\cos\pi f\tau - \operatorname{sinc} f\tau)$$



۳-۱-۱.

$$g(t) = e^{-t/RC}u(t)$$

$$h(t) = e^{-t/RC}\frac{du}{dt} + \frac{d}{dt}(e^{-t/RC})u(t) = \delta(t) - \frac{1}{RC}e^{-t/RC}u(t)$$

۳-۱-۲.

$$H(f) = \frac{j2\pi fL}{R + j2\pi fL} = \frac{jf}{f_l + jf}$$

۳-۱-۳.

$$H(f) = T\,\mathrm{sinc}\,fT\,e^{-j2\pi fT},\ X(f) = A\tau\,\mathrm{sinc}\,f\tau$$

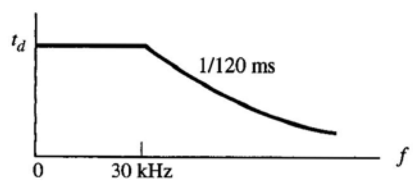
$$\tau \ll T,\ Y(f) \approx A\tau H(f),\ y(t) \approx A\tau h(t)$$

$$\tau = T,\ Y(f) = AT^2\,\mathrm{sinc}^2 fT\,e^{-j2\pi fT},\ y(t) = AT\Lambda\left(\frac{t-T}{T}\right)$$

$$\tau \gg T,\ Y(f) \approx TX(f),\ y(t) \approx Tx(t)$$

۳-۲-۱.

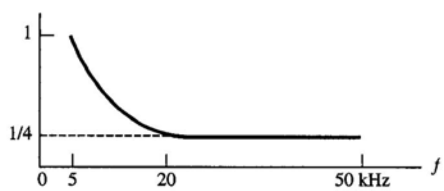
$$t_d(f) = \begin{cases} -\dfrac{1}{2\pi f}\left(-\dfrac{\pi}{2}\,\mathrm{rad}\right)\dfrac{f}{30\ \mathrm{kHz}} = \dfrac{1}{120}\ \mathrm{ms} & |f| < 30\ \mathrm{kHz} \\ -\dfrac{1}{2\pi f}\left(-\dfrac{\pi}{2}\,\mathrm{rad}\right) = \dfrac{1}{4f} & |f| > 30\ \mathrm{kHz} \end{cases}$$



۳-۲-۲.

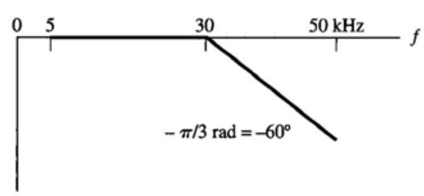
$$|H_{eq}(f)| = 1/4|H(f)|$$

$$= \begin{cases} \dfrac{1}{4}\dfrac{20\ \mathrm{kHz}}{f} & |f| < 20\ \mathrm{kHz} \\ \frac{1}{4} & |f| > 20\ \mathrm{kHz} \end{cases}$$



$$\arg H_{eq}(f) = -2\pi f\frac{10^{-3}}{120} - \arg H(f)$$

$$= \begin{cases} 0 & |f| < 30\ \mathrm{kHz} \\ -2\pi f\dfrac{10^{-3}}{120} + \dfrac{\pi}{2} & |f| > 30\ \mathrm{kHz} \end{cases}$$



۳-۳-۱.
الف.

$$P_{\mathrm{dBm}} = 10\log_{10}\left(\frac{P}{1\ \mathrm{mW}} \times \frac{10^3\ \mathrm{mW}}{1\ \mathrm{W}}\right)$$

$$= 10\log_{10}\frac{P}{1\ \mathrm{W}} + 10\log_{10}10^3 = P_{\mathrm{dBW}} + 30\ \mathrm{dB}$$

ب.

$$|H(f)|^2 = 10^{(-3\ \mathrm{dB}/10)} = 10^{-0.3} = 0.501 \Rightarrow |H(f)| \approx \frac{1}{\sqrt{2}}$$

۲-۳-۲.
الف.

$$33 \text{ dBm} - 24 \times 2.5 \text{ dB} = -27 \text{ dBm} = 10^{-2.7} \text{ mW} \approx 2\ \mu\text{W}$$

ب.

$$\begin{aligned} &-27 \text{ dBm} + 64 \text{ dB} - (40 - 24) \times 2.5 \text{ dB} \\ &\quad = -3 \text{ dBm} = 10^{-0.3} \text{ mW} \approx 0.5 \text{ mW} \end{aligned}$$

۳-۴-۱.

Let $f_c = f_l + B/2 = (f_l + f_u)/2$ and let $V(f) = 2K\Pi(f/B)$, so
$H(f) = \frac{1}{2}[V(f - f_c) + V(f + f_c)]e^{-j\omega t_d}$
$h(t) = v(t - t_d)\cos \omega_c(t - t_d) \quad$ where $v(t) = 2BK \operatorname{sinc} Bt$

۳-۴-۲.

$$|H(f)|_{\text{dB}} = 10 \log_{10} \frac{1}{1 + (f/B)^{2n}} \approx 10 \log_{10}\left(\frac{f}{B}\right)^{-2n}$$

$$= -20n \log_{10}\left(\frac{f}{B}\right) \quad \text{for } f > B$$

$$|H(2B)|_{\text{dB}} \approx -20n \log_{10} 2 = -6.0n \le -20 \text{ dB} \Rightarrow n \ge \frac{20}{6},\ n_{\min} = 4$$

۳-۴-۳.

$\tau_{\min} = 10\ \mu$s, but the minimum pulse spacing is $30\ \mu\text{s} - \tau_{\max} = 5\ \mu$s

$$B \ge \frac{1}{2 \times 5\ \mu\text{s}} = 100 \text{ kHz}, \quad t_r \approx \frac{1}{2B} = 5\ \mu\text{s}$$

۳-۵-۱.

$$\mathcal{F}[\hat{x}(t)] = (-j \operatorname{sgn} f)X(f)$$

$$\mathcal{F}\left[-\frac{1}{\pi t}\right] = -H_Q(f) = +j \operatorname{sgn} f$$

$$\mathcal{F}\left[\hat{x}(t) * \left(-\frac{1}{\pi t}\right)\right] = (\operatorname{sgn} f)^2 X(f)$$

$$= X(f) \Rightarrow \hat{x}(t) * \left(-\frac{1}{\pi t}\right) = x(t)$$

۳-۶-۱.

Let $z(t) = v(t) + w(t)$ where $v(t) = \frac{A}{2}e^{j\phi}e^{j\omega_0 t}$
$w(t) = \frac{A}{2}e^{-j\phi}e^{-j\omega_0 t}$
then $R_{vw}(\tau) = 0$ since $\omega_w \ne \omega_v$, so

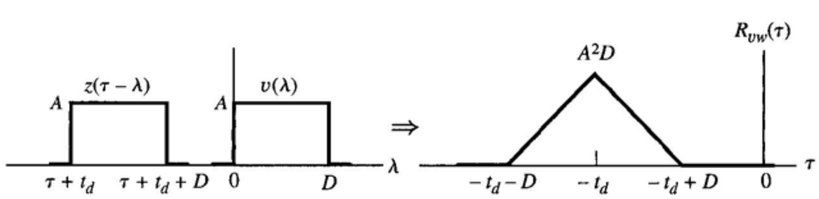
$$\begin{aligned} R_z(\tau) = R_v(\tau) + R_w(\tau) &= \left|\tfrac{A}{2}e^{j\phi}\right|^2 e^{j\omega_0 \tau} \\ &+ \left|\tfrac{A}{2}e^{-j\phi}\right|^2 e^{-j\omega_0 \tau} = \tfrac{A^2}{2}\cos \omega_0 \tau \end{aligned}$$

۳-۶-۲.

$z(t) = w^*(-t) = w(-t)$,

$$R_{vw}(\tau) = \int_{-\infty}^{\infty} v(\lambda)z(\tau - \lambda)\,d\lambda$$

$E_v = E_w = A^2 D$
$|R_{vw}(\tau)|^2_{\max} = (A^2 D)^2 = E_v E_w$ at
$\tau = -t_d$



.۳-۶-۳

$$\mathscr{F}_\tau[v^*(-\tau)] = \int_{-\infty}^{\infty} v^*(-\tau)e^{-j\omega\tau}\,d\tau$$
$$= \int_{-\infty}^{\infty} v^*(\lambda)e^{-j\omega\lambda}\,d\lambda$$
$$= \left[\int_{-\infty}^{\infty} v(\lambda)e^{-j\omega\lambda}\,d\lambda\right]^* = V^*(f) \text{ so}$$
$$G_v(f) = \mathscr{F}_\tau[R_v(\tau)] = \mathscr{F}_\tau[v(\tau) * v^*(-\tau)]$$
$$= V(f)V^*(f) = |V(f)|^2$$

.۴-۱-۱

$v_{bp}(t) = z(t) + z^*(t),\ z(t) = v_{lp}(t)e^{j\omega_c t}$

$V_{bp}(f) = \mathscr{F}[z(t)] + \mathscr{F}[z^*(t)]$

$\mathscr{F}[z(t)] = V_{lp}(f - f_c)$

and $\mathscr{F}[z^*(t)] = Z^*(-f) = V_{lp}^*(-f - f_c)$

so $V_{bp}(f) = V_{lp}(f - f_c) + V_{lp}^*(-f - f_c)$

.۴-۱-۲

$H_{lp}(f) = K_0 + K_1 f/f_c, \quad f_l - f_c < f < f_u - f_c$

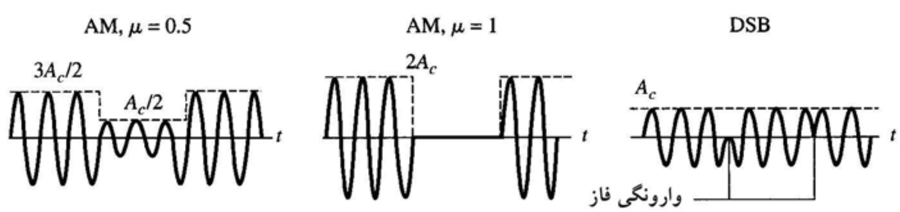
$Y_{lp}(f) = K_0 X_{lp}(f) + \dfrac{K_1}{j2\pi f_c}[j2\pi f X_{lp}(f)]$

$x_{bp}(t) = A_x(t)\cos\omega_c t \Rightarrow x_{lp}(t) = \frac{1}{2}A_x(t)$

so $y_{lp}(t) = \frac{1}{2}K_0 A_x(t) + j\frac{1}{2}\left[\dfrac{-K_1}{2\pi f_c}\dfrac{dA_x(t)}{dt}\right]$

$y_i(t) = K_0 A_x(t),\ y_q(t) = \dfrac{-K_1}{2\pi f_c}\dfrac{dA_x(t)}{dt}$

.۴-۲-۱



.۴-۲-۲

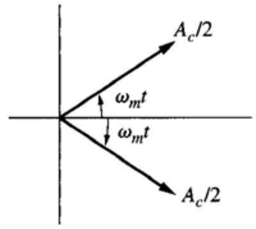
DSB: $S_T = 2P_{sb} = 20\text{ W},\ A_{\max}^2 = \dfrac{P_{sb}}{S_x/4} = 200\text{ W}$

AM: $P_c = \dfrac{P_{sb}}{\frac{1}{2}\mu^2 S_x} = 100\text{ W} \Rightarrow S_T = P_c + 2P_{sb} = 120\text{ W}$

$A_{\max}^2 = \dfrac{P_{sb}}{S_x/16} = 800\text{ W}$

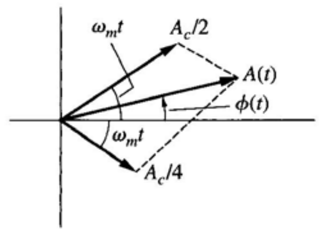
.۴-۲-۳

$$x_c(t) = \frac{A_c}{2}\cos(\omega_c - \omega_m)t + \frac{A_c}{2}\cos(\omega_c + \omega_m)t$$



$$v_i = \frac{A_c}{2}\cos\omega_m t + \frac{A_c}{4}\cos\omega_m t = \frac{3A_c}{4}\cos\omega_m t$$

$$v_q = \frac{A_c}{2}\sin\omega_m t - \frac{A_c}{4}\sin\omega_m t = \frac{A_c}{4}\sin\omega_m t$$



$$A(t) = \sqrt{(\tfrac{3}{4}A_c\cos\omega_m t)^2 + (\tfrac{1}{4}A_c\sin\omega_m t)^2} = \frac{A_c}{4}\sqrt{9\cos^2\omega_m t + \sin^2\omega_m t}$$

$$= \frac{A_c}{4}\sqrt{8\cos^2\omega_m t + 1} = \frac{A_c}{4}\sqrt{5 + 4\cos 2\omega_m t}$$

$$\phi(t) = \arctan\frac{A_c/4\sin\omega_m t}{3A_c/4\cos\omega_m t} = \arctan\left(\frac{\tan\omega_m t}{3}\right)$$

۴-۳-۱.

Expanding $\cos^3\theta = \frac{3}{4}\cos\theta + \frac{1}{4}\cos 3\theta$,

$$v_{out\pm} = a_1(\underline{A_c\cos\omega_c t} \pm \tfrac{1}{2}x) + a_2(A_c^2\cos^2\omega_c t \pm \underline{2\tfrac{x}{2}A_c\cos\omega_c t} + \tfrac{x^2}{4})$$
$$+ a_3(\underline{A_c^3\tfrac{3}{4}\cos\omega_c t} + A_c^3\tfrac{1}{4}\cos 3\omega_c t \pm 3\tfrac{x}{2}A_c^2\cos^2\omega_c t + \underline{3\tfrac{x^2}{4}A_c\cos\omega_c t} \pm \tfrac{x^3}{8})$$

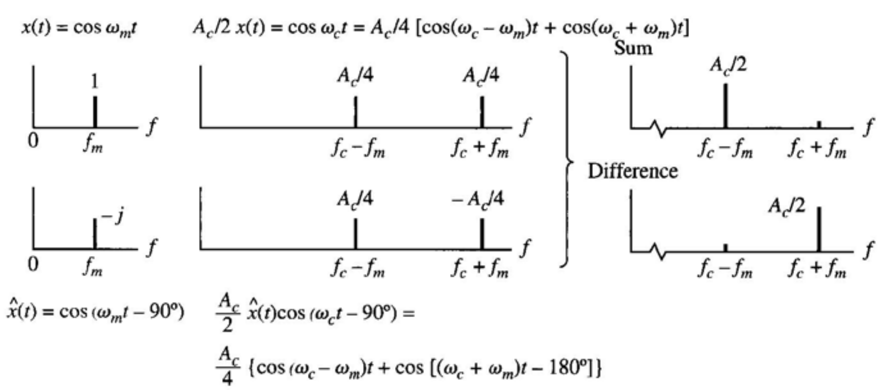
تنها جملاتی که از PDF عبور می کنند، زیرشان خط کشیده شده است، بنابراین :

$$x_c(t) = v_{out+} - v_{out-} = 2a_2x(t)A_c\cos\omega_c t = (2a_2A_c)x(t)\cos\omega_c t$$

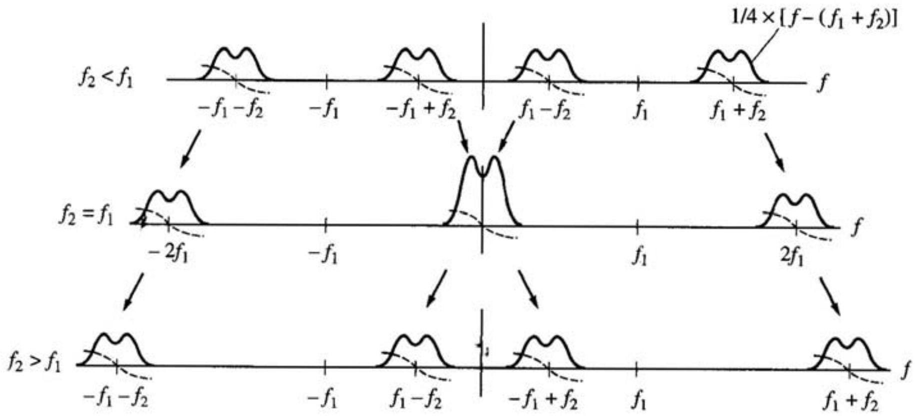
۴-۴-۱.

$$x_c(t) = \tfrac{1}{2}A_cA_m(\cos\omega_m t\cos\omega_c t \mp \sin\omega_m t\sin\omega_c t)$$
$$= \tfrac{1}{4}A_cA_m[\cos(\omega_c - \omega_m)t + \cos(\omega_c + \omega_m)t$$
$$\mp \cos(\omega_c - \omega_m)t \pm \cos(\omega_c + \omega_m)t]$$
$$= \tfrac{1}{2}A_cA_m\cos(\omega_c \pm \omega_m)t$$
$$A(t) = \tfrac{1}{2}A_c\sqrt{A_m^2\cos^2\omega_m t + A_m^2\sin^2\omega_m t} = \tfrac{1}{2}A_cA_m$$

۴-۴-۲.



۴-۵-۱.



۴-۵-۲.

Let $a = A_c A_m/2$

$$A^2(t) = (A_{LO}\cos\phi' + a\cos\omega_m t)^2 + (A_{LO}\sin\phi' \pm a\sin\omega_m t)^2$$
$$= A_{LO}^2 + a^2 + 2A_{LO}a\underbrace{(\cos\omega_m t\cos\phi' \pm \sin\omega_m t\sin\phi')}_{\cos(\omega_m t \mp \phi')} \quad \text{and}$$

$$A(t) = A_{LO}\sqrt{1 + \left(\frac{a}{A_{LO}}\right)^2 + \frac{2a}{A_{LO}}\cos(\omega_m t \mp \phi')}$$
$$\approx A_{LO} + \tfrac{1}{2}A_c A_m \cos(\omega_m t \mp \phi')$$

۵-۱-۱.

$$x_c(t) = A_c\cos[\omega_c t + \omega_c \mu x(t)t] \Rightarrow \theta_c(t) = 2\pi[f_c t + f_c\mu x(t)t]$$
$$f(t) = \tfrac{1}{2\pi}\dot{\theta}_c(t) = f_c + f_c\mu x(t) + f_c\mu\dot{x}(t)t$$
$$= f_c[1 + \mu\cos\omega_m t - \mu\omega_m t\sin\omega_m t]$$

so $f(t) \approx -f_c\mu\omega_m t\sin\omega_m t$ for $\mu\omega_m t \gg 1$ and $|f(t)| \to \infty$ as $t \to \infty$

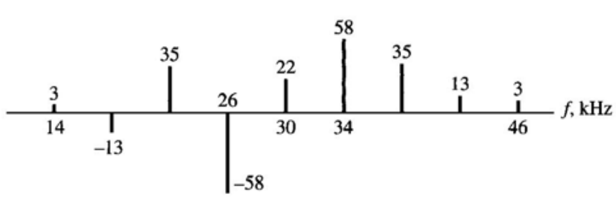
۵-۱-۲.

$$\mathscr{F}[\phi(t)] = \frac{\phi_\Delta}{2W}\Pi\left(\frac{f}{2W}\right),\ \mathscr{F}[\phi^2(t)] = \frac{\phi_\Delta}{2W}\Lambda\left(\frac{f}{2W}\right)$$
$$X_c(f) = \frac{1}{2}A_c\left\{\delta(f-f_c) + \frac{j\phi_\Delta}{2W}\Pi\left(\frac{f-f_c}{2W}\right) - \frac{\phi_\Delta}{4W}\Lambda\left(\frac{f-f_c}{2W}\right)\right\},\ f \ge 0$$

۵-۱-۳.

$\beta = 8\text{ kHz}/4\text{ kHz} = 2$

$f_c = 30\text{ kHz}$

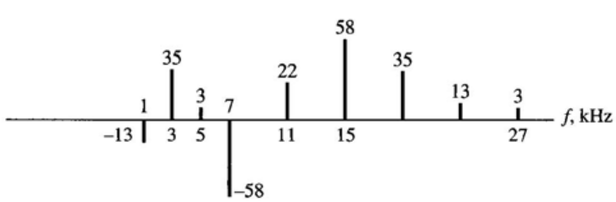


$f_c = 11\text{ kHz}$

Note "folded" terms at

$|11 - 12| = 1\text{ kHz}$

$|11 - 16| = 5\text{ kHz}$



۵-۲-۱.

D	$2M(D)$	تقریب
0.3	3.0	$2(D+1) = 2.6$
3.0	10	$2(D+2) = 10$
30	⋯	$2(D+1) = 62$

۵-۲-۲.

Since $H(f + f_c) = e^{-j2\pi t_1 f}$, we have $K_0 = 1$, $K_1 = 0$, and $t_0 = 0$ in Eq. (12), so $A(t) = A_c$,

$$\phi(t - t_1) = \beta \sin \omega_m(t - t_1)$$
$$= \beta(\cos \omega_m t_1 \sin \omega_m t - \sin \omega_m t_1 \cos \omega_m t)$$
$$\approx \beta(\sin \omega_m t - \omega_m t_1 \cos \omega_m t) \quad \omega_m t_1 \ll \pi$$

and $y_c(t) \approx A_c \cos(\omega_c t + \beta \sin \omega_m t - \beta\omega_m t_1 \cos \omega_m t)$

For Eq. (14), $|H(f_c)| = 1$ and $f(t) = f_c + \beta f_m \cos \omega_m t$, so

$\arg H[f(t)] = -2\pi t_1[f(t) - f_c] = -\beta\omega_m t_1 \cos \omega_m t$ and

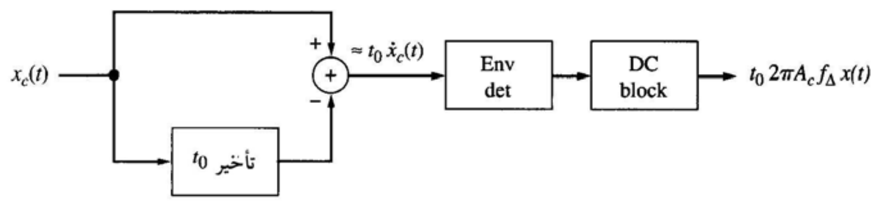
$$y_c(t) = A_c \cos(\omega_c t + \beta \sin \omega_m t - \beta\omega_m t_1 \cos \omega_m t)$$

۵-۳-۱.

$$x_c(t) = A_c \cos \omega_c t - A_c\phi_\Delta x \sin \omega_c t = A_c\sqrt{1 + (\phi_\Delta x)^2} \cos[\omega_c t + \arctan(\phi_\Delta x)]$$
$$\phi(t) = \arctan(\phi_\Delta x) = \phi_\Delta x(t) - \tfrac{1}{3}\phi_\Delta^3 x^3(t) + \tfrac{1}{5}\phi_\Delta^5 x^5(t) + \cdots$$

۵-۳-۲.

$$x_c(t) - x_c(t - t_0) \approx t_0 \dot{x}_c(t) = t_0 2\pi A_c[f_c + f_\Delta x(t)]\sin[\theta_c(t) \pm 180°]$$



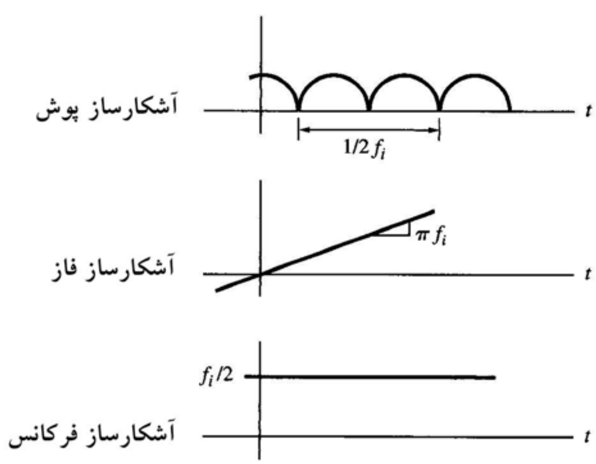
۵-۴-۱.

$$1 + \cos\theta_i = 2\cos^2\frac{\theta_i}{2} \text{ so}$$

$$A_v(t) = A_c\sqrt{2 + 2\cos\theta_i} = A_c\sqrt{4\cos^2\frac{\theta_i}{2}} = 2A_c\left|\cos\frac{\omega_i t}{2}\right|$$

$$\frac{\sin\theta_i}{1 + \cos\theta_i} = \frac{2\sin\frac{\theta_i}{2}\cos\frac{\theta_i}{2}}{2\cos\frac{\theta_i}{2}} = \tan\frac{\theta_i}{2} \text{ so}$$

$$\phi_v(t) = \arctan\left(\tan\frac{\theta_i}{2}\right) = \frac{\omega_i t}{2}$$



۵-۴-۲.

$$A_{mpe} = A_m\sqrt{1 + (f/B_{de})^2} \leq \frac{1\text{ kHz}}{15\text{ kHz}}\sqrt{1 + 7.5^2} \approx 0.5$$
$$\beta = 0.5 \times 75\text{ kHz}/15\text{ kHz} = 2.5, M(\beta) \approx 4.5$$
$$B \approx 2 \times 4.5 \times 15\text{ kHz} = 135\text{ kHz} < B_T$$

۶-۱-۱.

$$s_p(t) = \sum_{n=-\infty}^{\infty} c_n e^{-jn\omega_s t},\ p(t) = s_p(t)\Pi\left(\frac{t}{T_s}\right) \Rightarrow c_n = \frac{1}{T_s}P(nf_s)$$
$$S_p(f) = \mathscr{F}\left[\sum_n \frac{1}{T_s}P(nf_s)e^{-jn\omega_s t}\right] = f_s\sum_{n=-\infty}^{\infty}P(nf_s)\delta(f - nf_s)$$

۶-۱-۲. مقادیر نمونه ها یکسانند، پس امواج بازسازی شده برای هر دو سیگنال یکی است.

۶-۲-۱.

$$\frac{1}{\tau} = \frac{1}{0.1T_s} = 10f_s = 80\text{ kHz},\quad B_T \geq \frac{1}{2\tau} = 40\text{ kHz}$$

۶-۳-۱.

$$c_n = f_s\tau\ \text{sinc}\ nf_s\tau = \frac{1}{\pi n}\sin \pi nf_s\tau$$
$$x_p(t) = A\left[f_s\tau + \sum_{n=1}^{\infty}\frac{2}{\pi n}\sin \pi nf_s\tau \cos n\omega_s t\right] \quad \tau = \tau_0[1 + \mu x(t)]$$
$$= Af_s\tau_0[1 + \mu x(t)] + \sum_{n=1}^{\infty}\frac{2A}{\pi n}\sin\{n\pi f_s\tau_0[1 + \mu x(t)]\}\cos n\omega_s t$$

۷-۱-۱.

$$f_{IF} = 7.0 \text{ and } 10 < f_{LO} < 10.5 \text{ with } f_c' - 10.5 = 7 \Rightarrow 17 < f_c' < 17.5$$
$$f_{IF} = 7.0 \text{ and } 30 < f_{LO} < 31.5 \text{ with } 31.5 - f_c'' = 7 \Rightarrow 23 < f_c'' < 24.5$$
$$f_{IF} = 7.0 \text{ and } 30 < f_{LO} < 31.5 \text{ with } f_c''' - 31.5 = 7 \Rightarrow 37 < f_c''' < 38.5$$

با فیلتر LPF باتروررث مرتبه اول میزان حذف چنین است :

$$\left[20\log\frac{1}{\sqrt{1 + (f/4)^2}}\right]_{f=17,\,23,\,37\text{ MHz}} = -12.8\text{ dB}, -15.3\text{ dB, and}$$
$$-19.4\text{ dB}$$

۷-۱-۲.

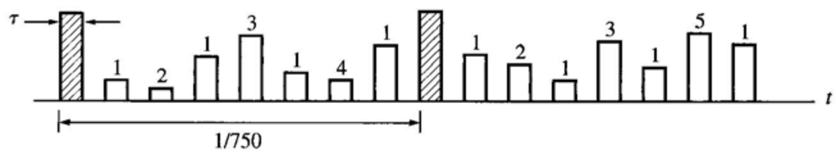
$$H_{RF}(f_c) = 1, H_{RF}(f_c') = \left[1 + jQ\left(x - \frac{1}{x}\right)\right]^{-1} \text{ where } x = \frac{f_c'}{f_c}$$
$$RR = 1 + 50^2\left(x - \frac{1}{x}\right)^2 = 10^6 \Rightarrow x \approx 20 \text{ or } \frac{1}{20}$$
$$\text{But } \frac{f_c'}{f_c} = 1 + \frac{2f_{IF}}{f_c} > 1 \quad \text{so take} \quad \frac{f_c'}{f_c} \approx 20 \text{ and } f_{IF} \approx 9.5f_c$$

۷-۲-۱.

$$(v_2\cos\omega_2 t)^2 v_1\cos\omega_1 t = \tfrac{1}{2}v_2^2(1 + \cos 2\omega_2 t)v_1\cos\omega_1 t$$
$$= \tfrac{1}{2}v_1v_2^2\cos\omega_1 t + \text{components at } |2f_2 \pm f_1|$$
$$\text{AM: } v_1v_2^2 = 1 + x_1(t) + \underbrace{2x_2(t)}_{\text{intelligible}} + \underbrace{2x_1(t)x_2(t) + x_1(t)x_2^2(t) + x_2^2(t)}_{\text{unintelligible}}$$
$$\text{DSB: } v_1v_2^2 = x_1(t)x_2^2(t) \text{ unintelligible}$$

۷-۲-۲.

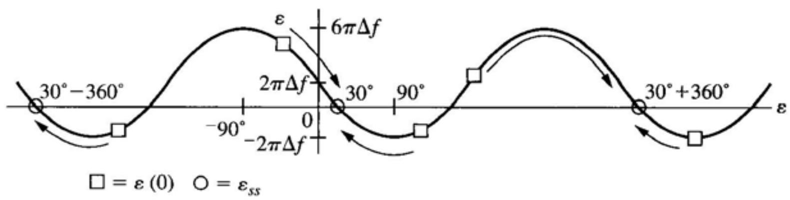
$\tau = \frac{1}{2} \times \frac{1}{8} \times \frac{1}{750}$, $B_T \geq \frac{1}{2\tau} = 8 \times 750 = 6$ kHz



۷-۲-۳.

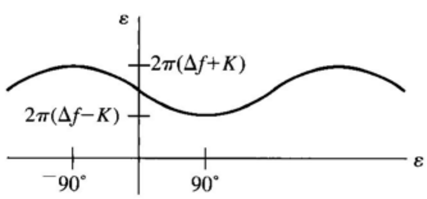
$T_g = (-60)/(-54.5 \times 4 \times 10^5) \approx 2.8\ \mu\text{s}$,
$T_s/M = 1/(10 \times 8 \times 10^3) = 12.5\ \mu\text{s}$,
$\tau = 12.5/5 = 2.5\ \mu\text{s}$, $t_0 \leq \frac{1}{2}(12.5 - 2.5 - 2.8) \approx 3.6\ \mu\text{s}$

۷-۳-۱.



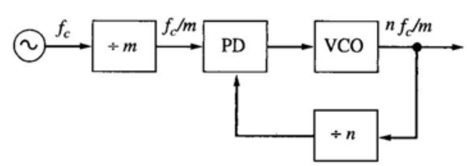
در ازای هر $0 < \varepsilon$ برای همه ε ها .

بنابراین $\varepsilon(t)$ به طور پیوسته افزایش می یابد و ε وجود ندارد.



۷-۳-۲.

$$f_v = \frac{nf_c}{m} - \Delta f, \quad K \geq |\Delta f| = \left| f_v - \frac{nf_c}{m} \right|$$



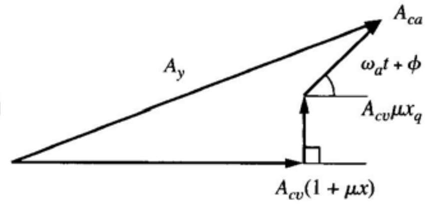
۷-۴-۱.

$$n_p = (37 \text{ cm} \times 40 \text{ lines/cm})(59 \text{ cm} \times 40 \text{ lines/cm}) \approx 3.5 \times 10^6$$

$$T_{frame} = \frac{1}{3.2 \times 10^3} \times \frac{0.714 n_p}{1 \times 1} = 781 \text{ sec} \approx 13 \text{ min}$$

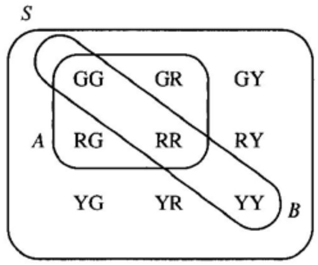
۷-۴-۲.

$-\sin \omega_{cv} t = \cos(\omega_{cv} t + 90°)$
$A_{ca} \ll A_{cv}$, $|\mu x| < 1$, and $|\mu x_q| \ll 1$
Thus, $A_y \approx A_{cv}(1 + \mu x) + A_{ca}\cos(\omega_a t + \phi)$



۸-۱-۱.

$M = 9$ equally likely outcomes
$P(A) = 4/9$
$P(B) = 3/9 = 1/3$
$P(AB) = P(GG + RR) = 2/9$
$P(A + B) = 5/9$



۸-۱-۲.

$P(D) = 4/8,\ P(BD) = 1/8,$
$P(B|D) = (1/8)/(4/8) = 2/8 = P(B)$
$P(D|B) = (1/8)/(2/8) = 4/8 = P(D),$
$P(B)P(D) = (2/8)(4/8) = 1/8 = P(BD)$

۸-۲-۱.

Outcome	*GG*	*GR*	*GY*	*RG*	*RR*	*RY*	*YG*	*YR*	*YY*
Weights	2,2	2,−1	2,0	−1,2	−1,−1	−1,0	0,2	0,−1	0,0
X	2.0	0.5	1.0	0.5	−1.0	−0.5	1.0	−0.5	0.0

x_i	−1.0	−0.5	0.0	0.5	1.0	2.0
$P_X(x_i)$	1/9	2/9	1/9	2/9	2/9	1/9
$F_X(x_i)$	1/9	3/9	4/9	6/9	8/9	9/9

$$P(-1.0 < X \le 1.0) = F_X(1.0) - F_X(-1.0) = 7/9$$

۸-۲-۲.

$$P(\pi < X < 3\pi/2) = \int_{\pi}^{3\pi/2} \frac{1}{2\pi}\, dx = \frac{1}{4},$$
$$P(X > 3\pi/2) = \int_{3\pi/2}^{2\pi} \frac{1}{2\pi}\, dx = \frac{1}{4}$$
$$P(\pi < Z \le 3\pi/2) = \int_{\pi^+}^{3\pi/2} \frac{1}{2\pi}\, dz = \frac{1}{4},$$
$$P(\pi \le Z \le 3\pi/2) = \int_{\pi^-}^{3\pi/2} \left[\frac{1}{2}\delta(z+\pi) + \frac{1}{2\pi}\right] dz = \frac{3}{4}$$

۸-۲-۳.

$p_X(x) = 1/4$ for $0 < x \le 4$, $g^{-1}(z) = z^2 \Rightarrow dg^{-1}(z)/dz = 2z$
$p_Z(z) = z/2 \quad 0 < z \le 2$
$\quad\quad = 0 \quad$ otherwise

۸-۳-۱.

$$m_X = \int_0^{2\pi} x\frac{1}{2\pi}\, dx = \pi \quad \overline{X^2} = \int_0^{2\pi} x^2 \frac{1}{2\pi}\, dx = \frac{4\pi^2}{3}$$
$$\sigma_X = \sqrt{(4\pi^2/3) - \pi^2} = \pi/\sqrt{3},$$
$$P(|X - m_X| < 2\sigma_X)$$
$$= P(\pi - 2\pi/\sqrt{3} < X < \pi + 2\pi/\sqrt{3}) = 1$$

.۸-۲-۲

$$
\begin{aligned}
E[X+Y] &= \int_{-\infty}^{\infty}\int_{-\infty}^{\infty}(x+y)p_{XY}(x,y)\,dx\,dy \\
&= \int_{-\infty}^{\infty} x\left[\int_{-\infty}^{\infty} p_{XY}(x,y)\,dy\right]dx \\
&\quad + \int_{-\infty}^{\infty} y\left[\int_{-\infty}^{\infty} p_{XY}(x,y)\,dx\right]dy \\
&= \int_{-\infty}^{\infty} x p_X(x)\,dx + \int_{-\infty}^{\infty} y p_Y(y)\,dy = \overline{X} + \overline{Y}
\end{aligned}
$$

.۸-۲-۳

$\Phi_X(2\pi t) = \mathscr{F}^{-1}[a^{-1}\Pi(f/a)] = \text{sinc}\, at$, so
$\Phi_X(\nu) = \text{sinc}\, at|_{t=\nu/2\pi} = \text{sinc}(a\nu/2\pi)$

.۸-۴-۱

$m = 10^4 \times 5 \times 10^{-5} = 0.5,\ P_I(i) \approx e^{-0.5}(0.5^i/i!)$

$$F_I(2) \approx e^{-0.5}\left(\frac{0.5^0}{0!} + \frac{0.5^1}{1!} + \frac{0.5^2}{2!}\right) = 0.986$$

.۸-۴-۲

$$
\begin{aligned}
&\sigma = 8 \text{ so } 9 = m + 0.5\sigma,\ 25 = m + 2.5\sigma \\
&P(9 < X \le 25) = P(X > 9) - P(X \ge 25) \\
&\qquad = P(X - m > 0.5\sigma) - P(X - m \ge 2.5\sigma) \\
&\qquad = Q(0.5) - Q(2.5) \approx 0.31 - 0.06 \approx 0.30
\end{aligned}
$$

.۸-۴-۳

$$F_R(r) = \int_{-\infty}^{r} p_R(\lambda)\,d\lambda = \int_0^r \left(\frac{\lambda}{\sigma^2}\right)e^{-\lambda^2/2\sigma^2}\,d\lambda \quad r \ge 0$$

Let $\alpha = \lambda^2/2\sigma^2$ so

$$F_R(r) = \int_0^{r^2/2\sigma^2} e^{-\alpha}\,d\alpha = 1 - e^{-r^2/2\sigma^2} \quad r \ge 0$$

.۹-۱-۱

$$
\begin{aligned}
&\overline{v(t)} = E[X + 3t] = \overline{X} + 3t = 3t \\
&R_v(t_1, t_2) = E[X^2 + 3(t_1 + t_2)X + 9t_1t_2] \\
&\qquad = \overline{X^2} + 3(t_1 + t_2)\overline{X} + 9t_1t_2 = 5 + 9t_1t_2 \\
&\quad \overline{v^2(t)} = R_v(t,t) = 5 + 9t^2
\end{aligned}
$$

.۹-۱-۲

$$
\begin{aligned}
E[z^2(t_1,t_2)] &= E[v^2(t_1) + v^2(t_2) \pm 2v(t_1)v(t_2)] \\
&= \overline{v^2(t_1)} + \overline{v^2(t_2)} \pm 2R_v(t_1,t_2) \ge 0
\end{aligned}
$$

Since $\overline{v^2(t)} = R_v(0)$ for all t,

$$
\begin{aligned}
|R_v(\tau)| &= |R_v(t, t-\tau)| \\
&\le \tfrac{1}{2}\left[\overline{v^2(t)} + \overline{v^2(t-\tau)}\right] = R_v(0)
\end{aligned}
$$

۹-۱-۲.

$$R_w(t_1, t_2) = E[4v(t_1)v(t_2) - 16v(t_1) - 16v(t_2) + 64]$$
$$= 4R_v(t_1, t_2) - 16[\overline{v(t_1)} + \overline{v(t_2)}] + 64$$
$$= 36e^{-5|t_1 - t_2|} + 64$$

Thus, $R_w(\tau) = 36e^{-5|\tau|} + 64$ and

$\overline{w^2} = R_w(0) = 100$, $m_w = \sqrt{R_w(\pm\infty)} = 8$,

$\sigma_w = \sqrt{100 - 8^2} = 6$

Hence, $w(t)$ is stationary and ergodic.

پس w(t) ایستا و ارگودیک است .

۹-۲-۱.

$$R_z(\tau) = E[v(t)v(t-\tau) - m_V v(t-\tau) - m_V v(t) + m_V^2]$$
$$= R_v(\tau) - m_V^2 - m_V^2 + m_V^2$$

Thus, $R_v(\tau) = R_z(\tau) + m_V^2 \Rightarrow G_v(f) = G_z(f) + m_V^2\delta(f)$

۹-۲-۲. بگذارید w(t) سینوسی با فاز تصادفی با A = 1 باشد، بنابراین :

Let $w(t)$ be a randomly phased sinusoid with $A = 1$, so

$G_w(f) = \frac{1}{4}[\delta(f - f_c) + \delta(f + f_c)]$ and

$G_z(f) = G_v(f) * G_w(f) = \frac{1}{4}[G_v(f - f_c) + G_v(f + f_c)]$

۹-۲-۳.

$G_x(f) = \sigma^2 D \operatorname{sinc}^2 fD \approx \sigma^2 D$ for $|f| \ll 1/D$. Thus, if $B \ll 1/D$,

$$G_y(f) \approx \frac{1}{1 + (f/B)^2}\sigma^2 D \quad \text{and} \quad R_y(\tau) \approx \sigma^2 D\pi B e^{-\pi B|\tau|}$$

۹-۳-۱.

$$\overline{v^2} = \frac{2(\pi 4 \times 10^{-22})^2}{3 \times 6.62 \times 10^{-34}} \times 1000 = 1.6 \times 10^{-6}\ \text{V}^2,$$

$\sigma_V \approx 1.26$ mV $\quad h/2k\mathcal{T} \approx 8 \times 10^{-13}$ so

$h|f|/2k\mathcal{T} \ll 1$ for $|f| \leq 10^9$

$$\int_{-10^9}^{10^9} G_v(f)\, df \approx 2 \times 10^9 G_v(0) = 1.6 \times 10^{-9}\ \text{V}^2, \text{ and}$$

$$\frac{1.6 \times 10^{-9}}{1.6 \times 10^{-6}} = 0.1\%$$

۹-۳-۲.

$|H(f)|^2 = 1/[1 + (f/B)^{2n}]$ and $g = |H(0)|^2 = 1$ so

$$B_N = \int_0^\infty \frac{df}{1 + (f/B)^{2n}} = B\int_0^\infty \frac{d\lambda}{1 + \lambda^{2n}}$$
$$= B\frac{\pi/2n}{\sin(\pi/2n)} = \frac{\pi B}{2n\sin(\pi/2n)}$$

and $[\sin(\pi/2n)]/(\pi/2n) = \operatorname{sinc}(1/2n) \to 1$ as $n \to \infty$

۹-۴-۱.

$$S_{R_{\text{dBm}}} + 174 - 10\log_{10}(5 \times 4.2 \times 10^6) \geq 50\ \text{dB}$$
$$\Rightarrow S_R \geq -51\ \text{dBm} = 8.4 \times 10^{-6}\ \text{mW}$$

$S_T \geq 10^{14} S_R = 840$ kW without repeater

$S_T \geq 840\ \text{kW}/(5 \times 10^6) = 168$ mW with repeater

۹-۵-۱.
الف.

$$\sigma_A/A = \sqrt{N_0/2E_p} = 0.1,$$
$$\sigma_t/\tau = \sqrt{N_0/4BE_p\tau} = \sqrt{N_0/2E_p} = 0.1$$

ب.

$$\sigma_A/A = \sqrt{N_0 B_T/A^2} = \sqrt{N_0 B_T \tau/E_p} = 0.4,$$
$$\sigma_t/\tau = \sqrt{N_0/4B_T E_p \tau} = 0.025$$

۹-۵-۲.

$$h_{\text{opt}}(t) = (2K/N_0)[u(t_d - t) - u(t_d - t - \tau)]$$
$$= \begin{cases} 1 & t_d - \tau < t < t_d \\ 0 & \text{otherwise} \end{cases}$$

so, with $2K/N_0 = 1$, $h_{\text{opt}}(t) = u(t - t_d + \tau) - u(t - t_d)$

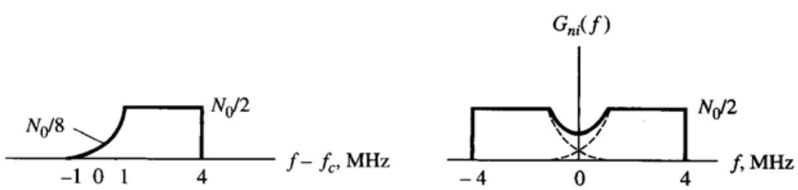
قابل ساخت بودن لازم می دارد که $h_{opt}(t) = 0$ در ازای $t < 0$ باشد، پس می گیریم که $t_d \geq \tau$

$$h_{\text{opt}}(t) * x_R(t) = A\Lambda\left(\frac{t - t_d}{\tau}\right) \text{ where, at } t = t_d,$$

$$A = \int_{t_d - \tau}^{t_d} A_p \, d\lambda = A_p \tau.$$

۱۰-۱-۱.

$G_n(f)$ for $f > 0$



$$G_{n_i}(0) = 2 \times N_0/8 = N_0/4$$

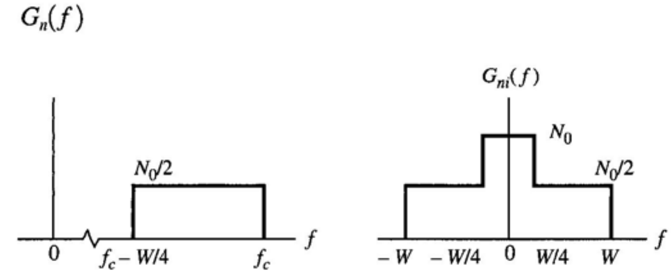
۱۰-۱-۲.

$$\overline{A_n} = \sqrt{\pi \times \frac{10^{-6}}{2}} \approx 1.3 \text{ mV and } \overline{A_n^2} = 2 \times 10^{-6}$$

so $\sigma_{A_n} = \sqrt{2 - \dfrac{\pi}{2}} \times 10^{-3} = 0.655$ mV

Let $a^2 = (2\overline{A_n})^2 = 2\pi N_R$ so $P(A_n > a) = e^{-\pi} = 0.043$

۱۰-۲-۱.



$$N_D = \frac{N_0}{2} \times 2W + \frac{N_0}{2} \times 2\frac{W}{4} = 1.25 N_0 W,$$

$$\left(\frac{S}{N}\right)_D = 0.8\gamma, \quad 10 \log 0.8 \approx -1 \text{ dB}$$

۱۰-۲-۲.

$$S_x = 1 \Rightarrow A_c^2 = S_R, \qquad P(A_c \geq A_n) = 0.99 \Rightarrow P(A_n > A_c) = 0.01$$

Thus, $e^{-A_c^2/2N_R} = e^{-S_R/2N_R} = 0.01$ and $\left(\frac{S}{N}\right)_{R_{\text{th}}} = 2 \ln \frac{1}{0.01} = 4 \ln 10 = 9.2$

۱۰-۳-۱.

$$|H_{\text{de}}(f)|^2 G_\xi(f) = \frac{N_0}{2S_R} \frac{f^2}{1 + (f/B_{\text{de}})^2} \Pi\left(\frac{f}{B_T}\right) \approx \frac{N_0}{2S_R} B_{\text{de}}^2$$

for $B_{\text{de}} < |f| < B_T/2$

$$N_D \approx \frac{N_0}{2S_R} B_{\text{de}}^2 \times 2\frac{B_T}{2} = \frac{N_0 B_{\text{de}}^2 B_T}{2S_R} = \left(\frac{B_T}{2W}\right) \frac{N_0 B_{\text{de}}^2 W}{S_R}$$

۱۰-۳-۲.

$$\left(\frac{f_\Delta}{B_{\text{de}}}\right)^2 S_x \frac{S_R(\text{FM})}{N_0 W} = \phi_\Delta^2 S_x \frac{S_R(\text{PM})}{N_0 W} \quad \text{where } \phi_\Delta \leq \pi \text{ and } S_T(FM) = 1 \text{ W}$$

$$\frac{S_T(\text{PM})}{S_T(\text{FM})} = \left(\frac{f_\Delta}{\phi_\Delta B_{\text{de}}}\right)^2 \geq \left(\frac{7.5}{\pi \times 2.1}\right)^2 \Rightarrow S_T(\text{PM}) \geq 130 \text{ W}$$

۱۰-۳-۳.

$$B_T = 5W \Rightarrow \gamma_{\text{th}} = 10 \times 5 = 50$$

so $\left(\frac{S}{N}\right)_D \geq \left(\frac{10B_{\text{de}}}{B_{\text{de}}}\right)^2 \times \frac{1}{2} \times 50 = 2500 \approx 34 \text{ dB}$

۱۰-۶-۱.

$\tau_{\max} = \tau_0(1 + \mu) \leq T_s$ and $\tau_{\min} = \tau_0(1 - \mu) \geq 0$ so

$$\tau_{\max} - \tau_{\min} = 2\mu\tau_0 \leq T_s \Rightarrow \mu\tau_0 \leq T_s/2 = 1/4W$$

$$\left(\frac{S}{N}\right)_D = 4(\mu\tau_0)^2 B_T \left(\frac{W}{f_s\tau_0}\right) S_x\gamma = 4\mu^2\tau_0 B_T \frac{W}{f_s} S_x\gamma \leq \frac{1}{2}\frac{B_T}{W} S_x\gamma$$

since $\mu \leq 1$, $\tau_0 \leq T_s/2 = 1/2f_s$, and $f_s \geq 2W$

۱۱-۱-۱.

$$\text{sinc}^2 at = \begin{cases} 1 & t = 0 \\ 0 & t = \pm\frac{1}{a}, \pm\frac{2}{a}, \ldots \end{cases} \quad \text{so take } r = a$$

$$\mathscr{F}[\text{sinc}^2 at] = \frac{1}{a}\Lambda\left(\frac{f}{a}\right) = 0 \text{ for } |f| > a \text{ so } B \geq a \Rightarrow r \leq B$$

۱۱-۱-۲.

$$P(f) = \frac{1}{r_b}\,\mathrm{sinc}\left(\frac{f}{r_b}\right) = 0 \text{ for } f = \pm r_b, \pm 2r_b, \ldots$$

$$\text{Thus, } G_x(f) = \frac{A^2}{4r_b}\,\mathrm{sinc}^2\frac{f}{r_b} + \frac{A^2}{4}\,\delta(f)$$

$$\overline{x^2} = A^2/2$$

که با بررسی x(t) یا انتگرالی از $G_x(f)$ است .

۱۱-۱-۳.

$$P(f) = \frac{1}{r_b}\,\Pi\left(\frac{f}{r_b}\right) = 0 \text{ for } |f| > \frac{r_b}{2}$$

$$\text{Thus, } G_x(f) = \frac{A^2}{r_b}\sin^2\frac{\pi f}{r_b}\,\Pi\left(\frac{f}{r_b}\right), \quad \overline{x^2} = \tfrac{1}{2}\frac{A^2}{r_b}\times 2\,\frac{r_b}{2} = \frac{A^2}{2}$$

۱۱-۲-۱.

$$A/\sigma = 2\sqrt{\tfrac{1}{2}\times 50} = 10$$

$$P_{e_0} = Q(0.4\times 10) \approx 3.4\times 10^{-5},\ P_{e_1} = Q(0.6\times 10) \approx 1.2\times 10^{-9}$$

$$P_e = \tfrac{1}{2}\left(P_{e_0} + P_{e_1}\right) \approx 1.7\times 10^{-5}$$

$$\text{whereas } P_{e_{\min}} = Q(0.5\times 10) \approx 3\times 10^{-7}$$

۱۱-۲-۲.
ب.

$$S_R = \tfrac{1}{4}A^2,\ \tau = \tfrac{1}{2}T_b = \frac{1}{2r_b},\ \sigma^2 = \frac{N_0}{2\tau} = N_0 r_b$$

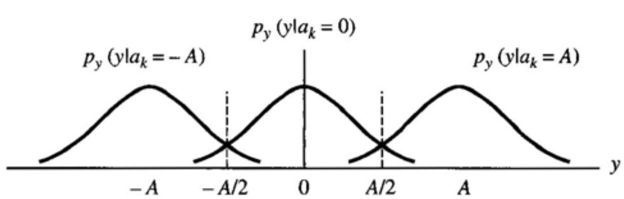
$$(A/2\sigma)^2 = A^2/4\sigma^2 = 4S_R/4N_0 r_b = S_R/N_0 r_b = \gamma_b$$

۱۱-۲-۳.

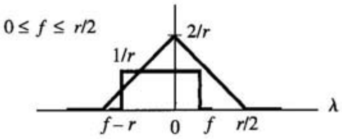
$$P_e = \tfrac{1}{2}\times 2Q(A/2\sigma) + 2\times\tfrac{1}{4}Q(A/2\sigma) = \tfrac{3}{2}Q(A/2\sigma)$$

$$S_R = \tfrac{1}{4}A^2 + \tfrac{1}{4}(-A)^2 + \tfrac{1}{2}0 = \frac{A^2}{2},\ \left(\frac{A}{2\sigma}\right)^2 = \frac{2S_R}{4N_R} \le \frac{S_R}{2N_0 r_b/2} = \gamma_b$$

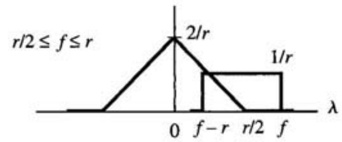
$$\text{so } P_e = \tfrac{3}{2}Q(\sqrt{\gamma_b})$$



۱۱-۳-۱. توجه کنید که P(f) تقارن زوج دارد، پس فقط f > 0 را در نظر بگیرید.

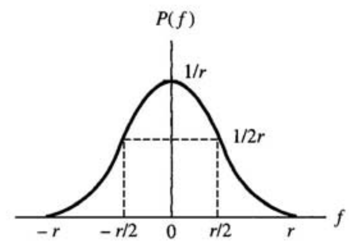


$$P(f) = \frac{1}{r}\left[\int_{f-r}^{0} \frac{2}{r}\left(1 + \frac{2\lambda}{r}\right) d\lambda + \int_{0}^{f} \frac{2}{r}\left(1 - \frac{2\lambda}{r}\right) d\lambda\right] = \frac{1}{r}\left(1 - \frac{2f^2}{r^2}\right)$$

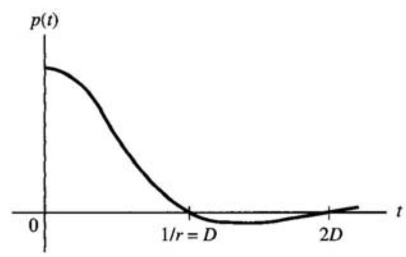


$$P(f) = \frac{1}{r}\int_{f-r}^{r/2} \frac{2}{r}\left(1 - \frac{2\lambda}{r}\right) d\lambda = \frac{2}{r}\left(1 - \frac{f}{r}\right)^2$$

$$\text{Thus, } P(f) = \begin{cases} \dfrac{1}{r}\left(1 - \dfrac{2f^2}{r^2}\right) & |f| \le \dfrac{r}{2} \\ \dfrac{2}{r}\left(1 - \dfrac{|f|}{r}\right)2 & \dfrac{r}{2} \le |f| \le r \end{cases}$$



$$p_\beta(t) = \operatorname{sinc}^2 \frac{rt}{2},\; p(t) = \operatorname{sinc}^2 \frac{rt}{2} \operatorname{sinc} rt$$



۱۱-۳-۲.

$$\text{Let } I_{HR} = \int_{-\infty}^{\infty} |V(f)|^2\, df \int_{-\infty}^{\infty} |W(f)|^2\, df \text{ with}$$

$$V(f) = |H_R(f)|\sqrt{G_n(f)},\; W(f) = \frac{|P(f)|}{|H_c(f)|\,|H_R(f)|}$$

آنگاه I_{HR} وقتی حداقل می‌شود که V(f) = g W(f) باشد، بنابراین :

$$|H_R(f)|\sqrt{G_n(f)} = g\,\frac{|P(f)|}{|H_c(f)|\,|H_R(f)|} \Rightarrow |H_R(f)|^2 = \frac{g|P(f)|}{\sqrt{G_n(f)}\,|H_c(f)|},$$

$$\text{and } |H_T(f)|^2 = \frac{|P(f)|^2}{|P_x(f)H_c(f)H_R(f)|^2} = \frac{|P(f)|\sqrt{G_n(f)}}{g|P_x(f)|^2|H_c(f)|}$$

۱۱-۳-۳.

m_k	m'_{k-2}	m'_k	$m'_k - m'_{k-2}$
0	0	0	0
0	1	1	0
1	0	1	1
1	1	0	−1

$$y(t_k) = (m'_k - m'_{k-2})A = \begin{cases} 0 & m_k = 0, m'_{k-2} = 0 \\ 0 & m_k = 0, m'_{k-2} = 1 \\ A & m_k = 1, m'_{k-2} = 0 \\ -A & m_k = 1, m'_{k-2} = 1 \end{cases}$$

.۱۱-۴-۱

$m_1 = m_2 + m_3 + m_4 + m_5$ and output $= m_5$

shift	m_1	m_2	m_3	m_4	m_5	shift	m_1	m_2	m_3	m_4	m_5
0	1	1	1	1	1	16	0	1	1	0	1
1	0	1	1	1	1	17	1	0	1	1	0
2	0	0	1	1	1	18	0	1	0	1	1
3	1	0	0	1	1	19	1	0	1	0	1
4	0	1	0	0	1	20	0	1	0	1	0
5	0	0	1	0	0	21	0	0	1	0	1
6	1	0	0	1	0	22	0	0	0	1	0
7	1	1	0	0	1	23	1	0	0	0	1
8	0	1	1	0	0	24	1	1	0	0	0
9	0	0	1	1	0	25	1	1	1	0	0
10	0	0	0	1	1	26	0	1	1	1	0
11	0	0	0	0	1	27	1	0	1	1	1
12	1	0	0	0	0	28	1	1	0	1	1
13	0	1	0	0	0	29	1	1	1	0	1
14	1	0	1	0	0	30	1	1	1	1	0
15	1	1	0	1	0	31	1	1	1	1	1

.۱۲-۱-۱

$\nu f_s \leq 36{,}000$ and $f_s \geq 2W = 6400 \qquad \nu \leq \dfrac{36{,}000}{6400} = 5.6 \Rightarrow \nu = 5$

so $q = 2^5 = 32$, $f_s = r/\nu = 7.2$ kHz

.۱۲-۱-۲
الف.

$4.8 + 6\nu \geq 50 \text{ dB} \Rightarrow \nu = 8,\ r = \nu f_s = 80 \text{ Mbps}$

ب.

$(S/N)_D = 4.8 + 6\nu - 10 \geq 50 \text{ dB} \Rightarrow \nu = 11,\ r = 110 \text{ Mbps}$

.۱۲-۱-۳

$3-$ bit quantizer $\Rightarrow$ 8 levels, with $x_{\max} = 8.75$ V $\Rightarrow$ step size $= 2.5$ V.

For an input of 0.6 V $\Rightarrow x_q = 1.25$ V $\Rightarrow \varepsilon_q = 1.25 - 0.60 = 0.65$ V.

With companding: $z(x) = 8.75\left(\dfrac{\ln(1 + 255 \times 0.6/8.75)}{\ln(1+255)}\right) = 4.60$

4.601 feeds to a quantizer $\Rightarrow x'_q = 3.75$ V.

x'_q is then expanded using Eq. (13):

$$\hat{x} = \frac{8.75}{255}\left[(1+255)^{3.75/8.75} - 1\right] = 0.34$$

$\varepsilon'_q = 0.60 - 0.34 = 0.26$ (with companding) versus

$\varepsilon_q = 0.65$ (without companding)

.۱۲-۲-۱

$1 + 4q^2P_e = 10^{0.1} = 1.259 \Rightarrow P_e = 0.065/q^2 \approx 10^{-6}$

$M = 2,\ P_e = Q[\sqrt{(S/N)_R}] = 10^{-6} \Rightarrow (S/N)_R \approx 4.76^2 = 13.6$ dB

Eq. (5) gives $(S/N)_{R_{th}} = 6(2^2 - 1) = 12.6$ dB

.۱۲-۲-۲

$$\gamma_{th} \approx 6\frac{B_T}{W}(M^2-1) \Rightarrow M_{th}^2 = 1 + \frac{W}{6B_T}\gamma_{th} = 1 + \frac{\gamma_{th}}{6b}$$

Thus, $(S/N)_{D_{th}} = 3M_{th}^{2b}S_x = 3\left(1+\frac{\gamma_{th}}{6b}\right)^b S_x$

For WBFM, $(S/N)_{D_{th}} = 3(b/2)^2 S_x\gamma_{th} = \frac{3}{4}b^2\gamma_{th}S_x$

.۱۲-۳-۱

$$W_{rms}^2 = \frac{1}{S_x}\int_{-W}^{W} f^2\frac{S_x}{2W}\,df = \frac{W^2}{3} \Rightarrow W_{rms} = \frac{W}{\sqrt{3}}$$

$$s = \frac{f_s\Delta\sqrt{3}}{2\pi\sigma W} = \frac{\Delta\sqrt{3}\,b}{\pi\sqrt{S_x}},$$

$$s_{opt} \approx \ln 2b \Rightarrow \Delta_{opt} = \frac{\pi\sqrt{S_x}}{\sqrt{3b}}\ln 2b = 0.393\sqrt{S_x}$$

.۱۲-۳-۲

PCM: $(S/N)_D = 4.8 + 6.0\nu + 10\log_{10} S_x$ dB

DPCM: $(S/N)_D = G_{p_{dB}} + 4.8 + 6.0\nu' + 10\log_{10} S_x$ dB

If $G_p = 6$ dB, then $6 + 6.0\nu' = 6.0\nu \Rightarrow \nu' = \nu - 1$

.۱۲-۴-۱

یک فریم به طور کلی 588 بیت متشکل از 33 نماد و 17 bit/symbol دارد. اما از 17 bits فقط 8 bit اطلاعات است ، پس 8 bit اطلاعات ضربدر 33 نماد برابر است با 264 bit/frame از اطلاعات .
خروجی 4.3218 Mbits/sec ضربدر یک frame/588 bits برابر است با 7350 frames/bits .

.۱۲-۵-۱

صوت PCM bits/frame = 30 channel * 8 bits/channel = 240 bits

$T_{frame} = 1/(8\text{ kHz}) = 125\ \mu\text{s}$

$$r = \frac{240+n}{125\ \mu\text{s}} = 2.048\text{ Mbps} \Rightarrow n = 256 - 240 = 16\text{ bits/frame}$$

.۱۳-۱-۱

$\alpha = 10^{-3}, n = 15$

$P(0,n) = (1-\alpha)^{15} = 0.985,\ P(1,n) = 15\alpha(1-\alpha)^{14} = 0.0148$

$$P(2,n) = \frac{15\times 14}{2}\alpha^2(1-\alpha)^{13} = 1.04\times 10^{-4}$$

$$P(3,n) = \frac{15\times 14\times 13}{3\times 2}\alpha^3(1-\alpha)^{12} = 4.50\times 10^{-7}$$

.۱۳-۱-۲

می‌خواهیم که $R_c' = r_b/r \geq 0.5$ **با فرض** $2t_d r_b/k = 2.2$ **و** $p \approx 10\alpha = 0.011$

عقب برگرد – N

$$R_c' \leq \frac{9}{10}\frac{0.989}{0.989 + 2.2\times 0.011} = 0.879$$

توقف – و – انتظار

$$R_c' \leq \frac{9}{10}\frac{0.989}{1+2.2} = 0.278$$

.۱۳-۲-۱

$$(c_1\quad c_2\quad c_3) = (m_1\quad m_2\quad m_3)\begin{bmatrix}1 & 1 & 0\\ 0 & 1 & 1\\ 1 & 0 & 1\end{bmatrix}$$

$c_1 = m_1 \oplus 0 \oplus m_3,\ c_2 = m_1 \oplus m_2 \oplus 0,\ c_3 = 0 \oplus m_2 \oplus m_3$

$m_1m_2m_3$	$c_1c_2c_3$	W
000	000	0
001	101	3
010	011	3
011	110	4
100	110	3
101	011	4
110	101	4
111	000	3

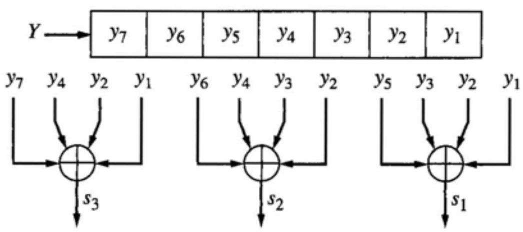
.۱۲-۲-۲

$$S = Y\left[P^T \mid I_q^T\right] = (y_1 \quad y_2 \quad \dots \quad y_n)\begin{bmatrix} p_{11} & p_{21} & \cdots & p_{k1} & | & 1 & 0 & \cdots & 0 \\ p_{12} & p_{22} & \cdots & p_{k2} & | & 0 & 1 & \cdots & 0 \\ \vdots & & & \vdots & | & \vdots & & & \vdots \\ p_{1q} & p_{2q} & \cdots & p_{kq} & | & 0 & 0 & \cdots & 1 \end{bmatrix}^T$$

$$s_j = y_1p_{1j} \oplus y_2p_{2j} \oplus \cdots \oplus y_kp_{kj} \oplus \underbrace{0 \oplus 0 \oplus \cdots}_{j-1 \text{ terms}} \oplus\, y_{k+j} \oplus \underbrace{0 \oplus 0 \oplus \cdots \oplus 0}_{g-j \text{ terms}}$$

$$\text{For } P^T = \begin{bmatrix} 1 & 1 & 1 & 0 \\ 0 & 1 & 1 & 1 \\ 1 & 1 & 0 & 1 \end{bmatrix}$$

$$s_1 = y_1 \oplus y_2 \oplus y_3 \oplus 0 \oplus y_5,\ s_2 = 0 \oplus y_2 \oplus y_3 \oplus y_4 \oplus y_6,$$
$$s_3 = y_1 \oplus y_2 \oplus 0 \oplus y_4 \oplus y_7$$



.۱۲-۲-۳

$$"\text{J}" = 1001010 \Rightarrow Q_m(p) = p^6 + p^3 + p$$
$$\text{CRC-8: } G(p) = p^8 + p^2 + p + 1$$
$$X(p) = Q_m(p)G(p) = p^{14} + p^{11} + p^9 + p^8 + p^7 + p^6 + p^5 + p^4 + p^2 + p$$

۷ نوع دریافت شده با خطا در دو رقم اول است ، پس

$$Y(p) = p^{13} + p^{11} + p^9 + p^8 + p^7 + p^6 + p^5 + p^4 + p^2 + p$$

$$\frac{Y(p)}{G(p)} = p^8 + p^2 + p + 1 \overline{\big) p^{13} + 0 + p^{11} + 0 + p^9 + p^8 + p^7 + p^6 + p^5 + p^4 + 0 + p^2 + p}\quad \text{quotient: } p^5 + p^3 + p + 1$$

$$\begin{array}{l} \underline{p^{13} + p^7 + p^6 + p^5} \\ p^{11} + p^9 + p^8 + p^4 + p^2 + p \\ \underline{p^{11} + p^5 + p^4 + p^3} \\ p^9 + p^8 + p^5 + p^3 + p^2 + p \\ \underline{p^9 + p^3 + p^2 + p} \\ p^8 + p^5 \\ \underline{p^8 + p^2 + p + 1} \\ p^5 + p^2 + p + 1 \end{array}$$

$$S(p) = \text{rem}\left[\frac{Y(p)}{G(p)}\right] = p^5 + p^2 + p + 1 \neq 0 \Rightarrow$$

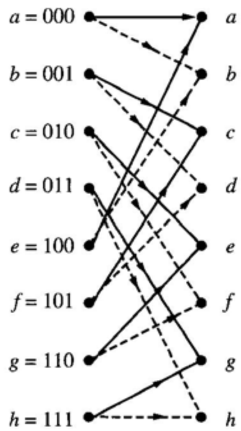
خطایی رخ داده است.

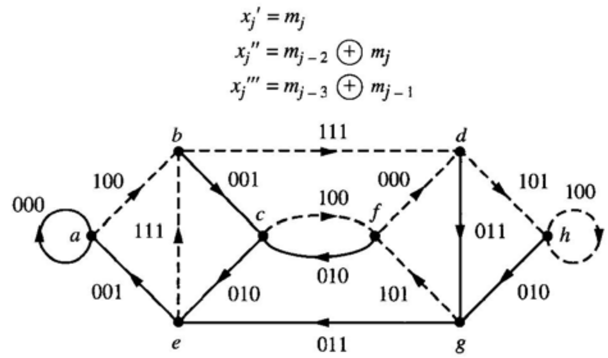
.۱۲-۲-۴

$$n = 63, k = 15 \Rightarrow t = \frac{63 - 15}{2} = 24$$

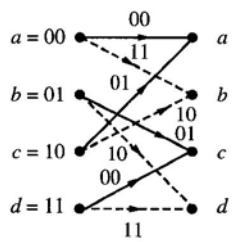
خطا قابل اصلاح است.

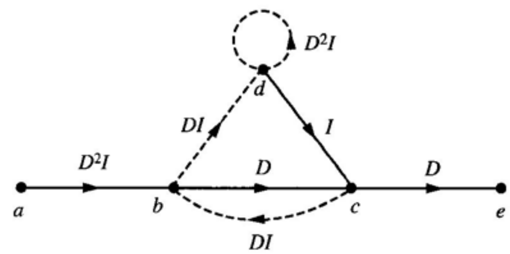
.۱۲-۳-۱





.۱۲-۳-۲





$$\left.\begin{aligned} abce &= D^4 I \\ abdce &= D^4 I^2 \end{aligned}\right\} \quad d_f = 4, \quad M(d_f) = 1 + 2 = 3$$

$$\alpha \approx \frac{1}{\sqrt{20\pi}} e^{-5} = 8.5 \times 10^{-4} \Rightarrow P_{be} \doteqdot 3 \times 2^4 \times \alpha^2 = 3.5 \times 10^{-5}$$

$$P_{ube} \approx \frac{1}{\sqrt{40\pi}} e^{-10} = 4.1 \times 10^{-6} < P_{be}$$

کدبندی احتمال خطا را وقتی $R_c d_f / 2 = 1$ باشد، افزایش می‌دهد.

$B_T \leq 0.1 f_c = 100 \text{ kHz}, \; r_b \leq (r_b/B_T) \times 100 \text{ kHz}$

(a) $r_b/B_T \approx 1$ so $r_b \leq 100$ kbps $\quad (b)$ $r_b/B_T \approx 2$ so $r_b \leq 200$ kbps

(c) $r_b/B_T \approx 2 \log_2 8 = 6$ so $r_b \leq 600$ kbps

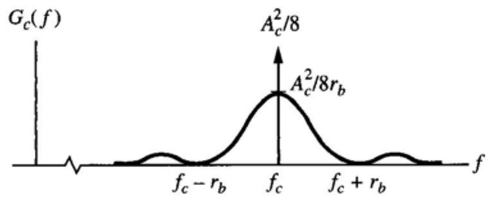
.۱۴-۱-۲

$$\phi_k = \pm\frac{\pi}{4} \Rightarrow I_k = \cos\phi_k = \frac{1}{\sqrt{2}},\ Q_k = \sin\phi_k = \pm\frac{1}{\sqrt{2}}$$

$$x_i(t) = \sum_k \frac{1}{\sqrt{2}} p_{T_b}(t - kT_b) = \frac{1}{\sqrt{2}} \Rightarrow G_i(f) = \frac{1}{2}\delta(f)$$

$$\overline{Q_k} = 0,\ \overline{Q_k^2} = \frac{1}{2} \Rightarrow G_q(f) = \frac{1}{2} r_b |P_{T_b}(f)|^2 = \frac{1}{2r_b}\operatorname{sinc}^2\frac{f}{r_b}$$

Thus, $G_{lp}(f) = \frac{1}{2}\delta(f) + \frac{1}{2r_b}\operatorname{sinc}^2\frac{f}{r_b}$



.۱۴-۱-۳

$$x_c(t) = A_c \sum_k [\cos(\omega_d a_k t)\cos(\omega_c t + \theta) - \sin(\omega_d a_k t)\sin(\omega_c t + \theta)] p_{T_b}(t - kT_b)$$

where $a_k = \pm 1$, $p_{T_b}(t) = u(t) - u(t - T_b)$, $\omega_d = \frac{\pi}{T_b} = \pi r_b$

so $\cos(\omega_d a_k t) = \cos\omega_d t$, $\sin(\omega_d a_k t) = a_k \sin\omega_d t$. Thus,

$x_i(t) = \sum_k \cos(\omega_d a_k t) p_{T_b}(t - kT_b) = \sum_k \cos\omega_d t\, p_{T_b}(t - kT_b) = \cos\omega_d t$, and

$x_q(t) = \sum_k \sin(\omega_d a_k t) p_{T_b}(t - kT_b) = \sum_k a_k \sin\omega_d t\, p_{T_b}(t - kT_b)$. But

$$\sin\omega_d t = \sin\frac{\pi t}{T_b} = \sin\left[\tfrac{\pi}{T_b}(t - kT_b) + k\pi\right]$$

$$= \cos k\pi \sin\left[\tfrac{\pi}{T_b}(t - kT_b)\right] = (-1)^k \sin[\pi r_b(t - kT_b)]$$

$$\text{so } x_q(t) = \sum_k \underbrace{(-1)^k a_k}_{Q_k} \underbrace{\sin[\pi r_b(t - kT_b)] p_{T_b}(t - kT_b)}_{p(T - kT_b)}$$

.۱۴-۲-۱

Let $V(\lambda) = s_1(\lambda) - s_0(\lambda)$ and $W^*(\lambda) = h(T_b - \lambda)$, so

$$\frac{|z_1 - z_0|^2}{4\sigma^2} = \frac{\left|\int_{-\infty}^{\infty} V(\lambda) W^*(\lambda)\, d\lambda\right|^2}{4\frac{N_0}{2}\int_{-\infty}^{\infty} |W(\lambda)|^2\, d\lambda} \le \frac{1}{2N_0}\int_{-\infty}^{\infty} |V(\lambda)|^2\, d\lambda$$

$$= \frac{1}{2N_0}\int_{-\infty}^{\infty} |s_1(\lambda) - s_0(\lambda)|^2\, d\lambda$$

تساوی هنگامی برقرار است که $W(\lambda) = KV(\lambda)$ **، پس**

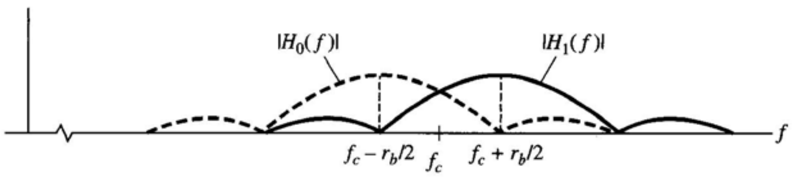
$$h(T_b - \lambda) = K[s_1(\lambda) - s_0(\lambda)] \Rightarrow h_{opt}(t) = K[s_1(T_b - t) - s_0(T_b - t)]$$

.۱۴-۲-۲

$$h(t) = A_c p_{T_b}(T_b - t)\cos[2\pi(f_c \pm f_d)(T_b - t)] \text{ with } f_cT_b = N_c, f_dT_b = \tfrac{1}{2}$$
$$= A_c[u(T_b - t) - u(-t)]\cos[2\pi(N_c \pm \tfrac{1}{2}) - 2\pi(f_c \pm f_d)t]$$
$$= -A_c\cos[2\pi(f_c \pm f_d)t][u(t) - u(t - T_b)], \quad f_d = \frac{r_b}{2}$$

since $[u(T_b - t) - u(-t)] = [u(t) - u(t - T_b)] = \Pi\left(\dfrac{t - \frac{T_b}{2}}{T_b}\right)$

Thus, $|H(f)| = \dfrac{A_cT_b}{2}\left|\text{sinc}\left[\dfrac{f - \left(f_c \pm \frac{r_b}{2}\right)}{r_b}\right] + \text{sinc}\left[\dfrac{f + \left(f_c \pm \frac{r_b}{2}\right)}{r_b}\right]\right|$



.۱۴-۳-۱

$$z(t) = \int_0^t A_c\cos(\omega_c\lambda + \theta)\,KA_c\cos(\omega_ct - \omega_c\lambda)\,d\lambda \quad KA_c = \frac{2}{T_b}$$
$$= \frac{2A_c}{T_b}\frac{1}{2}\left[\int_0^t \cos(\omega_ct + \theta)\,d\lambda + \int_0^t \cos(2\omega_c\lambda - \omega_ct + \theta)\,d\lambda\right]$$
$$= \frac{A_c}{T_b}\left[t\cos(\omega_ct + \theta) + \frac{\sin(\omega_ct + \theta) + \sin(\omega_ct - \theta)}{2\omega_c}\right] \quad 0 < t < T_b$$

where $\cos(\omega_ct + \theta) = \cos\omega_ct\cos\theta - \sin\omega_ct\sin\theta$ and

$\sin(\omega_ct + \theta) + \sin(\omega_ct - \theta) = 2\sin\omega_ct\cos\theta$

Thus, $z(t) = \dfrac{A_ct}{T_b}\left[\cos\theta\cos\omega_ct - \left(\sin\theta - \dfrac{\cos\theta}{\omega_ct}\right)\sin\omega_ct\right]$ and

$$A_z(t) = \frac{A_ct}{T_b}\sqrt{\cos^2\theta + \left(\sin\theta - \frac{\cos\theta}{\omega_ct}\right)^2}$$
$$= \frac{A_ct}{T_b}\sqrt{1 - \frac{2\sin\theta\cos\theta}{\omega_ct} + \left(\frac{\cos\theta}{\omega_ct}\right)^2}$$
$$\approx \frac{A_ct}{T_b} \quad \omega_ct \gg 1$$

.۱۴-۳-۲

$$A_c^2 \le 2\times10^{-6}W, \quad \gamma_b = \frac{A_c^2}{N_0}\frac{E_b}{A_c^2} \le 2\times10^{-6}\frac{E_b}{A_c^2}$$

OOK: $\dfrac{E_b}{A_c^2} = \dfrac{1}{4r_b} = 2.5\times10^{-6}$ so $\gamma_b \le 5$, $P_e \ge \frac{1}{2}[e^{-2.5} + Q(\sqrt{5})] \approx 5\times10^{-2}$

FSK: $\dfrac{E_b}{A_c^2} = \dfrac{1}{2r_b} = 5\times10^{-6}$ so $\gamma_b \le 10$, $P_e \ge \frac{1}{2}e^{-5} \approx 3\times10^{-3}$

DPSK: $\dfrac{E_b}{A_c^2} = \dfrac{1}{2r_b} = 5\times10^{-6}$ so $\gamma_b \le 10$, $P_e \ge \frac{1}{2}e^{-10} \approx 2\times10^{-5}$

.۱۴-۴-۱

Let $\psi = \omega_c t + \phi_k$ so

$$x_c^4 = A_c^4 \cos^3 \psi \cos \psi = \frac{A_c^4}{4}(3 \cos \psi + \cos 3\psi) \cos \psi$$

$$= \frac{A_c^4}{8}(3 + 4 \cos 2\psi + \cos 4\psi)$$

where $\cos 4\psi = \cos(4\omega_c t + 4\phi_k) = -\cos 4\omega_c t$ since $4\phi_k = \pi, 3\pi, 7\pi$

.۱۴-۴-۲

For correlation detection

$$y(t_k) = \int_{kD}^{(k+1)D} x_c(\lambda)\, KA_c \cos \omega_c \lambda \, d\lambda, \quad t_k = (k+1)D$$

For filter detection $y(t_k) = \int_{-\infty}^{\infty} x_c(\lambda)\, h(t_k - \lambda)\, d\lambda$

Thus, $h[(k+1)D - \lambda] = \begin{cases} KA_c \cos \omega_c \lambda & kD \le \lambda \le (k+1)D \\ 0 & \text{otherwise} \end{cases}$

So $h(t) = KA_c \cos[(k+1)\omega_c D - \omega_c t] \quad 0 \le t \le D$

$$= KA_c \cos \omega_c t\, p_D(t) \quad \text{since} \quad \omega_c D = 2\pi N_c$$

$$E = \tfrac{1}{2} A_c^2 D = \frac{A_c^2}{2r} \Rightarrow K = \frac{A_c}{E} = \frac{2r}{A_c}$$

$$\sigma^2 = \frac{N_0}{2} \int_{-\infty}^{\infty} |h(t)|^2 \, dt = \frac{N_0}{2} \int_0^D (KA_c)^2 \cos^2 \omega_c t \, dt$$

$$= \frac{N_0}{4}(KA_c)^2 D = \frac{A_c^2 N_0}{2E} = N_0 r$$

.۱۵-۱-۱

$$10 \log(J/S_R) = 10 \log(Pg) - 10 \log(E_b/N_J)$$
$$= 10 \log(10{,}000) - 10 \log(1.80 \times 10^{-11}/1.48 \times 10^{-13})$$
$$= 19.2 \text{ dB}$$

.۱۵-۱-۲

$P_e = Q(\sqrt{2E_b/N_0}) = 1 \times 10^{-7} \Rightarrow 2E_b/N_0 = 27.04$

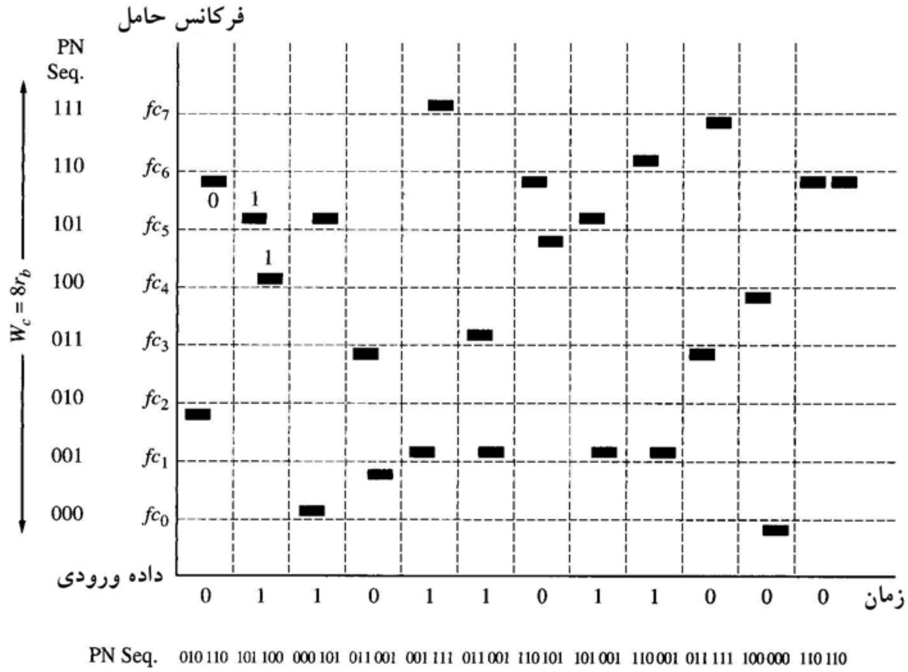
Multiple users:

$$P_e = Q\left(\frac{1}{\sqrt{(M-1)/3Pg + N_0/2E_b}}\right) = 1 \times 10^{-5}$$

$$= Q\left(\frac{1}{\sqrt{(M-1)/3000 + 1/27.04}}\right) \Rightarrow (M-1) = 54$$

$\Rightarrow$ 54 total users

.۱۵-۲-۱



.۱۵-۲-۲

$$P_e = \frac{1}{2}\left(\frac{M-1}{Y}\right) + \frac{1}{2}e^{-E_b/2N_0}\left(1 - \frac{M-1}{Y}\right)$$

فرض کنید جمله دوم نقش چندانی در خطای کل ندارد ، به نحوی که با M = 54 کاربر ، داریم :

$$10^{-5} = \frac{1}{2}\left(\frac{54-1}{Y}\right) \Rightarrow Y = 2650$$

ولی با FH-SS ، $P_g = 2^k \Rightarrow k = 12 \Rightarrow Y = 4096$.

با مقایسه تمرین ۲-۱-۱۵ برای M = 54 و همان p_e **لازم است که** $p_g = 1000$ **باشد.**

.۱۵-۳-۱

$m_1 = m_2 + m_5$ و خروجی $= m_5$

جابه‌جایی	m_1	m_2	m_3	m_4	m_5	جابه‌جایی	m_1	m_2	m_3	m_4	m_5
0	1	1	1	1	1	8	0	0	1	0	1
1	0	1	1	1	1	9	1	0	0	1	0
2	0	0	1	1	1	10	0	1	0	0	1
3	1	0	0	1	1	11	0	0	1	0	0
4	1	1	0	0	1	12	0	0	0	1	0
5	0	1	1	0	0	13	0	0	0	0	1
6	1	0	1	1	0	14	1	0	0	0	0
7	0	1	0	1	1	15	0	1	0	0	0

جابه‌جایی	m_1	m_2	m_3	m_4	m_5	جابه‌جایی	m_1	m_2	m_3	m_4	m_5
16	1	0	1	0	0	24	0	1	1	0	1
17	0	1	0	1	0	25	0	0	1	1	0
18	1	0	1	0	1	26	0	0	0	1	1
19	1	1	0	1	0	27	1	0	0	0	1
20	1	1	1	0	1	28	1	1	0	0	0
21	0	1	1	1	0	29	1	1	1	0	0
22	1	0	1	1	1	30	1	1	1	1	0
23	1	1	0	1	1	31	1	1	1	1	1

خروجی فوق با وضعیت تمام 1 در مقدار اولیه رخ می‌دهد . هر مجموعه مقادیر اولیه غیرصفر تولید خروجی تأخیردار را می‌نماید. بنابراین این آرایش ثبات فقط یک رشته منحصر به فرد را تولید می نماید. هر آرایش ثبات n بیتی برای تولید یک رشته ml فقط یک رشته خروجی منحصر جدای از مقادیر اولیه دارد.

.۱۶-۱-۱

$$P_2 + P_3 = 1 - P_1 \text{ so } 2P_2 = 2P_3 = 1 - p \text{ and}$$

$$H(X) = p \log \frac{1}{p} + 2\frac{1-p}{2} \log \frac{2}{1-p} = p \log \frac{1}{p} + (1-p)\left[\log \frac{1}{1-p} + \log 2\right]$$

$$= p \log \frac{1}{p} + (1-p) \log \frac{1}{1-p} + (1-p) = \Omega(p) + 1 - p$$

$$H(X)|_{\max} = \log M = \log 3 = 1.58 \text{ at } p = 1/M = 1/3$$

.۱۶-۱-۲

x_i	P_i	1	2	3	Codeword	N_i	I_i
A	1/2	0			0	1	1
B	1/4	1	0		10	2	2
C	1/8	1	1	0	110	3	3
D	1/8	1	1	1	111	3	3

$$N_0 = \tfrac{1}{2} \times 1 + \tfrac{1}{2} \times 1 + \tfrac{1}{8} \times 1 = \tfrac{7}{8} = \overline{N}/2$$

$$N_1 = \tfrac{1}{4} \times 1 + \tfrac{1}{8} \times 2 + \tfrac{1}{8} \times 3 = \tfrac{7}{8} = \overline{N}/2$$

.۱۶-۱-۳

از جدول ۵-۱-۱۶ با **p = 0.9** دارای مقایسه داده $\overline{N}/\overline{E} = 0.50$ هستیم به طوری که $r_b / r = 0.50$.

اما $R = rH(X) \le r_b$. بنابراین $H(X) \le r_b / r = 0.50 bits/sample$.

.۱۶-۲-۱

$$H(Y \mid X) = P(x_1)\left[P(y_1 \mid x_1) \log \frac{1}{P(y_1 \mid x_1)} + P(y_2 \mid x_1) \log \frac{1}{P(y_2 \mid x_1)}\right]$$

$$+ P(x_2)\left[P(y_1 \mid x_1) \log \frac{1}{P(y_1 \mid x_2)} + P(y_2 \mid x_2) \log \frac{1}{P(y_2 \mid x_2)}\right]$$

$$= p\left[(1-\alpha) \log \frac{1}{1-\alpha} + \alpha \log \frac{1}{\alpha}\right]$$

$$+ (1-p)\left[\alpha \log \frac{1}{\alpha} + (1-\alpha) \log \frac{1}{1-\alpha}\right]$$

$$= \alpha \log \frac{1}{\alpha} + (1-\alpha) \log \frac{1}{1-\alpha} = \Omega(\alpha)$$

.۱۶-۲-۲

$$P(x_i y_j) = P(x_i)P(y_j) \quad P(x_i|y_j) = P(x_i y_j)/P(y_j) = P(x_i)$$

$$\text{Thus, } H(X \mid Y) = \sum_{x,y} P(x_i)P(y_j) \log \frac{1}{P(x_i)}$$

$$= \left[\sum_y P(y_j)\right]\left[\sum_x P(x_i) \log \frac{1}{P(x_i)}\right] = 1 \times H(X)$$

$$\text{so } I(X; Y) = H(X) - H(X|Y) = 0$$

.۱۶-۳-۱

(a) $p(x) = 0$ for $|x| > M$ so

$$I = \int_{-M}^{M} p(x) \log \frac{1}{p(x)}\, dx \quad \text{and} \quad \int_{-M}^{M} p(x)\, dx = 1 \Rightarrow F_1 = p, c_1 = 1$$

$$-\frac{(\ln p + 1)}{\ln 2} + \lambda_1 = 0 \Rightarrow \ln p = \lambda_1 \ln 2 - 1 \Rightarrow p = e^{(\lambda_1 \ln 2 - 1)} = \text{constant}$$

Thus, $p(x) = \dfrac{1}{2M}$ for $-M < x < M$, and $H(X) = \displaystyle\int_{-M}^{M} \frac{1}{2M} \log 2M\, dx$

$$= \log 2M$$

(b) $p(z) = 1/2KM$ for $-KM < z < KM$ so $H(Z) = \log 2KM$

But $dz/dx = K$ so $H_0(Z) - H_0(X) = -\log K$ and

$$H_{\text{abs}}(Z) - H_{\text{abs}}(X) = \log 2KM - \log 2M - \log K$$
$$= \log [2KM/(2M \times K)] = 0$$

۱۶-۳-۲.

(a) $R = r \log 64 \le B \log (1 + S/N) \Rightarrow r \le (3 \times 10^3 \log 1001)/6$

$= 5000$ symbols/sec

(b) $S/N_0B = 10^3 \Rightarrow S/N_0 = 3 \times 10^3 \times 10^3 = 3 \times 10^6$

$B = 1$ kHz:

$C = 10^3 \log (1 + 3 \times 10^6/10^3) \approx 1.2 \times 10^4 \Rightarrow r \le 1.2 \times 10^4/6 = 2000$

$B \to \infty$:

$C_\infty = 1.44 \times 3 \times 10^6 = 4.32 \times 10^6 \Rightarrow r \le 4.32 \times 10^6/6 = 720{,}000$

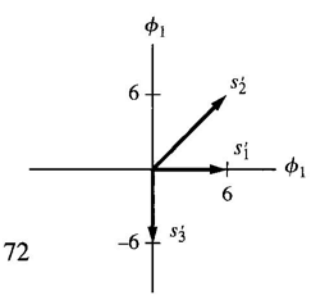
۱۶-۴-۱.

(a) $\|s_1'\|^2 = (3\sqrt{2})^2 \times 2 = 36 \quad \phi_1 = s_1'/6$

$$\alpha_{21} = \int s_2'\phi_1\, dt = 3\int_0^2 dt = 6 \quad g_2 = s_2' - 6\phi_1$$

$\|g_2\|^2 = 36 \quad \phi_2 = g_2/6$

(b) $\left\|s_2'\right\|^2 = 6^2 + 6^2 = 72 \quad \left\|s_2'\right\|^2 = \displaystyle\int_0^4 (3\sqrt{2})^2\, dt = 18 \times 4 = 72$



۱۶-۵-۱.

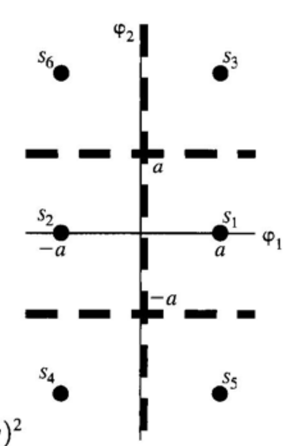
$$E_i = a^2 \qquad i = 1, 2$$
$$= a^2 + (2a)^2 \qquad i = 3, 4, 5, 6$$
$$E_s = [2 \times a^2 + 4 \times 5a^2]/6 = 11a^2/3$$

$$\frac{a}{\sqrt{N_0/2}} = \sqrt{\frac{6E}{11N_0}} \text{ so let } q = Q\left(\sqrt{\frac{6E}{11N_0}}\right)$$

For $i = 1, 2$

$$P(c \mid m_i) = \int_{-a}^{a} p_\beta(\beta_1)\, d\beta_1 \int_{-a}^{\infty} p_\beta(\beta_2)\, d\beta_2 = (1 - 2q)(1 - q)$$

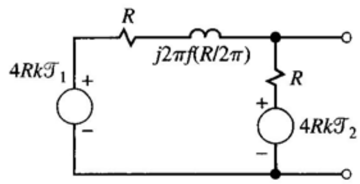
For $i = 3, 4, 5, 6$ $P(c \mid m_i) = \displaystyle\int_{-a}^{\infty} p_\beta(\beta_1)\, d\beta_1 \int_{-a}^{\infty} p_\beta(\beta_2)\, d\beta_2 = (1 - q)^2$



$P_c = \frac{1}{6}[2(1 - 2q)(1 - q) + 4(1 - q)^2] = \frac{1}{3}(3 - 7q + 4q^2)$

Thus, $P_e = 1 - P_c = \frac{1}{3}(7q - 4q^2)$

الف – ۱



$$i_n^2(f) = \frac{4Rk\mathcal{T}_1}{|R + jfR|^2} + \frac{4Rk\mathcal{T}_2}{R^2} = \frac{4k}{R}\left(\frac{\mathcal{T}_1}{1 + f^{\,2}} + \mathcal{T}_2\right)$$

$$Z(f) = \frac{R(R + jfR)}{R + R + jfR} = \frac{R(1 + jf)}{2 + jf}, \quad |Z(f)|^2 = R^2\frac{1 + f^2}{4 + f^2},$$

$$\mathrm{Re}[Z(f)] = R\frac{2 + f^2}{4 + f^2}$$

$$v_n^2(f) = |Z(f)|^2 i_n^2(f) = 4kR\frac{\mathcal{T}_1 + (1 + f^{\,2})\mathcal{T}_2}{4 + f^{\,2}}$$

$$\eta(f) = \frac{v_n^2(f)}{4\,\mathrm{Re}[Z(f)]} = k\frac{\mathcal{T}_1 + (1 + f^{\,2})\mathcal{T}_2}{2 + f^{\,2}}, \text{ If } \mathcal{T}_1 = \mathcal{T}_2 = \mathcal{T}, \text{ then}$$

$$\eta(f) = k\mathcal{T}.$$

الف – ۲

الف.

$$N_o = 10^6 k(\mathcal{T}_0 + \mathcal{T}_e) \times 2 \times 10^6$$
$$= 2 \times 10^{12} \times 4 \times 10^{-21}\frac{\mathcal{T}_0 + \mathcal{T}_e}{\mathcal{T}_0} = 40 \times 10^{-9}$$

بنابراین :

$$(\mathcal{T}_0 + \mathcal{T}_e)/\mathcal{T}_0 = 5 \Rightarrow \mathcal{T}_e = 4\mathcal{T}_0, F = 1 + 4\mathcal{T}_0/\mathcal{T}_0 = 5$$

ب.

$$F = \mathcal{T}_x/\mathcal{T}_0 = 5, \mathcal{T}_i = \mathcal{T}_0 + \mathcal{T}_x = 6\mathcal{T}_0 = 1740 \text{ K}$$

الف – ۳

با FET :

$$\mathcal{T}_e = 9 + \frac{14.5}{100} + 1.8 + 2.0 = 12.9, \quad \mathcal{T}_N = 42.9 \text{ K}$$

بدون :

$$\mathcal{T}_e = 9 + \frac{14.5}{100} + \frac{1.05 \times 1860}{100} = 28.7, \quad \mathcal{T}_N = 58.7 \text{ K}$$

توجه کنید که FET $(S/N)_R$ را به اندازه $58.7/42.9 = 1.37 \approx 1.4dB$ افزایش می دهد.

پاسخ به مسائل انتخاب شده

پاسخ‌های انتخاب شده در اینجا برای مسائلی که با (*) علامت خورده‌اند، آمده است .

۲-۱-۸.

$0.23A^2, 0.24A^2, 0.21A^2$

۲-۲-۴.

$-j(A/\pi f)[\text{sinc } 2f\tau - \cos 2\pi f\tau]$

۲-۲-۶.

50%, 84%

۲-۲-۱۰.

$AW[\text{sinc } (2Wt - \frac{1}{2}) - \text{sinc } (2Wt + \frac{1}{2})]$

۲-۳-۱.

$2A\tau \text{ sinc } f\tau \cos 2\pi fT$

۲-۳-۶.

$(1/|a|)V(f/a)e^{-j\omega t_d/a}$

۲-۳-۱۳.

$(j4Abf)/[b^2 + (2\pi f)^2]^2$

۲-۴-۲.

$$\begin{aligned} y(t) &= 0 && t < 0, t > 5 \\ &= At^2/2 && 0 < t < 2 \\ &= 2A && 2 < t < 3 \\ &= (A/2)[4 - (t-3)^2] && 3 < t < 5 \end{aligned}$$

۲-۴-۷.

$$\begin{aligned} y(t) &= 0 && t < 0 \\ &= [ab/(a-b)][e^{-bt} - e^{-at}] && t > 0 \end{aligned}$$

۲-۴-۱۴.

$$y(t) = \tfrac{1}{2} \text{ sinc}\left(\frac{t}{2}\right)$$

(راهنمایی : از دوگانگی استفاده کنید).

۲-۵-۵.

$2A\tau \text{ sinc } 2f\tau \; e^{-j2\pi f\tau}$

۲-۵-۱۱.

$2A\tau \text{ sinc } f\tau(1 + \cos 4\pi fT)$

۲-۵-۱۳.

4

۳-۱-۳.

$AH^2(f)e^{-j2\pi ft_d}$

۳-۱-۹.

$$y(t) \approx 2\pi B \int_{-\infty}^{t} x(\lambda)\, d\lambda$$

۳-۱-۱۴.

$$h(t) = \frac{1}{K}\delta(t) - \frac{1}{K^2}e^{-t/K}u(t), \; g(t) = \frac{1}{K}e^{-t/K}u(t)$$

۳-۲-۳.

$$\begin{aligned} y(t) = {} & 1.28 \cos(\omega_0 t + 72°) + 0.31 \cos(3\omega_0 t + 45°) \\ & + 0.14 \cos(5\omega_0 t + 31°) \end{aligned}$$

۳-۲-۸.

$$y(t) \approx \frac{\alpha}{2}x(t) + x(t-T) - \frac{\alpha}{2}x(t-2T)$$

.۲-۳-۱

$\ell_1 = 22$ km, $g_2 = 56$ dB, $g_4 = 34$ dB

.۲-۳-۶

$r = 0.9$ m

.۲-۴-۲

$h(t) = K\delta(t - t_d) - 2BK \operatorname{sinc} B(t - t_d) \cos \omega_c(t - t_d)$

.۲-۴-۸

$g(t) = 1 - e^{-bt}(\sin bt + \cos bt)$ for $t \geq 0$, $t_r \approx 1/2.8B$

.۲-۵-۲

$\hat{v}(t) = \lim_{t\to\infty}(A/\pi)\ln|(2t + \tau)/(2t - \tau)| = 0$

.۲-۵-۵

$\hat{x}(t) = 4 \sin \omega_0 t + \frac{4}{9} \sin 3\omega_0 t + \frac{4}{25} \sin 5\omega_0 t$

.۲-۶-۵

$$G_v(f) = \left(\frac{A}{2W}\right)^2 \Pi\left(\frac{f}{2W}\right), R_v(\tau) = \left(\frac{A^2}{2W}\right)\operatorname{sinc} 2W\tau, E_v = \frac{A^2}{2W}$$

.۲-۶-۱۰

$R_v(\tau) = A^2/2, P_v = A^2/2, G_v(f) = (A^2/2)\delta(f)$

.۴-۱-۴

$v_{lp}(t) = 400 \operatorname{sinc} 400t\, e^{-j2\pi 100t}$, $v_i(t) = 800 \operatorname{sinc} 400t \cos 2\pi 100t$,
$v_q(t) = -800 \operatorname{sinc} 400t \sin 2\pi 100t$

.۴-۱-۱۰

$y_{bp}(t) = a(1 - e^{-\pi Bt}) \cos \omega_c t\, u(t)$

.۴-۲-۳

AM: $B_T = 400$, $S_T = 68$; DSB: $B_T = 400$, $S_T = 50$

.۴-۲-۹

$5 < f_c < 50$

.۴-۳-۲

$K = \sqrt{b/a}$

.۴-۳-۷

$f_c > 200$

.۴-۴-۷

$S_T = 7A_c^2/4$, $B_T = 400$

.۴-۴-۱۲

$x_c(t) = (A_c/2)[\cos \omega_m t \cos \omega_c t - 2a \sin \omega_m t \sin \omega_c t]$

.۴-۵-۵

$a = \frac{1}{2}$ no distortion; $a = 1$ or $a = 0$

.۵-۱-۴

$\theta_c(t) = 2\pi[f_1 t + (f_2 - f_1)t^2/T]$

.۵-۱-۱۰

$f(t) = 40 + 40 \cos 2\pi 20t$; $S_T = 6441.5$

.۵-۲-۵

$B_T = 10^{13}$, $f_\Delta = 5 \times 10^{12}$

.۵-۲-۹

$y_c(t) = A_c[\cos \omega_c t - \phi_\Delta(\pi f_c/Q)\tilde{x}(t) \sin \omega_c t]$;
$\phi(t) = \arctan[\phi_\Delta(\pi f_c/Q)\tilde{x}(t)]$

.۵-۲-۱۵

$f_\Delta < (f_c - 2W)/9$

.۵-۳-۵. سیگنال فرکانس‌های تقویت شده پایین دارد.

.۵-۳-۱۱

$K_1 = A_c/2\sqrt{2}f_c$, $K_2 = A_c/8\sqrt{2}f_c^2$; $f_\Delta/f_c < 0.08$

۵-۴-۵. S_x به شدت افزایش می‌یابد و اثر زیادی روی **DSB** دارد .

$P_{sb}/A_{\max}^2 = S_x/4$ for DSB however $P_{sb}/A_{\max}^2 = S_x/16$ for AM.

۵-۴-۱۰.

$$y_D(t) = \{(1 + \rho \cos[\phi(t) - \theta_i(t)])\phi(t)/2\pi + (\rho + \cos[\phi(t) - \theta_i(t)])\rho f_i\}/\{1 + \rho^2 + 2\rho \cos[\phi(t) - \theta_i(t)]\}$$

۶-۱-۴.

$K_1 = 2$ and $K_2 = \pi/2$

۶-۱-۱۵.

$f_s \leq 12$ MHz, $W_{presampling} \leq 137.5$ MHz

۶-۱-۱۷.

الف. **1.64%**   **ب.** **14.3% –**

۶-۱-۲۰.

الف. **100 Hz**   **ب.** **200 Hz**   **پ.** **400 kHz**

۶-۲-۳.
الف.

$$H(f) = \text{sinc}\, f\tau\, e^{-j\omega\tau/2},\ X_p(f) = P(f)\overline{X}_\delta(f) \text{ where } \overline{X}_\delta(f) = f_s \sum_n H(f - nf_s)X(f - nf_s)$$

ب.

$$H_{eq}(f) = Ke^{-j\omega(t_d - \tau/2)}/\text{sinc}^2 f\tau, \quad |f| \leq W$$

۶-۳-۱.

$B_T \geq 400$ kHz

۷-۱-۱.

$f_{IF} \geq 532.5$ kHz, $f_{LO} = 1072.5$ to 2132.5 kHz, $10 \text{ kHz} < B_{RF} < 1065$ kHz

۷-۱-۳.

$C = 6$ to 25.6 nF, 19.3 to $3{,}506$ nF

۷-۱-۹.
الف.

50–54 MHz, 50.910 to 54.910 MHz

ب.

50–54 MHz, 64 to 68 MHz

۷-۱-۱۲. الف.

2 MHz at 0 dB, 2.9 MHz at −10 dB, 4.550 at −23.1 dB, 5.365 MHz at −25.4 dB

۷-۱-۱۴.

الف. **-24 dB**   **ب.** **-35.6 dB**

۷-۲-۴.

$B_g \geq 0.76W$, $B_T \geq 17W$

۷-۲-۱۱.

$r = 150$ kHz, $\tau = 2\ \mu$s, $B_T \geq 250$ kHz

۷-۲-۱۳.

الف. $B_T \geq 250$ kHz   **ب.** $B_T \approx 250$ kHz

۷-۲-۱۸.

$M = 28$

۷-۳-۵.

$$\cos\theta_v(t) = \cos[(\omega_c + \omega_1)t + \phi_0 + \phi_1 + 90^0 - \varepsilon_{ss}]$$

۷-۳-۸.

$f_v = 5$ kHz, 50 kHz

.۷-۳-۱۲

الف. $A_\varepsilon = \frac{f_\Delta}{K}\frac{A_m}{\sqrt{1+(f_m/K)^2}}$ ب. $K \ge 2f_\Delta$

.۷-۴-۴

$n_p = 25.921, B = 805 \text{ kHz}$

.۷-۴-۶

$n_p = 2.18 \times 10^5, T_{line} = 64\ \mu\text{s}, B = 4.99 \text{ MHz}$

.۸-۱-۱

$P(A^cB) = 2/12$

.۸-۱-۵

$P(C) = P(A) + P(B) - 2P(AB)$

.۸-۱-۱۱ P (همه دم‌ها) = 11/24

.۸-۲-۱

$P(X \ge 2) = 0.4$

.۸-۲-۵

$K = 0.01$

.۸-۲-۹

$p_Z(z) = e^{-(z+5)}u(z+5)$

.۸-۲-۱۵

$p_Y(y) = e^{-y}u(y)$

.۸-۳-۱

$m_X = 1/a$

.۸-۳-۵

$m_X = \frac{K-1}{2}a$

.۸-۳-۹

$\beta = -m_X$

.۸-۳-۱۵

$\Phi_X(\nu) = \left(1 - j\frac{\nu}{a}\right)^{-1}$

.۸-۴-۱

$P(i < 3) = 56/1024$

.۸-۴-۵

$P(I > 1) = 0.264$

.۸-۴-۹

$P(X > 20) = Q(0.5) \approx 0.31$

.۸-۴-۱۷

$E[Y] = e^{\sigma_X^2/2}e^{m_X}$

.۸-۴-۲۴

$m_Z = 0, \sigma_Z^2 = 100$

.۹-۱-۱

$\overline{v(t)} = \frac{3}{t}(e^{2t} - 1)$

.۹-۱-۷

$R_{vw}(t_1, t_2) = \sigma^2 \sin \omega_0(t_1 - t_2)$

.۹-۱-۱۰

$\overline{z(t)} = 0$

.۹-۲-۱

$\langle v(t)\rangle = \pm 3$

.۹-۲-۱۲

$R_{yx}(\tau) = \mathscr{F}_\tau^{-1}[(j2\pi f)G_x(f)]$

.۹-۳-۳

$\overline{y^2} = N_0 T/2$

.۹-۳-۷

$\overline{y^2} = N_{0v} R/4L$

.۹-۳-۱۰

$\bar{z} = \sqrt{\frac{2}{\pi}}\,\sigma \approx 16\ \mu\text{v}$

.۹-۳-۱۴

$B_N = \sqrt{\pi}/2\sqrt{2}\,a$

.۹-۴-۱

$(S/N)_{D_{dB}} = 61\ \text{dB}$

.۹-۴-۵

$(S/N)_D = 2S_T/3LN_0W$

.۹-۴-۹

$m_{min} = 5$

.۹-۵-۱

$(\sigma_A/A)^2 = k\mathcal{T}_N B_N \tau/E_p = 0.4$

.۹-۵-۵

$E_p \geq 5 \times 10^{-8}$

.۹-۵-۸

$h_{opt}(t) = \dfrac{2K\tau}{N_0}\,\Lambda\left(\dfrac{t - t_d}{\tau}\right)$

.۱۰-۱-۳

$G_n(f) \div N_0 = 0.1 \quad \text{at} \quad f/f_c = \pm 0.5$

.۱۰-۱-۷

$\sigma_Y = \sqrt{8 - 2\pi} = 1.3$

.۱۰-۱-۱۰

$R_n(\tau) = N_0 B_T \operatorname{sinc} B_T\tau \cos \omega_c \tau$

.۱۰-۱-۱۶

$R_{n_i n_q}(\tau) = -\pi N_0 B_T^2 \tau \operatorname{sinc}^2 B_T \tau$

.۱۰-۲-۱

$(S/N)_D = 50\ \text{dB}$

.۱۰-۲-۵

$(S/N)_D = \gamma/2$

.۱۰-۲-۱۱

$g_T = \gamma/\gamma_{th} \approx 1500 = 32\ \text{dB}$

.۱۰-۳-۱

$\text{FM}: N_D = N_0 W^3/3S_R = 1.67 \times 10^5$

.۱۰-۳-۶

$(S/N)_D = 290 = 24.6\ \text{dB}$

.۱۰-۳-۱۰

$(S/N)_{D_{th}} \leq 2030 \approx 33\ \text{dB}$

.۱۰-۴-۱

$S_T \approx 200\ \text{W}$

.۱۰-۴-۵

$(S/N)_D = 90 = 19.5\ \text{dB}$

.۱۰-۶-۱

$(S/N)_D = 2.78 \times 10^5 = 54.4\ \text{dB}$

.۱۱-۱-۷

$B \geq 160\ \text{kHz}$

.۱۱-۱-۱۱

$r \approx 0.7B$

۱۱-۲-۱.

$(S/N)_R = 19.2, P_e = 6 \times 10^{-6}$

۱۱-۲-۴.

$P_e = \frac{1}{2} O\left(\frac{A-2\alpha}{2\sigma}\right) + \frac{1}{2} Q\left(\frac{A+2\alpha}{2\sigma}\right)$, $P_e = 3.7 \times 10^{-4}$ and 3.4×10^{-5} (if $\epsilon = 0$)

۱۱-۲-۸. (بازساز شونده) $P_e = 1.5 \times 10^{-22}$ (بازسازنشونده) $P_e = 1.2 \times 10^{-2}$

۱۱-۲-۱۳.

$M_{\min} = 16, S_R \geq 670$ pW

۱۱-۳-۳.

الف. 3 kbps ب. 4 kbps پ. 4.8 kbps

۱۱-۴-۱. خروجی درهم : 010010111001100 ، مقدار dc : 0.47 (درهم شده) ، 0.80 (درهم نشده)

۱۲-۱-۱.

$\nu = 3, f_s \leq 33.3$ kHz, $n = 3$

۱۲-۱-۵.

$M = 3, \nu = 5, f_s \leq 6.4$ kHz

۱۲-۱-۱۰.

$q = 4096, \Delta = 0.488$ mV, $(S/N)_D = 74$ dB

۱۲-۱-۱۳. **24 Mbits**

۱۲-۲-۱.

$M = 8, \nu = 2, q = 64, S_R = 56.7$ mW

۱۲-۲-۴.

$\gamma \approx 22.8$ dB (PCM), $\gamma = 50$ dB (analog), advantage: 27.2 dB

۱۲-۳-۲. **0.372**

۱۲-۳-۷.

$W_{rms} = 1.3 \text{ kHz}, K = \frac{f_0 S_x}{2 \arctan (W/f_0)}$

۱۲-۳-۱۰.

$n = 1$: $c_1 = \rho_1, G_\rho = 10.1$ dB, $n = 2$: $c_1 = 0.9744, c_2 = -0.0256, G_\rho = 10.1$ dB

۱۲-۴-۱. **5.9 Gbits**

۱۲-۵-۱.

$N = 4$, efficiency $= 7.8\%$

۱۲-۵-۴. 247 secs/page (هر دو کانال B به کار رفته است .

۱۳-۱-۱. **0.6561 =(بی خطا) P ، 0.2916 = (خطای آشکار شده) P ، 0.0523 = (خطای آشکار نشده)P .**

۱۳-۱-۵.

(31, 26): $\gamma_b = 7.0$ dB, (31, 21): $\gamma_b = 8.2$ dB, (31, 16): $\gamma_b = 8.3$ dB, uncoded: $\gamma_b = 10.5$ dB

۱۳-۱-۱۰.

$P_{be} \approx 10^{-6}, N \geq 10, r_b \leq 269$ kbps

۱۳-۲-۱۳.

$Q_M(p) = p^2 + p + 1, C(p) = 0 + 0 + p + 1, X = (1\,0\,1\,0\,0\,1\,1)$

۱۳-۲-۱۹.

$\alpha = 5 \times 10^{-4}, P_{be} = 1.5 \times 10^{-6}$

۱۳-۲-۲۳.

$X = (1\,0\,0\,0\,1\,0\,1\,1\,0\,1\,0\,1\,0\,1\,0\,0\,1\,1\,1)$

۱۳-۳-۶.

$X = (101 \quad 100 \quad 010 \quad 000 \quad 100 \quad 000 \quad 011 \quad 000)$

۱۳-۳-۱۱.

الف. مسیر حداقل وزن

$abc = D^3 I^1,\ d_f = 3,\ M(d_f) = 1$

ب.

$T(D, I) = \dfrac{D^3 I}{1 - DI}$ (c) Eq. (9): $P_{be} = 8\alpha^{3/2}$, Eq. (10): $P_{be} = 8\alpha^{3/2}$

۱۳-۳-۱۳.

$Y + \hat{E} = 00 \quad 11 \quad 01 \quad 01 \quad 11 \quad 11 \quad 10 \quad 11$
$\hat{M} = 0 \quad 1 \quad 1 \quad 0 \quad 0 \quad 1 \quad 0 \quad 0$

۱۳-۴-۱.

$x = \{8, 27, 51\} \rightarrow y = \{2, 3, 6\}$ with $pq = 55,\ e = 7,\ d = 23$

۱۴-۱-۱.

$\overline{x_c^2} = \dfrac{A_c^2}{12}(M-1)(2M-1),\ \dfrac{P_c}{\overline{x_c^2}} = 1/2\ (M = 2),\ \dfrac{P_c}{\overline{x_c^2}} = 3/4\ (M \gg 1)$

۱۴-۱-۱۴.

$r_b = 385$ bps

۱۴-۲-۴.

$P_e = Q(\sqrt{1.216\gamma_b})$

۱۴-۲-۶.

$\theta_\varepsilon < \arccos(3.74/4.27) \approx 29°$

۱۴-۲-۱۴.

الف. $A_c = 0.00133$ **ب.** $A_c = 0.0023$

۱۴-۳-۱.

$\gamma_b > 10.9$ dB, $P_{e1} < 3 \times 10^{-4}$

۱۴-۳-۴.

الف. $P_e = 3.4 \times 10^{-5}$ **ب.** $P_e = 1.76 \times 10^{-4}$

۱۴-۳-۸.

الف. 11.8 kbps **ب. 23.5 kbps** **پ. 28.4 kbps**

۱۴-۴-۱.

الف. $\gamma_b \geq 10.5$ dB **ب.** $\gamma_b \geq 12.8$ dB

۱۴-۴-۳.

الف. 16-QAM with $\gamma_b \geq 14.4$ dB **ب.** 16-PSK with $\gamma_b \geq 18.4$ dB

۱۴-۴-۶. **5.2**

.۱۴-۴-۱۱

الف. $P_e = 2.32 \times 10^{-5}$ ب. $P_e = 1.8 \times 10^{-10}$ پ. $P_e = 0.4, (d)\ P_e = 0.017$

.۱۴-۵-۱ سرعت نماد خروجی تغییر نمی‌کند.

$P_e = 1.6 \times 10^{-11}$

.۱۴-۵-۳

$$x_2x_1 = \{00,\quad 01,\quad 10,\quad 01,\quad 11,\quad 00\} \rightarrow$$
$$y_3y_2y_1 = \{000,\quad 100,\quad 011,\quad 010,\quad 111,\quad 111\}$$

.۱۵-۱-۱

الف. $W_c = 203$ kcps ب. $B_T = 0.41$ MHz

.۱۵-۱-۵

$W_c > 487$ kcps

.۱۵-۲-۱

$Pg = 2^7 = 256,\ B_T = 768$ kHz

.۱۵-۲-۴

$P_e = 4.95 \times 10^{-2}$

.۱۵-۳-۵

$\{0000\quad 0000\quad 1001\quad 0100\quad 1001\quad 1110\quad 1010\quad 110\},\ |R_{st}(\tau)|_{\max} = 0.29$

.۱۵-۴-۳

$\overline{T}_{acq} = 0.51$ secs, $\sigma_{\text{acq}} = 0.38$ secs

.۱۶-۱-۱

$I(\text{not } F) = \log 5/4 = 0.322$ bits

.۱۶-۱-۴

$H(X) = 1.94$ bits

.۱۶-۱-۹

$$H(X) = \frac{1}{3}\log 3 + p\log\frac{1}{p} + \left(\frac{2}{3} - p\right)\log\frac{1}{\frac{2}{3} - p}$$

.۱۶-۱-۱۶

$H(X) = 0.811$ bits

.۱۶-۲-۸

$C_s = 0.577$ bits/symbol

.۱۶-۳-۱

$H(X) = \log\sqrt{12S}$

.۱۶-۳-۵

$$p(x) = \frac{1}{m}e^{-x/m}u(x) \quad H(X) = \log em$$

.۱۶-۳-۱۰

$S \geq 10^{-3}(2^{R/1000} - 1)$

.۱۶-۳-۱۴

$S_T = \gamma L N_0 W$

.۱۶-۴-۵

$$s_1 = \sqrt{2}\,\phi_1 \quad s_2 = \sqrt{\frac{2}{3}}\,\phi_2 \quad s_3 = \frac{\sqrt{2}}{3}\phi_1 + \sqrt{\frac{8}{45}}\,\phi_3$$

.۱۶-۵-۱

$z_1 = (y, s_1) \quad z_2 = (y, s_2)$

.۱۶-۵-۵

$$P_e = \frac{20}{9}Q\left(\sqrt{\frac{9E}{24N_0}}\right) - \frac{16}{9}Q^2\left(\sqrt{\frac{9E}{24N_0}}\right)$$

الف – ۱.

$$v_n^2(f) = 4R_1 k\mathcal{T}_1 + 4R_2 k\mathcal{T}_2$$

الف – ۲.

$$i_n^2(f) \approx 4(r/2)k\mathcal{T}, \quad r \approx k\mathcal{T}/qI$$

الف – ۳.

$$F = 26$$

الف – ۴.

$$\mathcal{T} \leq 103\ \mathrm{K}$$