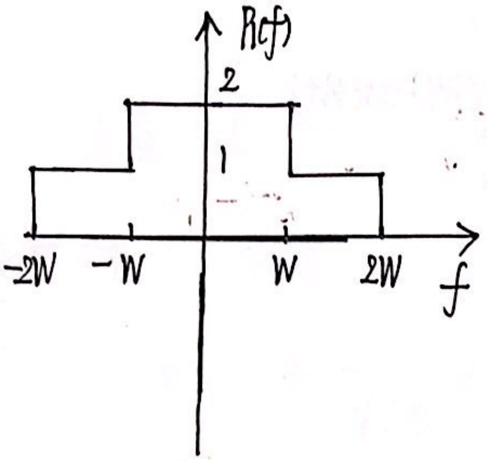
5.11

(a) $P_1(f)=\Pi\left(\frac{f}{2W}\right)+\Pi\left(\frac{f}{W}\right)$



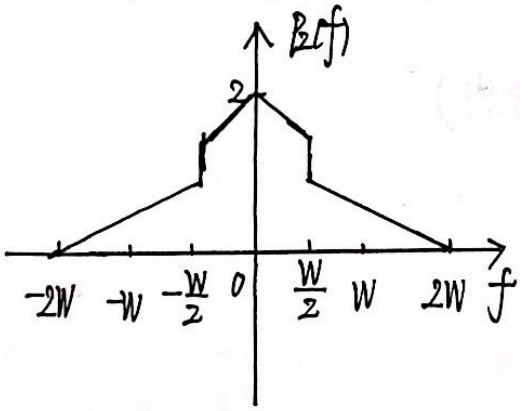
频域条件为

$$\sum_{m=-\infty}^{\infty} V(f+mT)=\frac{1}{T}$$

取 $T=\frac{1}{1.5W}=\frac{2}{3W}$ 时，满足条件

$$p(t)=2W\operatorname{sinc}(2Wt)+W\operatorname{sinc}(Wt)$$

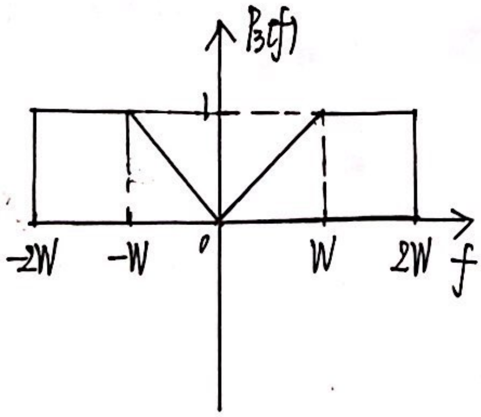
(b) $P_2(f)=\Lambda\left(\frac{f}{2W}\right)+\Pi\left(\frac{f}{W}\right)$



$P_2(f)$ 不满足条件

$$p(t)=W\operatorname{sinc}^2(2Wt)+W\operatorname{sinc}(Wt)$$

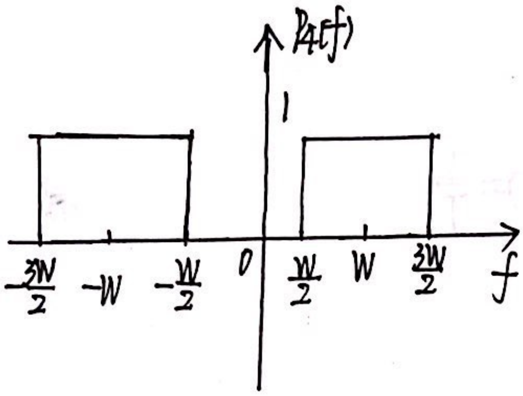
(c) $P_3(f)=\Pi\left(\frac{f}{4W}\right)-\Lambda\left(\frac{f}{W}\right)$



$P_3(f)$ 不满足条件

$$p(t)=4W\operatorname{sinc}(4Wt)-W\operatorname{sinc}^2(Wt)$$

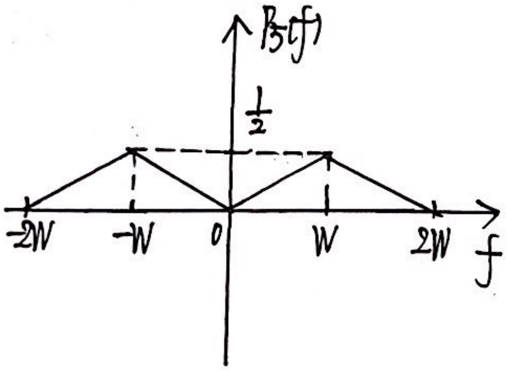
(d) $P_4(f)=\Pi\left(\frac{f-W}{W}\right)+\Pi\left(\frac{f+W}{W}\right)$



满足条件 $T=\frac{1}{W}$

$p(t)=2W\,\mathrm{sinc}(Wt)\cos(Wt)$

(e) $P_5(f)=\Lambda\left(\frac{f}{2W}\right)-\Lambda\left(\frac{f}{W}\right)$



满足条件 $T=\frac{1}{W}$

$p(t)=2W\,\mathrm{sinc}^2(2Wt)-W\,\mathrm{sinc}^2(Wt)$

要点：无ISI的频域条件（同时요知时域条件）

5.13

$$v(t)=\mathrm{sinc}\left(\frac{t}{T}\right)\frac{\cos(\pi\beta t/T)}{1-(2\beta t/T)^2}$$

$$\Rightarrow \begin{cases} \frac{1+\beta}{2T}=7\ \text{kHz} \\ \frac{1}{T}=9\ \text{kbps} \end{cases} \Rightarrow \beta=\frac{5}{9}$$

9.6

对于二进制PAM，接收信号为：

$$r = \pm\sqrt{E_i} + y_n(T) \quad (i=1,2) \quad E_i\text{为信号能量}$$

$y_n(T)$是零均值，方差$\sigma_n^2 = \frac{1}{2}N_0$的高斯随机变量；

条件PDF $p(r|s_i)$为：

$$p(r|s_1) = \frac{1}{\sqrt{\pi N_0}} e^{-\frac{(r-\sqrt{E_1})^2}{N_0}} \qquad s_1: A_1 \text{ sent}$$

$$p(r|s_2) = \frac{1}{\sqrt{\pi N_0}} e^{-\frac{(r+\sqrt{E_2})^2}{N_0}} \qquad s_2: A_2 \text{ sent}$$

门限设置为0（题目条件）

$$P_E = \frac{1}{2}Pr(\text{error}|A_1 \text{ sent}) + \frac{1}{2}Pr(\text{error}|A_2 \text{ sent})$$

$$= \frac{1}{2}\int_{-\infty}^{0} \frac{1}{\sqrt{\pi N_0}} e^{-\frac{(r-\sqrt{E_1})^2}{N_0}} dr + \frac{1}{2}\int_{0}^{\infty} \frac{1}{\sqrt{\pi N_0}} e^{-\frac{(r+\sqrt{E_2})^2}{N_0}} dr$$

对于$\int_{-\infty}^{0} \frac{1}{\sqrt{\pi N_0}} e^{-\frac{(r-\sqrt{E_1})^2}{N_0}} dr$，令$\frac{x}{\sqrt{2}} = \frac{r-\sqrt{E_1}}{\sqrt{N_0}}$

$$\Rightarrow \text{原式} = \int_{-\infty}^{-\sqrt{\frac{2}{N_0}E_1}} \frac{1}{\sqrt{2\pi}} e^{-\frac{x^2}{2}} dx$$

$$= \int_{\sqrt{\frac{2}{N_0}E_1}}^{\infty} \frac{1}{\sqrt{2\pi}} e^{-\frac{x^2}{2}} dx$$

$$= Q\left[\sqrt{\frac{2}{N_0}E_1}\right]$$

对于 $\int_0^{\infty} \frac{1}{\sqrt{\pi N_0}} e^{-\frac{(r+\sqrt{E_2})^2}{N_0}} dr$ 令 $\frac{x}{\sqrt{2}} = \frac{r+\sqrt{E_2}}{\sqrt{N_0}}$

$\Rightarrow$ 原式 $= \int_{\sqrt{\frac{2}{N_0}E_2}}^{\infty} \frac{1}{\sqrt{2\pi}} e^{-\frac{x^2}{2}} dx = Q[\sqrt{\frac{2}{N_0}E_2}]$

$$E = \frac{A_1^2+A_2^2}{2}T = \frac{A_1^2 T}{2}(1+\rho^2)$$

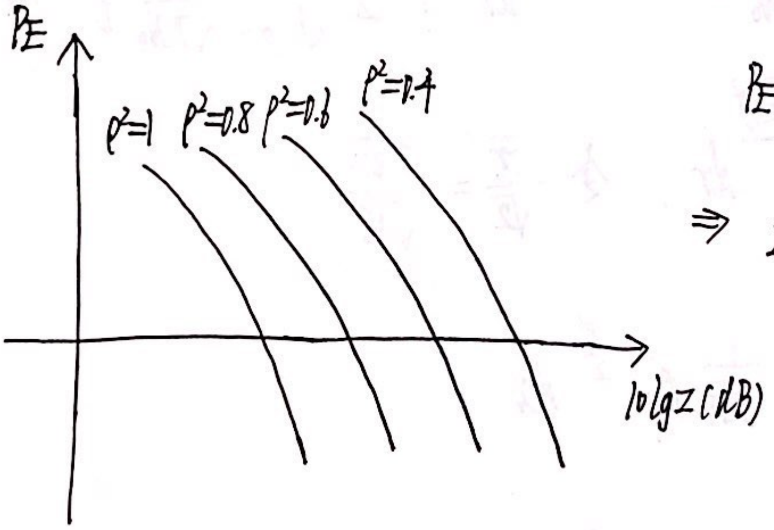
$E_1 = A_1^2 T \quad E_2 = A_2^2 T \quad \Rightarrow \quad E_1 = \frac{2E}{1+\rho^2} \quad E_2 = \frac{2\rho^2 E}{1+\rho^2}$

$$\Rightarrow P_E = \frac{1}{2}Q(\sqrt{\frac{2}{N_0}E_1}) + \frac{1}{2}Q(\sqrt{\frac{2}{N_0}E_2})$$

$$= \frac{1}{2}Q(\sqrt{\frac{2}{N_0}\cdot\frac{2E}{1+\rho^2}}) + \frac{1}{2}Q(\sqrt{\frac{2}{N_0}\cdot\frac{2\rho^2}{1+\rho^2}E})$$

$$= \frac{1}{2}Q(\sqrt{\frac{4Z}{1+\rho^2}}) + \frac{1}{2}Q(\sqrt{\frac{2\rho^2(2Z)}{1+\rho^2}}) \quad Z = \frac{E}{N_0}$$

(b)



$P_E = 10^{-6}$

$$\Rightarrow Z = \begin{cases} 10.5 & \rho^2=1 \\ 10.8 & \rho^2=0.8 \\ 11.5 & \rho^2=0.6 \\ 13 & \rho^2=0.4 \end{cases}$$

9.11

$$|e^{j2\pi f t_0}|=1$$

(a) $y(t_0)=s(t_0)+n(t_0)$

$$SNR=\frac{s^2(t_0)}{E[n^2(t_0)]}=\frac{\left|\int_{-\infty}^{\infty}H(f)S(f)e^{j2\pi f t_0}\right|^2}{\frac{1}{2}N_0\int_{-\infty}^{\infty}|H(f)|^2df}\leq\frac{\int_{-\infty}^{\infty}|H(f)|^2df\int_{-\infty}^{\infty}|S(f)|^2df}{\frac{1}{2}N_0\int_{-\infty}^{\infty}|H(f)|^2df}$$

$$=\frac{2\int_{-\infty}^{\infty}|S(f)|^2df}{N_0}$$

等号当且仅当 $H(f)e^{j2\pi f t_0}=KS^*(f)$ 时成立　(K 可被吸收入 N_0'，N_0' 为等效噪声谱密度)

$\Rightarrow H_m(f)=S^*(f)\exp(-j2\pi f t_0)$　(t_0 表示采样时刻)

(b) $$h_m(t)=\int_{-\infty}^{\infty}H_m(f)e^{j2\pi ft}df=\int_{-\infty}^{\infty}S^*(f)e^{-j2\pi f t_0}\cdot e^{j2\pi ft}df$$

$$=s(-(t-t_0))=s(t_0-t)$$

$s(-t)\leftrightarrow S^*(f)$

$s(-(t-t_0))\leftrightarrow S^*(f)e^{-j2\pi f t_0}$

(c) $$h_{mr}(t)=\begin{cases}s(t_0-t) & t\geq 0\\ 0 & t<0\end{cases}\qquad s(t)=A\Pi[(t-T/2)/T]$$

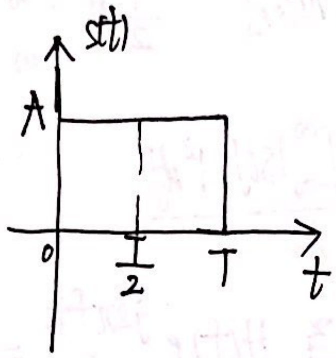
$t_0=0$　$h_{mr}(t)=A\delta(t)$

$t_0=\frac{T}{2}$　$$h_{mr}(t)=\begin{cases}A\Pi[(t-T/4)/(T/2)]\\ 0 & t<0\end{cases}$$

$t_0=T \quad h_{mr}(t)=\begin{cases} A\Pi[(t-T/2)/T] & t>0 \\ 0 & t<0 \end{cases}$

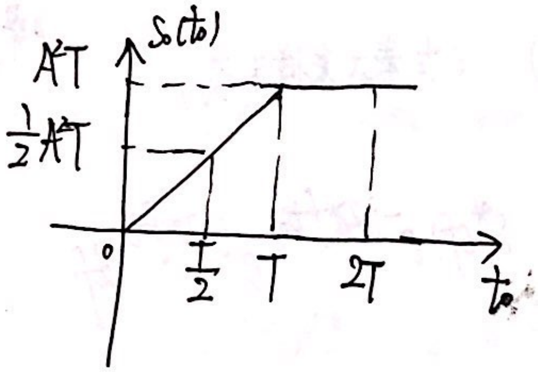
$t_0=2T \quad h_{mr}(t)=\begin{cases} A\Pi[(t-3T/2)/T] & t>0 \\ 0 & t<0 \end{cases}$

(d)



$$s_o(t_0) = s(t_0) * h_{mr}(t_0)$$

$$= \begin{cases} 0 & t_0=0 \\ \frac{1}{2}A^2T & t_0=\frac{T}{2} \\ A^2T & t_0=T,2T \end{cases}$$



$t_0 \geqslant T$时，满足因果性要求

9.19

(a) binary ASK

$$P_{2ASK} = Q\left(\sqrt{\frac{E_b(1-\rho)}{N_0}}\right) = Q(\sqrt{z}) = 10^{-5}$$

$$\Rightarrow z = 4.265^2 = 18.190$$

(b) $P_{BPSK} = Q(\sqrt{2z})$

$$\Rightarrow z = \frac{1}{2} \times 4.265^2 = 9.10$$

(c) binary FSK

$$P_{2FSK} = Q(\sqrt{z})$$

$$\Rightarrow z = 4.265^2 = 18.190$$

(d) BPSK with a phase error of 5 degrees

$$P_E(\phi) = Q(\sqrt{2Z\cos^2\phi})$$

$$D = -20\log_{10}\cos\phi = 0.033\,dB$$

$$Z_{BPSK} = 9.59\,dB$$

$$Z = 9.59 + 0.033\,dB = 9.623\,dB = 9.169$$

(e) $m = \frac{1}{\sqrt{2}}$

$$P_E = Q(\sqrt{2(1-m^2)Z}) = Q(\sqrt{Z}) \Rightarrow Z = 18.190$$

(f) $m = \frac{1}{2}$ with a phase error of 5 degrees

$$D = 0.033\,dB$$

$Z_{PSK} = 12.598\,dB$ $\quad Z = 12.598 + 0.033\,dB = 12.631\,dB = 18.327$