✓ $T_s < \frac{1}{2f_m}$ یا $f_s > 2f_m$

✓ $I(A) = -\log_\alpha P_A$

✓ $H = \lim_{N\to\infty} \frac{I_{total}}{N} = \sum_{i=1}^{M} P_i \log \frac{1}{P_i}$ $\quad bit/symbol$

✓ $R\,(\frac{bit}{sec}) = r_s\,(\frac{sym}{sec}) \times H$

✓ مدل مارکوف : $\xrightarrow{m}$ مرتبه منبع ، منبع ، مثال $P_1 = P_3 P_{31} + P_1 P_{11}$

$H_1 = P \log \frac{1}{P} + (1-P) \log \frac{1}{1-P} \Rightarrow H = P_1 H_1 + P_2 H_2 + \dots$

✓ $e = \frac{H}{H_{max}} = \frac{H}{\log M}$ $\qquad \rho = 1 - e$

✓ کدینگ با طول ثابت $\rightarrow$ $e' = \frac{H'}{\log_2^2} = H'$ و $H' = \frac{H}{n}$

$$\frac{e'}{e} = \frac{H/n}{H/\log_2^M} = \frac{\log_2^M}{n}$$

✓ کدینگ با طول متغیر $\rightarrow$ $I_{s_i} = \log \frac{1}{P_i} = n_i$

$\bar{n} = \sum_{i=1}^{M} P_i n_i = \sum P_i \log \frac{1}{P_i} = H$

$H' = \frac{H}{\bar{n}} = 1 \frac{bit}{binit}$ $\qquad \frac{e}{e'} = e$, $\rho' = 0$

$e' = \frac{H'}{\log_2^2}$

✓ $P_i^t = P\{x = i\}$ $\qquad P_i^r = P\{y = i\}$

✓ $P_{ij} = P\{y = j | x = i\}$

✓ $P\{x = i, y = j\} = P\{y = j | x = i\}\, P\{x = i\} = P_{ij} P_i^t$

✓ $P_j^r = \sum_{i=1}^{M} P_{ij} P_i^t$

✓ $H(x) = \sum_{i=1}^{M} P_i^t \log \frac{1}{P_i^t}$ $\qquad H(y) = \sum_{j=1}^{M} P_j^r \log \frac{1}{P_j^r}$

✓ $H(x,y) = \sum_{i=1}^{M} \sum_{j=1}^{M} P(x=i, y=j) \log \frac{1}{P(x=i, y=j)}$

✓ $H(y|x) = \sum_{j=1}^{M} \sum_{i=1}^{M} P(x=i, y=j) \log \frac{1}{P(y=j|x=i)}$

✓ $H(x|y) = \sum_{i=1}^{M} \sum_{j=1}^{M} P(x=i, y=j) \log \frac{1}{P(x=i, y=j)}$

✓ $H(x \to y) = H(x) - H(x|y) = H(y) - H(y|x)$

✓ کانال باینری $\rightarrow P_0^r = P\alpha + \bar{P}\bar{\beta}$

ادامه باینری $\rightarrow$ $P_1^r = \bar{P}\beta + P\bar{\alpha} = 1 - P_0^r$

$H(y) = f_{P_0^r}$ $\qquad H(y|x) = P f_\alpha + \bar{P} f_\beta$

✓ $D_t = r_s H(x \to y)$ میزان اطلاعات انتقالی کانال در واحد زمان

✓ ظرفیت کانال گسسته : $C = r_s H_{max}(x \to y)$

در باینری (کانال) $\rightarrow$ $P = \frac{1}{\alpha - \beta} \left(\frac{1}{1 + 2^{\frac{f_\alpha - f_\beta}{1-\alpha-\beta}}} - 1 \right)$

✓ ظرفیت کانال پیوسته : $r_s = 2B \rightarrow$ پهنای باند سیگنال

$H(x) = \int_{-\infty}^{+\infty} f(x) \log \frac{1}{f(x)}\, dx$

$\sigma_x^2 = \int_{-\infty}^{+\infty} (x-\mu)^2 f(x)\, dx$

$H_{max}(x) = \ln \sqrt{2\pi e \sigma_x^2}$ $\qquad nat/symbol$

✓ ظرفیت کانال با نویز گوسی : $\sigma_n^2 = N = \frac{\eta}{2} \times B \times 2 = \eta B$

$C = r_s H_{max}(x \to y) = 2B\,(H(y) - \overset{\text{نویز}}{H(y|x)})_{max}$

$C = B \log_2^{(1 + \frac{S}{N})}$ $\qquad \frac{S}{N} \rightarrow 10 \log \frac{S}{N}$

PAM , PWM , PPM

$z(t) = \sum_{k=-\infty}^{\infty} a_k \overset{\text{شکل پالس}}{h(t-kT)} = [\sum a_k \delta(t-kT)] * h(t)$

$R_x(\tau) = \lim_{T\to\infty} \frac{1}{2T} \int_{-T}^{T} E\{x(t) x(t-\tau)\}\, d\tau$

$F\{R(\tau)\} = S_x(f)$ $\qquad S_y(f) = S_x(f) |H(f)|^2$

$S_z(f) = S_g(f) |H(f)|^2$

$R_i = E\{a_k, a_{k+i}\} \rightarrow R_y(\tau) = \frac{1}{T} \sum_{-\infty}^{+\infty} R_i \delta(\tau - iT)$

$S_g(f) = \frac{1}{T} R_i e^{-j2\pi f iT} = \frac{R_0}{T} + \frac{1}{T} \sum_{i=1}^{\infty} 2R_i \cos(2\pi f iT)$

توان سیگنال PAM : $\int_{-\infty}^{\infty} S_z(f)\, df$

$t: \; P(kT) = \begin{cases} 1 & k=0 \\ 0 & k \neq 0 \end{cases}$

$f: \; \sum P(f - \frac{k}{T}) = T$

$P(f)$: $B < \frac{1}{2T} \rightarrow ISI$

$B = \frac{1}{2T} \rightarrow P(f) = rect$

$\frac{1}{2T} < B < \frac{1}{T} \rightarrow$ حول $\frac{1}{2T}$ تقارن فرد

کمترین پهنای باند برای PAM : $\frac{R_s}{2} = \frac{1}{2T}$

4-PAM : $R_b = 2R_s$

$y(mT) = \sum a_k P_r((m-k)T) + n(mT)$

[illegible] $\rightarrow y_m = a_m \overbrace{P_r(0)}^{k} + n(mT)$

$P_e = P_e|_{a_m=a} P(a_m=a) + P_e|_{a_m=-a} P(a_m=-a)$

$Q(x) = \int_x^{\infty} \frac{1}{\sqrt{2\pi\sigma_x^2}} e^{-\frac{(x-\mu)^2}{2\sigma_x^2}} dx$

M-PAM $\rightarrow P_e|_{a_m=a} = 2Q\left(\frac{ka}{\sigma}\right)$

$P_e = 2\left(1-\frac{1}{M}\right) Q\left(\frac{ka}{\sigma}\right)$

$Q(x) \simeq \begin{cases} 0.4 e^{-\frac{x^2}{2}} & x > 3 \\ 0.2 [\sqrt{x^2+4}\, e^{-\frac{x^2}{2}}] & x > \frac{1}{2} \end{cases}$

$x \simeq \sqrt{-2\ln(8Q)} \qquad 10^{-99} < Q < 10^{-2}$

در حالت کلی: $P_r(t) = P_g(t) * h_T(t) * h_c(t) * h_R(t)$

$H_T(f) H_R(f) = \frac{L P_r(f)}{P_g(f)}$

طیف PAM با فرض سمبل‌های مستقل از کل: $\frac{\bar{a^2}}{T} |P_g(f)|^2$

طیف PAM ارسالی $\frac{\bar{a^2}}{T} |P_g(f)|^2 |H_T(f)|^2$ و $\bar{a^2} = \frac{M^2-1}{3} a^2$

$S_T = \frac{M^2-1}{3T} a^2 \int_{-\infty}^{+\infty} |P_g(f) H_T(f)|^2 df$

$K = P_r(0) = \int_{-\infty}^{+\infty} P_r(f) df = \int_{-\infty}^{+\infty} \frac{1}{L} P_g(f) H_T(f) H_R(f) df$

$\sigma^2 = \int_{-\infty}^{+\infty} G_n(f) |H_R(f)|^2 df$

$\left| \int_{-\infty}^{+\infty} U(f) V^*(f) df \right|^2 \le \int_{-\infty}^{+\infty} |U(f)|^2 df \times \int_{-\infty}^{+\infty} |V(f)|^2 df$

$U(f) = K_0 V^*(f)$

$|H_R(f)|^2 = \frac{L}{K_0} P_r(f) \qquad |H_T(f)| = LK_0 \frac{P_r(f)}{|P_g(f)|^2}$

$P_e = 2\left(1-\frac{1}{M}\right) Q\left(\sqrt{\frac{6 S_R T}{(M^2-1)\eta}}\right)$

حالت کلی: $|H_R(f)|^2 = \frac{1}{K_0} \left| \frac{P_r(f)}{H_c(f)} \right| \times \frac{1}{\sqrt{G_n(f)}}$

$|H_T(f)| = K_0 \left| \frac{P_r(f)}{H_c(f)} \right| \times \frac{\sqrt{G_n(f)}}{|P_g(f)|^2}$

$P_e = 2\left(1-\frac{1}{M}\right) Q\left(\sqrt{\frac{3 S_T T}{M^2-1} \left[\frac{\int_{-\infty}^{+\infty} P_r(f) df}{\frac{P_r(f)}{H_c(f)} \sqrt{G_n(f)} df}\right]}\right)$

$r_s = \frac{r_b}{\log_2 M} \qquad T = \frac{1}{r_s} = \frac{\log_2 M}{r_b}$

$BW > \frac{r_s}{2}$

$\frac{BW_{M\text{-PAM}}}{BW_{\text{binary-PAM}}} = \frac{1}{\log_2 M}$

Pe ها دو $\rightarrow \frac{\text{M-ary توان}}{\text{binary توان}} = \frac{M^2-1}{3\log_2 M}$

تکرارکننده:

$P_{eN} = 2\left(1-\frac{1}{M}\right) Q\left(\sqrt{\frac{6 S_R T}{(M^2-1) N\eta}}\right)$

$P_{eN} = 1-(1-P_e)^N = 1-(1-NP_e) = NP_e$

شکل موج PAM: $G_x(f) = G_a(f) |P(f)|^2$

$a_k \delta(t-kT)$

$G_a(f) = \frac{1}{T} \sum_{i=-\infty}^{+\infty} R_i e^{j2\pi f i T}$

✓ AMI یا Bipolar $\rightarrow$ $\begin{matrix} 0 \\ 1 \end{matrix} \Big|$ $\overset{0}{\pm 1}$ تناوبی برای R_i بیت تکراری

✓ HDB3: $0000 < \begin{matrix} 000D \\ 100D \end{matrix}$

✓ 4B3T $\rightarrow$ زوج‌ها + [illegible]

ترانسورسال: $f(t) = C_{-2}\delta(t) + C_{-1}\delta(t-\tau) + C_0\delta(t-2\tau) + \dots$

$f(t) = \sum_{n=-N}^{N} C_n \delta(t-n\tau)$

$F(f) = \sum_{n=-N}^{N} C_n e^{-j2\pi f n\tau}$

$P_{eq}(t) = \sum_{n=-N}^{+N} C_n P_r(t-nT) \rightarrow \begin{matrix} P_{eq}(T) = 0 \\ P_{eq}(2T) = 0 \end{matrix}$

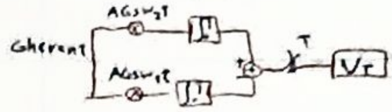
آستانه $T = \frac{\ln \frac{1-P}{P}}{\frac{2ka}{\sigma^2}}$

طیف فیلتر: $P_r(f) = \begin{cases} T & |f| < \frac{r_s}{2} - \beta \\ T\cos^2 \frac{\pi}{4\beta}\left(|f| - \frac{r_s}{2} + \beta\right) & \frac{r_s}{2} - \beta < |f| \le \frac{r_s}{2} + \beta \\ 0 & |f| > \frac{r_s}{2} + \beta \end{cases}$

$0 < \beta < \frac{r_s}{2} \rightarrow P_r(t) = \frac{\cos 2\pi\beta t}{1-(4\beta t)^2} \left(\frac{\sin \pi r_s t}{\pi r_s t}\right)$

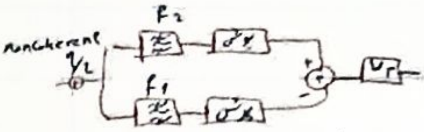
$dBw = 10\log P$, $dBm = dBw + 30db$

Coherent

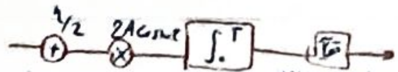


$P_e = Q\left(\sqrt{\frac{E}{2\eta}}\right)$

noncoherent



$P_e = \frac{1}{2} e^{-\frac{S_R T}{4\eta}}$



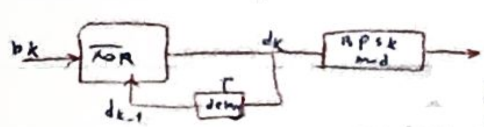
✓ PSK → $s_1(t) = -A\cos wt$, $s_2 = A\cos wt$, ~~[illegible]~~

$z(t) = Ab(t)\cos wt$, $b(t) = \sum_k a_k \, rect\left(\frac{t-kT}{T}\right)$ $a_k = \pm 1$

$G_z(f) = \frac{A^2 T}{4}\left[\operatorname{sinc}^2(f-f_c)T + \operatorname{sinc}^2(f+f_c)T\right]$

$B = \frac{2}{T}$, $V_T = 0$, $S_R = \frac{A^2}{2}$, $P_e = Q\left(\sqrt{\frac{A^2 T}{\eta}}\right) = Q\left(\sqrt{\frac{2S_R T}{\eta}}\right)$

ناهمدوس



$d_k = \overline{d_{k-1}\,(XOR)\,b_k}$

$d_k = \overline{d_{k-1}\,(XOR)\,b_k}$

$\begin{smallmatrix}1,1\\0,0\end{smallmatrix} \to 1$

سیگنال ورودی → b_k

d_k

فاز ارسالی ← $\begin{smallmatrix}1 \to 0\\0 \to \pi\end{smallmatrix}$

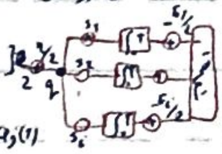
دریافتی میرسد

✓ $\lambda = \log_2^{M}$, $T = \frac{\lambda}{r_b} = \frac{\log_2^M}{r_b}$

$\frac{Pulse}{sec}$ $r_s = \frac{1}{T} = \frac{r_b}{\lambda}$

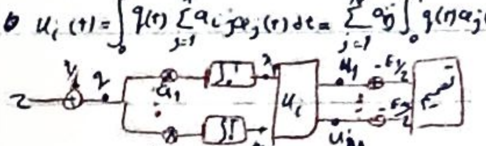
$\int_0^T (q(t) - s_i(t))^2 dt \longrightarrow Min \longrightarrow$ s_i ارسالی است

$L = \int_0^T q^2(t) - 2\left[\int_0^T q(t)s_i(t) - \frac{E_i}{2}\right]$



$u_i = \int_0^T q(t)s_i(t)\,dt$, $s_i(t) = \sum_{j=1}^{n} a_{ij}\alpha_j(t)$

$u_i(t) = \int_0^T q(t)\sum_{j=1}^{n} a_{ij}\alpha_j(t)\,dt = \sum_{j=1}^{N} a_{ij}\int_0^T q(t)\alpha_j(t)\,dt = \sum_{j=1}^{N} a_{ij}x_j$



✓ M-PSK → $s_1(t) = A\cos\left(w_c t - \frac{2\pi}{M}\right) =$

$A\cos\frac{2\pi}{M}\underbrace{\cos w_c t}_{\alpha_1(t)} + A\sin\frac{2\pi}{M}\underbrace{\sin w_c t}_{\alpha_2(t)}$

$z(t) = AB_1(t)\cos w_c t + AB_2(t)\sin(w_c t)$

$B_1(t) = \sum_k a_k \, rect\left(\frac{t-kT}{T}\right)$, $a_k = \cos\frac{2\pi}{M}$, $\cos\frac{4\pi}{M}$, $\cos 2\pi$

$B = \frac{2}{T}$

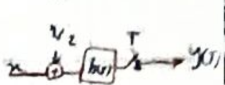
$\int_0^\infty x^3 e^{-ax^2}dx = \frac{1}{2a^2}$, $d_k = \overline{d_{k-1}\,XOR\,b_k} \odot \overline{d_{k-1}.\,b_k}$

$x = \begin{cases} s_1(t-(k-1)T) & b_k = 0 \\ s_2(t-(k-1)T) & b_k = 1 \end{cases}$ $(k-1)T \le t \le kT$

✓ فصل ۹ binary ASK : $0 / A\cos(2\pi f_c t)$

FSK → $A\cos(2\pi(f_c - f_d)t) / A\cos(2\pi(f_c + f_d)t)$

PSK → $A\cos(2\pi f_c t) / -A\cos(2\pi f_c t)$



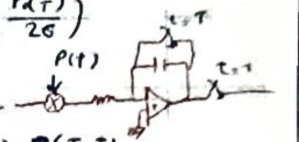
✓ فیلتر منطبق → $H(f) = (P(f)e^{j2\pi fT})^*$, $h(t) = P(T-t)$

آشکارسازی

✓ $y(t) = P(t) * h(t) + n(t)$ <
$y(T) < \frac{P_o(T)}{2}$ پالس نبوده
$y(T) > \frac{P_o(T)}{2}$ پالس بوده

$\left[\frac{P_o^2(T)}{\sigma^2}\right]_{max} = \frac{2E}{\eta}$, $P_e = Q\left(\frac{P_o(T)}{2\sigma}\right)$

$\sigma_n^2 = \int_{-\infty}^{+\infty} \eta/2\,|H(f)|^2 df$

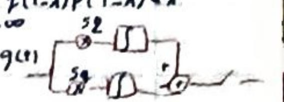


✓ correlator → $q(t) = \begin{Bmatrix}0\\P(t)\end{Bmatrix} + n'(t)$, $h(t) = P(T-t)$

$y(t) = q(t) * h(t) = \int_{-\infty}^{+\infty} q(t-\lambda)h(\lambda)d\lambda = \int_{-\infty}^{+\infty} q(t-\lambda)P(T-\lambda)d\lambda$

→ $y(T) = \int_{-\infty}^{+\infty} q(u)P(u)du = \langle q(t)P(t)\rangle$

خروجی کامل ورودی کامل



$y(T) = \begin{Bmatrix} s_{10}(T) \\ s_{20}(T) \end{Bmatrix} + n(T)$ $s_{10}(t) = s_1(t) * h(t)$, $s_{20}(t) = s_2(t) * h(t)$

آستانه بهینه $T = \frac{s_{10}(T) + s_{20}(T)}{2}$, $P_e = Q\left(\frac{s_{20}(T) - s_{10}(T)}{2\sigma}\right)$

$P_o(t) = s_{20}(t) - s_{10}(t) \rightarrow P_e = Q\left(\frac{P_o(T)}{2\sigma}\right)$

, $h(t) = s_2(T-t) - s_1(T-t) = P(T-t)$

✓ ASK → $z(t) = d(t)A\cos 2\pi f_c t$, $d(t) = \frac{1}{2}(1 + b(t))$ PAM

$A\cos(2\pi f_c t) \xrightarrow{\mathcal{F}} \frac{A^2}{4}\left[\delta(f-f_c) + \delta(f+f_c)\right]$, $B = \frac{2}{T} = 2R_s$

$rect\left(\frac{t}{T}\right) \xrightarrow{F} T\operatorname{sinc}(fT)$, $G_b(f) = \frac{1}{T}T^2\operatorname{sinc}^2(fT)$

$V_T = \frac{A^2 T}{4}$, $P_e = Q\left(\sqrt{\frac{E}{2\eta}}\right)$, $E = \frac{A^2 T}{2}$, $P_e = Q\left(\sqrt{\frac{A^2 T}{4\eta}}\right)$

$P_e = Q\left(\sqrt{\frac{S_R T}{\eta}}\right)$, در PAM: $P_e = Q\left(\sqrt{\frac{2S_R T}{\eta}}\right)$

noncoherent → پوش سیگنال (2) $\xrightarrow[f_c]{BPF}$ (1) مقایسه (3)

$P_e = \frac{1}{2}e^{-\frac{S_R T}{4\eta}}$, $S_R = \frac{A^2}{4}$ ⟹ AGC

✓ FSK → $z(t) = \frac{A}{2}[1 + b(t)]\cos 2\pi f_2 t + \frac{A}{2}[1 + b(t)]\cos 2\pi f_1 t$

$f_1 = f_c - f_d$, $f_2 = f_c + f_d$, $B \simeq 2f_d + \frac{2}{T}$

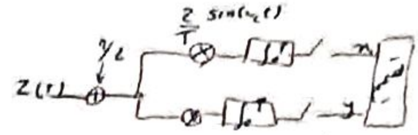
$S_{o}(T) = \int_0^T s_1(t)\left[s_2(t) - s_1(t)\right]dt \rightarrow V_T = 0 \rightarrow$ AGC ✗

$P = Q\left(\sqrt{\frac{E}{2\eta}}\right)$, $E = \int_0^T [s_2(t) - s_1(t)]^2 dt$, $E = A^2 T[1 - \operatorname{sinc}(f_2 - f_1)2T]$

$P_e = Q\left(\sqrt{\frac{A^2 T(1 - \operatorname{sinc}(2(f_2 - f_1)T))}{2\eta}}\right) = Q\left(\sqrt{\frac{A^2 T}{2\eta}k}\right)$

$S_R = \frac{A^2}{2} \times \frac{1}{2} + \frac{A^2}{2} \times \frac{1}{2} = \frac{A^2}{2}$

$Q(\sqrt{A}) \simeq \frac{1}{\sqrt{2\pi}\sqrt{A}}e^{-A}$



$$MPSK \rightarrow \text{فاز} \rightarrow q(t)=s_i(t)=A\cos\left(\omega_c t-\frac{2\pi i}{M}\right)\rightarrow s_{i(t)}\begin{cases}x\\y\end{cases}$$

$$x=\frac{2}{T}\int_0^T q(t)\cos\omega_c t\,dt = A\cos\frac{2\pi i}{M},\quad y=A\sin\frac{2\pi i}{M}$$

$$n(t)\rightarrow\begin{cases}x=\frac{2}{T}\int_0^T n(t)\cos\omega_c t\,dt\\ y=\frac{2}{T}\int_0^T n(t)\sin\omega_c t\,dt\end{cases}$$

$$\eta_x=\frac{2}{T}\int_0^T n(t)\cos\omega_c t\,dt=\frac{2}{T}\int_0^T \overline{n(t)}\cos\omega_c t\,dt=0$$

$$\sigma_x^2=\frac{4}{T^2}E\left[\int_0^T n(t)\cos(\omega_c t)\,dt\right]^2=\frac{2\eta}{T}\times\frac{T}{2}=\frac{\eta}{T}$$

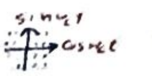
$$4PSK\rightarrow P_e=Q\left(\frac{A\sqrt{2}/2}{\sigma}\right)+Q\left(\frac{A\sqrt{2}/2}{\sigma}\right)-\cancel{Q^2\left(\frac{A\sqrt{2}/2}{\sigma}\right)}$$

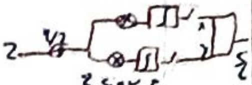
$$\boxed{\sigma^2=\frac{\eta}{T}},\quad MPSK\rightarrow P_e=2Q\left(\frac{A\sin\frac{\pi}{M}}{\sigma}\right)$$

$$r_b: T=\frac{\log_2^M}{r_b},\quad S_R=\frac{A^2}{2},\quad P_e=2Q\left(\sqrt{\frac{2S_R\log_2^M\sin^2\left(\frac{\pi}{M}\right)}{\eta\, r_b}}\right)$$

$$B=\frac{2}{T}=\frac{2r_b}{\log_2^M}$$

✓ MQAM, MASK/PSK $\rightarrow$



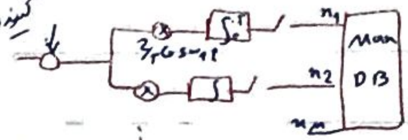


$$16\rightarrow P_{e_t}=4\times\frac{1}{16}\times4Q\left(\frac{A}{\sigma}\right)+\frac{8}{16}\times3Q\left(\frac{A}{\sigma}\right)+\frac{4}{16}\times2Q\left(\frac{A}{\sigma}\right)$$

$$S_R=\frac{4}{16}\left(\frac{A^2+A^2}{2}\right)+\frac{8}{16}\left(\frac{A^2+9A^2}{2}\right)+\frac{4}{16}\left(\frac{9A^2+9A^2}{2}\right)=5A^2$$

✓ $MFSK\rightarrow S_i(t)=A\cos\omega_i t$

گیرنده



$$\int_0^T A^2\cos(\omega_i t)\cos(\omega_j t)\,dt=0\rightarrow(\omega_i-\omega_j)T=n\pi$$

$$B=\frac{M+3}{2T},\quad P_e=(M-1)Q\left(\frac{d}{\sigma}\right)\rightarrow \frac{A\sqrt{2}}{2}$$

$$S_R=\frac{A^2}{2},\ \sigma=\sqrt{\frac{\eta}{T}},\ T=\frac{\log_2^M}{r_b}\rightarrow P_e=(M-1)Q\left(\sqrt{\frac{S_R T}{\eta}}\right)$$

خطای بیت / خطای کد

$$q=P\{d_k\neq\hat{d}_k\},\quad P_e=P\{b_k\neq\hat{b}_k\}$$

کدشده

$$C=DG\rightarrow G=[I_{k\times k}\,|\,P_{k\times n-k}]_{k\times n}$$

پیام

$$H=[P^T_{n-k\times k}\,|\,I_{n-k\times n-k}],\quad GH^T=0$$

$$CH^T=DGH^T=0\rightarrow$$ هر کلمه کد درست سندرم صفر C

$$S=RH^T=(C+E)H^T=EH^T\xrightarrow{S\neq0}$$ ستون H

ملاحظه $\quad d(C,R)+d(C',R)\geq d(C,C')$

$$d(C,C')\geq d_{min}\rightarrow t'+d(C',R)\geq d(C,C')\geq d_{min}$$

$$d(C',R)\geq d_{min}-t'$$

$$\Rightarrow d_{min}-t'\leq d(C',R)<d(C,R)=t'\rightarrow t'<\frac{d_{min}}{2}$$

همینگ $\rightarrow n\geq k+\log_2^{n+1}$

$$(12,8)\rightarrow 2^4-1-4=11$$

✓ S	C_1	C_2	C_3	C_{2^k}
E_2H^T	E_2	C_2+E_2	C_3+E_2	
E_3H^T	E_3	C_2+E_3	C_3+E_3	
$E_{2^{n-k}}H^T$	$E_{2^{n-k}}$	$C_2+E_{2^{n-k}}$	$C_3+E_{2^{n-k}}$	

کدهای خطای پراکنده

$$R=C_i+E_2,\quad S=RH^T=(C_i+E_2)H^T=E_2H^T$$

✓ $r_b\rightarrow\square\rightarrow r_b\frac{n}{k}=r_c$

ورودی A
ارسال AA
دریافتی BB
خروجی A

$$d_{min}\rightarrow\left[\frac{d_{min}-1}{2}\right],\ d_{min}-1$$

(تصحیح، تشخیص)

$$rect(at)\rightarrow\frac{1}{|a|}\,sinc\left(\frac{f}{a}\right)$$

$$sinc(at)\rightarrow\frac{1}{|a|}\,rect\left(\frac{f}{a}\right)$$

$$sinc^2(at)\rightarrow\frac{1}{|a|}\,tri\left(\frac{f}{|a|}\right)$$

$$tri(at)\rightarrow\frac{1}{|a|}\,sinc^2\left(\frac{f}{a}\right)$$

$$V_T=\frac{N_0}{2B}\log_e\frac{P(0)}{P(1)}$$

باینری PSK $\rightarrow S_{01}=-A^2T_b,\ S_{02}=A^2T_b,\ N_0=\eta A^2T_b$

$$B=A^2T_B$$