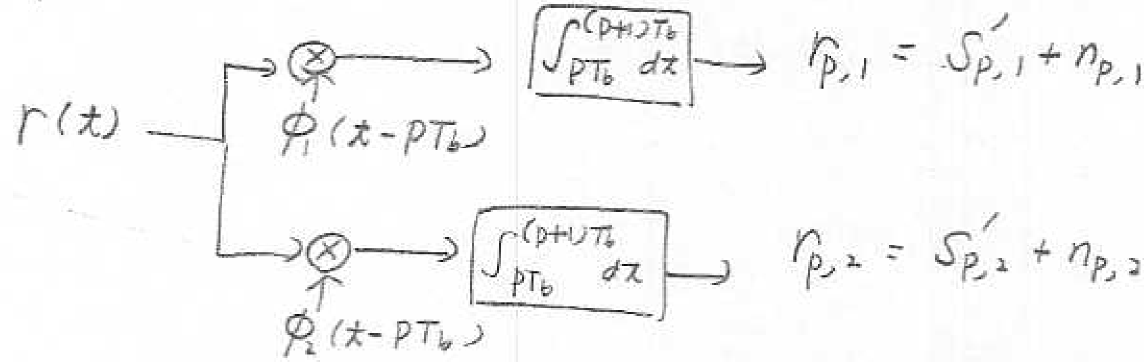
Homework 3 Solution

Spring of 2003

1. (a) $\phi_1(t) = \cos(\omega_c t)\,, \quad 0 \le t < T_b$

$\phi_2(t) = \sin(\omega_c t)\,, \quad 0 \le t < T_b$

(b)



(c) $r(t) = s(t) \circledast h(t) + n(t)$

$$= \sum_{k=-\infty}^{\infty} \left\{ a_k \cos[\omega_c(t-kT_b)] + b_k \sin[\omega_c(t-kT_b)] \right\} \times \mathrm{rect}\left(\frac{t-kT_b}{T_b}\right) \circledast h(t) + n(t)$$

$$= s'(t) + n(t),$$

where $s'(t) = \sum_{k=-\infty}^{\infty} \left\{ a_k \cos[\omega_c(t-kT_b)] + b_k \sin[\omega_c(t-kT_b)] \right\} \mathrm{rect}\left[\frac{t-kT_b}{T_b}\right] \circledast h(t)$, $\mathrm{rect}(t) = \begin{cases} 1, & 0 \le t < 1 \\ 0, & \text{elsewhere} \end{cases}$

$$S'(t) = \sum_{k=-\infty}^{\infty} a_k \int_0^{B_f T_b} \cos\left[\omega_c (t - kT_b - \tau)\right]$$

$$\times \operatorname{rect}\left[\frac{t - kT_b - \tau}{T_b}\right] h(\tau)\, d\tau$$

$$+ \sum_{k=-\infty}^{\infty} b_k \int_0^{B_f T_b} \sin\left[\omega_c (t - kT_b - \tau)\right]$$

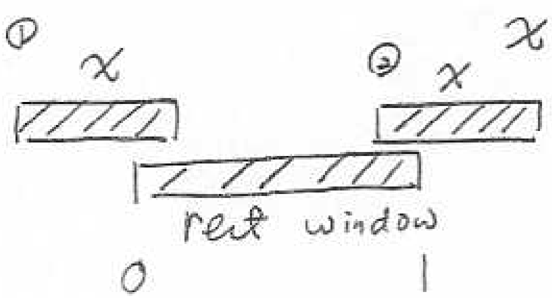
$$\times \operatorname{rect}\left[\frac{t - kT_b - \tau}{T_b}\right] h(\tau)\, d\tau$$

Since $0 \le \tau \le B_f T_b$ and $pT_b \le t < (p+1) T_b$

$$(p - B_f) T_b \le t - \tau < (p+1) T_b$$

$$\Rightarrow \quad p - B_f \le \frac{t - \tau}{T_b} < p + 1$$

$$\Rightarrow \quad p - k - B_f \le \underbrace{\frac{t - kT_b - \tau}{T_b}}_{x} < p + 1 - k$$



$\therefore$ ① $0 < p + 1 - k$ and ② $p - k - B_f < 1$, $p \in \mathbb{Z}$

$$\Rightarrow \quad k < p + 1 \;\cap\; k > p - B_f - 1, \quad k \in \mathbb{Z}$$

$\Rightarrow \quad p - B_f \le k \le p$ (the transmitted symbol indices interfering the current symbol p at the receiver)

$$S'_{p,1} = \int_{pT_b}^{(p+1)T_b} s'(t) \cos\left[\omega_c(t - pT_b)\right] dt$$

$$= \sum_{k=p-B_f}^{p} a_k \int_{pT_b}^{(p+1)T_b} \int_{t-(k+1)T_b}^{t-kT_b} \cos\left[\omega_c(t - kT_b - \tau)\right]$$

$$\times \cos\left[\omega_c(t - pT_b)\right] h(\tau)\, d\tau\, dt$$

$$+ \sum_{k=p-B_f}^{p} b_k \int_{pT_b}^{(p+1)T_b} \int_{t-(k+1)T_b}^{t-kT_b} \sin\left[\omega_c(t - kT_b - \tau)\right]$$

$$\times \cos\left[\omega_c(t - pT_b)\right] h(\tau)\, d\tau\, dt$$

$$S'_{p,2} = \sum_{k=p-B_f}^{p} a_k \int_{pT_b}^{(p+1)T_b} \int_{t-(k+1)T_b}^{t-kT_b} \cos\left[\omega_c(t - kT_b - \tau)\right]$$

$$\times \sin\left[\omega_c(t - pT_b)\right] h(\tau)\, d\tau\, dt$$

$$+ \sum_{k=p-B_f}^{p} b_k \int_{pT_b}^{(p+1)T_b} \int_{t-(k+1)T_b}^{t-kT_b} \sin\left[\omega_c(t - kT_b - \tau)\right]$$

$$\times \sin\left[\omega_c(t - pT_b)\right] h(\tau)\, d\tau\, dt$$

$$n_{p,1} = \int_{pT_b}^{(p+1)T_b} n(t) \cos\left[\omega_c(t - pT_b)\right] dt$$

$$n_{p,2} = \int_{pT_b}^{(p+1)T_b} n(t) \sin\left[\omega_c(t - pT_b)\right] dt$$

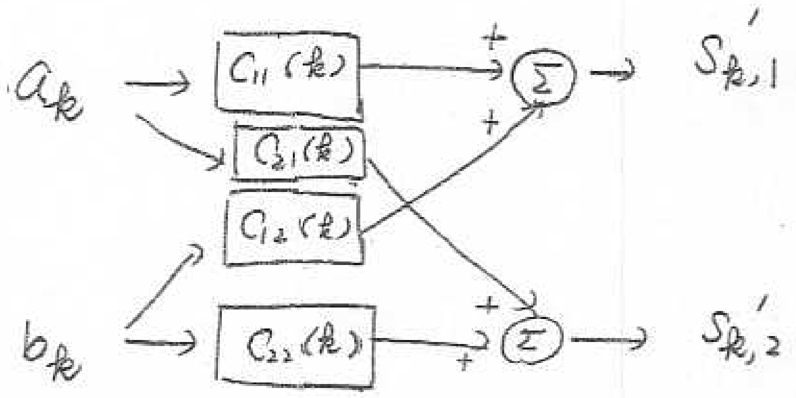
$$r_{p,1} = s'_{p,1} + n_{p,1}$$
$$r_{p,2} = s'_{p,2} + n_{p,2} \quad , \quad \forall p \in \mathbb{Z}$$

(d)
$$E[n_{p,1}] = \int_{pT_b}^{(p+1)T_b} E[n(t)] \cos[\omega_c(t - pT_b)]\, dt$$
$$= 0$$

$$E[n_{p,2}] = \int_{pT_b}^{(p+1)T_b} E[n(t)] \sin[\omega_c(t - pT_b)]\, dt$$
$$= 0$$

$$E\{n_{p,i}\, n_{q,j}\}$$
$$= \int_{pT_b}^{(p+1)T_b} \int_{qT_b}^{(q+1)T_b} E[n(t)\, n(t')]\, \phi_i(t - pT_b)\, \phi_j(t' - qT_b)\, dt\, dt'$$
$$= \delta(p-q)\, \delta(i-j) \int_{pT_b}^{(p+1)T_b} \frac{N_0}{2} \phi_i^2(t - pT_b)\, dt$$
$$= \frac{N_0 T_b}{4} \delta(p-q)\, \delta(i-j) \quad , \text{ where } \omega_c \gg 1$$

(e)



$$C_{11}(k) = \int_{pT_b}^{(p+1)T_b} \int_0^{B_f T_b} \cos\left[\omega_c(t - kT_b - \tau)\right]$$

$$\mathrm{rect}\left[\frac{t - kT_b - \tau}{T_b}\right] h(\tau)\, d\tau \cos\left[\omega_c(t - pT_b)\right]$$

$$\mathrm{rect}\left[\frac{t - pT_b}{T_b}\right] dt$$

$$C_{12}(k) = \int_{pT_b}^{(p+1)T_b} \int_0^{B_f T_b} \sin\left[\omega_c(t - kT_b - \tau)\right]$$

$$\mathrm{rect}\left[\frac{(t - kT_b - \tau)}{T_b}\right] h(\tau) \cos\left[\omega_c(t - pT_b)\right]$$

$$\mathrm{rect}\left[\frac{t - pT_b}{T_b}\right] dt$$

$$C_{21}(k) = \int_{pT_b}^{(p+1)T_b} \int_0^{B_f T_b} \cos\left[\omega_c(t - kT_b - \tau)\right]$$

$$\mathrm{rect}\left[\frac{(t - kT_b - \tau)}{T_b}\right] h(\tau) \sin\left[\omega_c(t - pT_b)\right]$$

$$\mathrm{rect}\left[\frac{t - pT_b}{T_b}\right] dt$$

$$C_{22}(k) = \int_{pT_b}^{(p+1)T_b} \int_0^{B_f T_b} \sin\left[\omega_c(t - kT_b - \tau)\right]$$

$$\mathrm{rect}\left[\frac{(t - kT_b - \tau)}{T_b}\right] h(\tau) \sin\left[\omega_c(t - pT_b)\right]$$

$$\mathrm{rect}\left[\frac{t - pT_b}{T_b}\right] dt$$

(f) Let $t' = t - pT_b$, $l = p - k$,

$$C_{11}(l) = \int_0^{B_f T_b} h(\tau) \int_0^{T_b} \cos\left[\omega_c (t' + lT_b - \tau)\right]$$

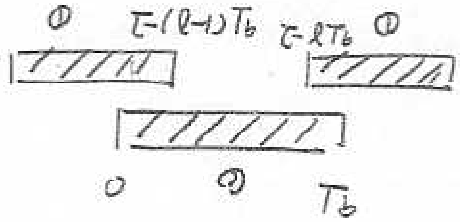
$$\text{rect}\left[\frac{t' + lT_b - \tau}{T_b}\right] \cos\left[\omega_c t'\right] \text{rect}\left[\frac{t'}{T_b}\right]$$

$$dt' \, d\tau$$

window ① : $0 \le t' + lT_b - \tau < T_b$

$$\Rightarrow \quad \tau - lT_b \le t' < \tau - (l-1)T_b$$

window ② : $0 \le t' < T_b$



$\therefore$ overlap of ① & ②

$$\Rightarrow \quad 0 < \tau - (l-1)T_b \le T_b$$

or $\quad 0 < \tau - lT_b \le T_b$

$$\Rightarrow \quad (l-1)T_b < \tau \le lT_b$$

or $\quad lT_b < \tau \le (l+1)T_b$

$$\therefore \quad C_{11}(l) = \int_{(l-1)T_b^+}^{lT_b} h(\tau) \int_0^{\tau-(l-1)T_b} \cos\left[\omega_c(t'+lT_b-\tau)\right]$$

$$\times \cos\left[\omega_c t'\right] dt'\, d\tau$$

$$+ \int_{lT_b^+}^{(l+1)T_b} h(\tau) \int_{\tau-lT_b}^{T_b} \cos\left[\omega_c(t'+lT_b-\tau)\right]$$

$$\times \cos\left[\omega_c t'\right] dt'\, d\tau$$

Similarly,

$$C_{12}(l) = \int_{(l-1)T_b^+}^{lT_b} h(\tau) \int_0^{\tau-(l-1)T_b} \sin\left[\omega_c(t'+lT_b-\tau)\right]$$

$$\times \cos\left[\omega_c t'\right] dt'\, d\tau$$

$$+ \int_{lT_b^+}^{(l+1)T_b} h(\tau) \int_{\tau-lT_b}^{T_b} \sin\left[\omega_c(t'+lT_b-\tau)\right]$$

$$\times \cos\left[\omega_c t'\right] dt'\, d\tau$$

$$C_{21}(l) = \int_{(l-1)T_b^+}^{lT_b} h(\tau) \int_0^{\tau-(l-1)T_b} \cos\left[\omega_c(t'+lT_b-\tau)\right]$$

$$\times \sin\left[\omega_c t'\right] dt'\, d\tau$$

$$+ \int_{lT_b^+}^{(l+1)T_b} h(\tau) \int_{\tau-lT_b}^{T_b} \cos\left[\omega_c(t'+lT_b-\tau)\right]$$

$$\times \sin\left[\omega_c t'\right] dt'\, d\tau$$

$$C_{22}(\ell) = \int_{(\ell-1)T_b^+}^{\ell T_b} h(\tau) \int_0^{\tau-(\ell-1)T_b} \sin\left[\omega_c(t'+\ell T_b-\tau)\right]$$

$$\times \sin\left[\omega_c t'\right] dt' d\tau$$

$$+ \int_{\ell T_b^+}^{(\ell+1)T_b} h(\tau) \int_{\tau-\ell T_b}^{T_b} \sin\left[\omega_c(t'+\ell T_b-\tau)\right]$$

$$\times \sin\left[\omega_c t'\right] dt' d\tau$$

$$\int_x^y \cos\left[\omega_c(t'+\ell T_b-\tau)\right] \cos(\omega_c t') dt'$$

$$= \int_x^y \frac{1}{2}\left\{\cos\left[\omega_c(\ell T_b-\tau)\right] + \cos\left[2\omega_c t'\right.\right.$$

$$\left.\left. + \omega_c(\ell T_b-\tau)\right]\right\} dt'$$

$$= \frac{(y-x)}{2}\cos\left[\omega_c(\ell T_b-\tau)\right] + \cancelto{0}{\frac{\sin\left[2\omega_c t'+\omega_c(\ell T_b-\tau)\right]}{4\omega_c}}\Bigg|$$

$$\omega_c >> 1$$

$$\approx \frac{(y-x)}{2}\cos\left[\omega_c(\ell T_b-\tau)\right]$$

$$\int_x^y \sin\left[\omega_c(t'+\ell T_b-\tau)\right] \cos\left[\omega_c t'\right] dt'$$

$$= \int_x^y \frac{1}{2}\left\{\sin\left[\omega_c(\ell T_b-\tau)\right] + \sin\left[2\omega_c t' + \omega_c(\ell T_b-\tau)\right]\right\}$$

$$dt'$$

$$= \frac{(y-x)}{2}\sin\left[\omega_c(\ell T_b-\tau)\right] - \cancelto{0}{\frac{\cos\left[2\omega_c t'+\omega_c(\ell T_b-\tau)\right]}{4\omega_c}}\Bigg|_x^y$$

$$\omega_c >> 1$$

$$\approx \frac{(y-x)}{2} \sin\left[\omega_c(lT_b-\tau)\right]$$

$$\int_x^y \sin\left[\omega_c(t'+lT_b-\tau)\right]\sin(\omega_c t')\,dt'$$

$$= \int_x^y \frac{1}{2}\left\{\cos\left[\omega_c(lT_b-\tau)\right] - \cos\left[2\omega_c t' + \omega_c(lT_b-\tau)\right]\right\} dt'$$

$$= \frac{(y-x)}{2}\cos\left[\omega_c(lT_b-\tau)\right] - \left.\cancel{\frac{\sin\left[2\omega_c t' + \omega_c(lT_b-\tau)\right]}{4\omega_c}}^{\,0}\right|_x^y$$

$$\omega_c \gg 1$$

$$\approx \frac{(y-x)}{2}\cos\left[\omega_c(lT_b-\tau)\right]$$

$$\int_x^y \cos\left[\omega_c(t'+lT_b-\tau)\right]\sin(\omega_c t')\,dt'$$

$$= \int_x^y \frac{1}{2}\left\{-\sin\left[\omega_c(lT_b-\tau)\right] + \sin\left[2\omega_c t' + \omega_c(lT_b-\tau)\right]\right\} dt'$$

$$= -\frac{(y-x)}{2}\sin\left[\omega_c(lT_b-\tau)\right] - \left.\cancel{\frac{\cos\left[2\omega_c t' + \omega_c(lT_b-\tau)\right]}{4\omega_c}}^{\,0}\right|$$

$$\omega_c \gg 1$$

$$\approx \frac{(x-y)}{2}\sin\left[\omega_c(lT_b-\tau)\right]$$

Hence $C_{11}(\ell) = C_{22}(\ell)$

$$= \int_{(\ell-1)T_b^+}^{\ell T_b} h(\tau) \left[\frac{\tau - (\ell-1) T_b}{2} \right] \cos\left[\omega_c (\ell T_b - \tau)\right] d\tau$$

$$+ \int_{\ell T_b^+}^{(\ell+1) T_b} h(\tau) \left[\frac{T_b - \tau + \ell T_b}{2} \right] \cos\left[\omega_c (\ell T_b - \tau)\right] d\tau$$

$$C_{12}(\ell) = - C_{21}(\ell)$$

$$= \int_{(\ell-1)T_b^+}^{\ell T_b} h(\tau) \left[\frac{\tau - (\ell-1) T_b}{2} \right] \sin\left[\omega_c (\ell T_b - \tau)\right] d\tau$$

$$+ \int_{\ell T_b^+}^{(\ell+1) T_b} h(\tau) \left[\frac{T_b - \tau + \ell T_b}{2} \right] \sin\left[\omega_c (\ell T_b - \tau)\right] d\tau$$

$p - B_f \le k \le p$, $\ell = p - k \Rightarrow 0 \le \ell \le B_f$

$$\therefore S_{p,1}' = \sum_{\ell=0}^{B_f} a_{p-\ell}\, C_{11}(\ell) + \sum_{\ell=0}^{B_f} b_{p-\ell}\, C_{12}(\ell)$$

$$S_{p,2}' = \sum_{\ell=0}^{B_f} a_{p-\ell}\, C_{21}(\ell) + \sum_{\ell=0}^{B_f} b_{p-\ell}\, C_{22}(\ell)$$

$$= - \sum_{\ell=0}^{B_f} a_{p-\ell}\, C_{12}(\ell) + \sum_{\ell=0}^{B_f} b_{p-\ell}\, C_{11}(\ell)$$

Define $\underset{\sim}{S_p'} = S_{p,1}' + \sqrt{-1}\, S_{p,2}'$

$$\underset{\sim}{S_p} = a_p + \sqrt{-1}\, b_p$$

$$\underset{\sim}{C}(\ell) = C_{11}(\ell) - \sqrt{-1}\, C_{12}(\ell)$$

Therefore,

$$s'_{p,1} = Re\{ \underset{\sim}{s}'_p \}$$

$$= Re\Big\{ \sum_{\ell=0}^{Bf} \underset{\sim}{s}_{p-\ell}\, \underset{\sim}{c}(\ell) \Big\}$$

$$s'_{p,2} = Im\{ \underset{\sim}{s}'_p \}$$

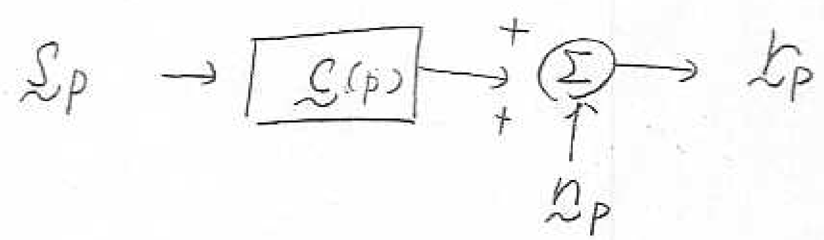
$$= Im\Big\{ \sum_{\ell=0}^{Bf} \underset{\sim}{s}_{p-\ell}\, \underset{\sim}{c}(\ell) \Big\}$$

$$\therefore\ \underset{\sim}{s}'_p = \sum_{\ell=0}^{Bf} \underset{\sim}{s}_{p-\ell}\, \underset{\sim}{c}(\ell), \quad p \in \mathbb{Z}$$

Define $\underset{\sim}{n}_p = n_{p,1} + \sqrt{-1}\, n_{p,2}$

$$\underset{\sim}{r}_p = r_{p,1} + \sqrt{-1}\, r_{p,2}$$

Then the system can be modeled as



$$\underset{\sim}{r}_p = \underset{\sim}{s}_p \circledast \underset{\sim}{c}(p) + \underset{\sim}{n}_p$$

2.

(a)

$l = -1$,

$$C_{11}(-1) = \int_{0^+}^{0} \delta(\tau) \left[\frac{-\tau}{2} \right]$$

$$\cos\left[\omega_c(-T_b - \tau)\right] d\tau = 0$$

$$C_{12}(-1) = \int_{0^+}^{0} \delta(\tau) \left[\frac{-\tau}{2} \right] \sin\left[\omega_c(-T_b - \tau)\right] d\tau$$

$$= 0$$

$l = 0$,

$$C_{11}(0) = \int_{-T_b^+}^{0} \delta(\tau) \left[\frac{\tau + T_b}{2} \right] \cos\left[\omega_c \tau\right] d\tau$$

$$= \frac{T_b}{2}$$

$$C_{12}(0) = \int_{-T_b^+}^{0} \delta(\tau) \left[\frac{\tau + T_b}{2} \right] \sin\left[-\omega_c \tau\right] d\tau$$

$$= 0$$

$l = 40$,

$$C_{11}(40) = \int_{39T_b^+}^{40T_b} 0.631\, \delta(\tau - 40T_b) \left[\frac{\tau - 39T_b}{2} \right]$$

$$\times \cos\left[\omega_c(40T_b - \tau)\right] d\tau$$

$$= \frac{T_b}{2} \times 0.6310$$

$$C_{12}(40) = \int_{39T_b^+}^{40T_b} 0.631\,\delta(\tau - 40T_b)\left[\frac{\tau - 39T_b}{2}\right]$$

$$\times \sin\left[\omega_c(40T_b - \tau)\right] d\tau = 0$$

$l = 80$,

$$C_{11}(80) = \int_{79T_b^+}^{80T_b} 0.1\,\delta(\tau - 80T_b)\left[\frac{\tau - 79T_b}{2}\right]$$

$$\times \cos\left[\omega_c(80T_b - \tau)\right] d\tau$$

$$= \frac{T_b}{2} \times 0.1$$

$$C_{12}(80) = 0$$

$l = 120$,

$$C_{11}(120) = \int_{119T_b^+}^{120T_b} 0.01\,\delta(\tau - 120T_b)\left[\frac{\tau - 119T_b}{2}\right]$$

$$\times \cos\left[\omega_c(120T_b - \tau)\right] d\tau$$

$$= \frac{T_b}{2} \times 0.01$$

$$\therefore\ \underset{\sim}{C}(l) = \frac{T_b}{2}\left[\delta(l) + 0.6310\,\delta(l-40)\right.$$

$$\left. + 0.1\,\delta(l-80) + 0.01\,\delta(l-120)\right]$$

(b)

The perfect equalizer's Z-transform should be

$$W(z) = \frac{1}{\frac{T_b}{2}\left[1 + 0.6310 z^{-40} + 0.1 z^{-80} + 0.01 z^{-120}\right.}$$

or $$r'(p) = -0.6310\, r'(p-40) - 0.1\, r'(p-80) - 0.01\, r'(p-120) + r(p), \quad \forall p \in \mathbb{Z}$$

$$r(p) \longrightarrow \boxed{W(p)} \longrightarrow r'(p)$$

received sequence — perfect equalizer — equalized sequence

(c) From Matlab, $W(0) = 4 \times 10^{7}$,

$W(1) = W(2) = \cdots = W(15) \approx 0$.

3.

(a) $\phi(t) = \cos(\omega_c t)\,, \quad 0 \le t < T_b$

(b)

$$r(t) \longrightarrow \underset{\substack{\uparrow \\ \phi(t - pT_b)}}{\otimes} \longrightarrow \boxed{\int_{pT_b}^{(p+1)T_b} dt} \longrightarrow r_p = s_p' + n_p$$

(c) $r(t) = s(t) \circledast h(t) + n(t)$

$$= \sum_{k=-\infty}^{\infty} m_k \cos\left[\omega_c (t - kT_b)\right] \operatorname{rect}\left[\frac{t - kT_b}{T_b}\right]$$

$$\circledast\, h(t) + n(t) = s'(t) + n(t),$$

where $\operatorname{rect}(t) = \begin{cases} 1, & 0 \le t < 1 \\ 0, & \text{elsewhere} \end{cases}$,

$$s'(t) = s(t) \circledast h(t)$$

$$= \sum_{k=-\infty}^{\infty} m_k \int_0^{B_f T_b} \cos\left[\omega_c (t - kT_b - \tau)\right]$$

$$\times \operatorname{rect}\left[\frac{t - kT_b - \tau}{T_b}\right] h(\tau)\, d\tau$$

$$s_p' = \int_{pT_b}^{(p+1)T_b} s'(t) \cos\left[\omega_c (t - pT_b)\right] dt$$

$$= \sum_{k=p-B_f}^{p} m_k \int_{pT_b}^{(p+1)T_b} \int_{t-(k+1)T_b}^{t-kT_b} \cos\left[\omega_c(t-kT_b-\tau)\right]$$

$$\times \cos\left[\omega_c(t-pT_b)\right] h(\tau)\, d\tau\, dt$$

$$n_p = \int_{pT_b}^{(p+1)T_b} n(t) \cos\left[\omega_c(t-pT_b)\right] dt$$

$$r_p = s_p' + n_p, \qquad \forall p \in \mathbb{Z}$$

(d)

$$E[n_p] = 0$$

$$E\{n_p n_q] = \frac{N_0 T_b}{4} \delta(p-q)$$

(e)

$$a_k \rightarrow \boxed{C(k)} \longrightarrow s_k'$$

$$C(k) = \int_{pT_b}^{(p+1)T_b} \int_0^{B_f T_b} \cos\left[\omega_c(t-kT_b-\tau)\right]$$

$$\times \operatorname{rect}'\left[\frac{t-kT_b-\tau}{T_b}\right] h(\tau)\, d\tau \cos\left[\omega_c(t-pT_b)\right]$$

$$\times \operatorname{rect}\left[\frac{t-pT_b}{T_b}\right] dt$$

(f) Let $l = p - k$, $t' = t - pT_b$,

$$C(l) = \int_{(l-1)T_b^+}^{lT_b} h(\tau) \int_0^{\tau-(l-1)T_b} \cos\left[\omega_c(t' + lT_b - \tau)\right]$$

$$\times \cos\left[\omega_c t'\right] dt' d\tau$$

$$+ \int_{lT_b^+}^{(l+1)T_b} h(\tau) \int_{\tau - lT_b}^{T_b} \cos\left[\omega_c(t' + lT_b - \tau)\right]$$

$$\times \cos\left[\omega_c t'\right] dt' d\tau$$

$$\simeq \int_{(l-1)T_b^+}^{lT_b} h(\tau) \left[\frac{\tau - (l-1)T_b}{2}\right] \cos\left[\omega_c(lT_b - \tau)\right] d\tau$$

$$+ \int_{lT_b^+}^{(l+1)T_b} h(\tau) \left[\frac{T_b - \tau + lT_b}{2}\right] \cos\left[\omega_c(lT_b - \tau)\right] d$$

$r_p = s_p \circledast C(p) + n_p$, all are real

4. (a) Similar to 2(a),

$$C(l) = \frac{T_b}{2}\left[\delta(l) + 0.6310\,\delta(l-40)\right.$$

$$\left. + 0.1\,\delta(l-80) + 0.01\,\delta(l-120)\right]$$

(b) Similar to 2 (b),

$$W(z) = \frac{2}{T_b \left[1 + 0.6310\, z^{-40} + 0.1\, z^{-80} + 0.01\, z^{-120}\right]}$$

or

$$r'_p = -0.6310\, r'_{p-40} - 0.1\, r'_{p-80} - 0.01\, r'_{p-120} + r_p \,, \quad \forall p \in \mathbb{Z}$$

$$r_p \rightarrow \boxed{W_p} \rightarrow r'_p$$

received sequence

perfect equalizer

equalized sequence

(c) Similar to 2 (c),

$w(0) = 4 \times 10^7$, $\quad w(1) = w(2) = \cdots = w(15) = 0$

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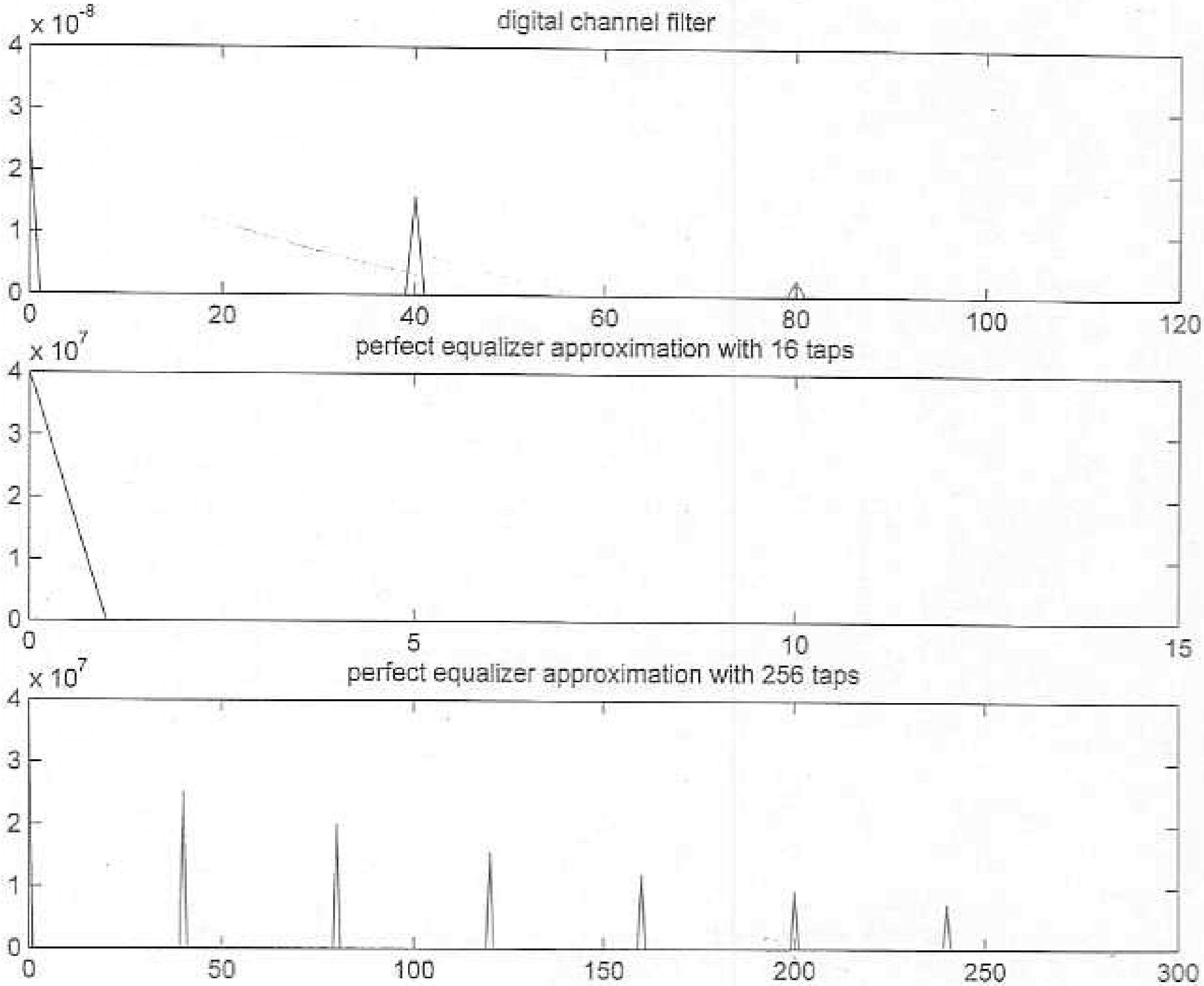
%EE7000 Spring of 2003
%Homework 4

%Problem 1
%(c)

Tb = 0.05e-6;
c = zeros(1,121);
c(1) = Tb/2;
c(41) = Tb/2 * 0.6310;
c(81) = Tb/2 * 0.1;
c(121) = Tb/2 * 0.01;

a = c;
a(41) = -a(41);
a(81) = -a(81);
a(121) = -a(121);

w16 = filter(1,a,[1 zeros(1,15)]);
w256 = filter(1,a,[1 zeros(1,255)]);
subplot(311)
plot(0:1:120, c)
title('digital channel filter')
subplot(312);
plot(0:1:15, w16);
title('perfect equalizer approximation with 16 taps');
subplot(313);
plot(0:1:255, w256);
title('perfect equalizer approximation with 256 taps');
```


digital channel filter
x 10^-8
0
20
40
60
80
100
120
perfect equalizer approximation with 16 taps
x 10^7
0
5
10
15
perfect equalizer approximation with 256 taps
x 10^7
0
50
100
150
200
250
300
4
3
2
1
0