Chapter 5

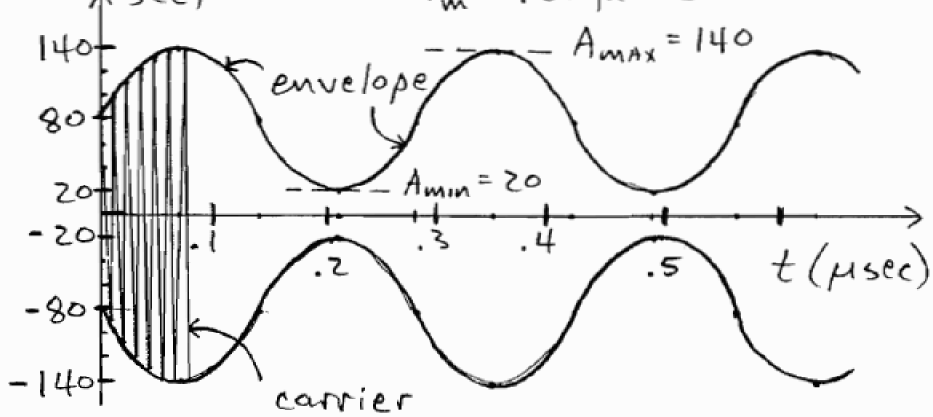
5-2

(a.) $m(t) = -0.2 + 0.6 \sin \omega_1 t$

$f_m = f_1 = 3.57$ MHz ; $\underline{\underline{A_c = 100}}$

$$s(t) = 100\,(0.8 + 0.6 \sin \omega_1 t) \cos \omega_c t$$

$T_m = .28\ \mu\text{sec}$



(b.) $\%\ \text{pos. mod.} = \dfrac{A_{max} - A_c}{A_c}(100) = \dfrac{140 - 100}{100}(100)$

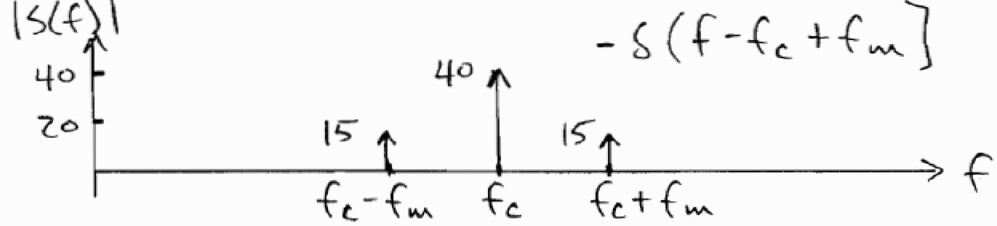
$= \underline{\underline{40\%}}$

$\%\ \text{neg. mod.} = \dfrac{A_c - A_{MIN}}{A_c}(100) = \dfrac{100 - 20}{100}(100)$

$= \underline{\underline{80\%}}$

(c.) $\underline{f > 0}$

$$S(f) = 40\,\delta(f - f_c) - j15\left[\delta(f - f_c - f_m) - \delta(f - f_c + f_m)\right]$$



5-4

From (5-5a)

$$\% \text{ Pos. Mod.} = \frac{A_{max} - A_c}{A_c}(100) \overset{\text{given}}{=} 120$$

where:

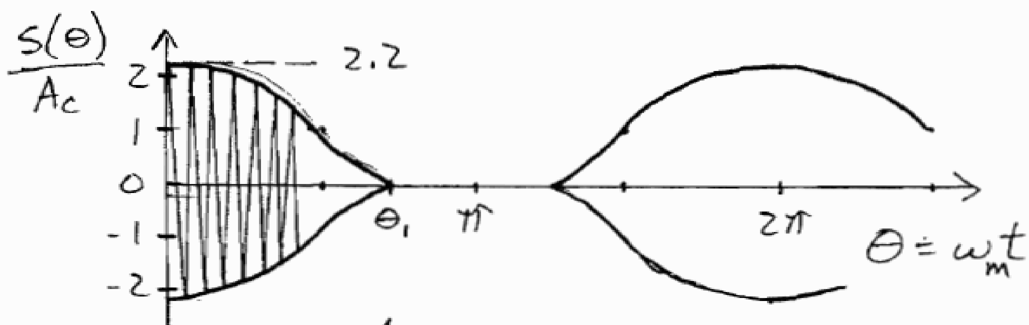
$$s(t) = \begin{cases} A_c[1 + A_m \cos\omega_m t]\cos\omega_c t\,; & m(t) \geq -1 \\ 0 & ; \; m(t) < -1 \end{cases}$$

$$m(t) = A_m \cos\omega_m t \quad ; \quad A_{max} = A_c[1 + A_m]$$

$$\frac{A_{max} - A_c}{A_c} = \underline{\underline{A_m = 1.2}}$$

$$g(t) = \begin{cases} A_c\{1 + 1.2\cos\omega_m t\}, & 1.2\cos\omega_m t \geq -1 \\ 0 & , \; 1.2\cos\omega_m t < -1 \end{cases}$$

$$= \sum_{n=-\infty}^{\infty} c_n e^{jn\omega_m t} \Rightarrow G(f) = \sum_{-\infty}^{\infty} c_n \delta(f - nf_m)$$



$$A_m \cos\theta_1 = -1$$

Aside:

$$\theta_1 = \cos^{-1}\left(\frac{-1}{1.2}\right) = \underline{146.4°}$$

$$c_n = \frac{1}{T_0}\int_{-T_0/2}^{T_0/2} g(t)\, e^{-jn\omega_m t}\, dt$$

$$= \frac{A_c}{2\pi}\int_{-\theta_1}^{\theta_1} [1 + A_m\cos\theta]\, e^{-jn\theta}\, d\theta$$

5-4 (Continued)

$$c_n = \frac{A_c}{2\pi}\left[\left.\frac{e^{-jn\theta}}{-jn}\right|_{-\theta_1}^{\theta_1} + A_m \int_{-\theta_1}^{\theta_1} (\cos\theta)\, e^{-jn\theta}\, d\theta \right]$$

$$= \frac{A_c}{2\pi}\left[\frac{2}{n}\left(\frac{e^{jn\theta_1} - e^{-jn\theta_1}}{j2}\right) + A_m \frac{e^{-jn\theta}}{(-jn)^2+1} \cdot \left.\left(-jn\cos\theta + \sin\theta\right)\right|_{-\theta_1}^{\theta_1} \right]$$

Using Sec. A-5 where $a = -jn$

$$= \frac{A_c}{2\pi}\left[\frac{2\sin n\theta_1}{n} + A_m \left\{ \frac{e^{-jn\theta_1}(-jn\cos\theta_1 + \sin\theta_1)}{1-n^2} - \frac{e^{jn\theta_1}(-jn\cos\theta_1 - \sin\theta_1)}{1-n^2} \right\} \right]$$

$$= \frac{A_c}{2\pi}\left[2\theta_1\left(\frac{\sin n\theta_1}{n\theta_1}\right) + A_m \left\{ \frac{jn(2j)\left(\frac{e^{jn\theta_1} - e^{-jn\theta_1}}{2j}\right)\cos\theta_1}{1-n^2} + \frac{2\left(\frac{e^{jn\theta_1} + e^{-jn\theta_1}}{2}\right)\sin\theta_1}{1-n^2} \right\} \right]$$

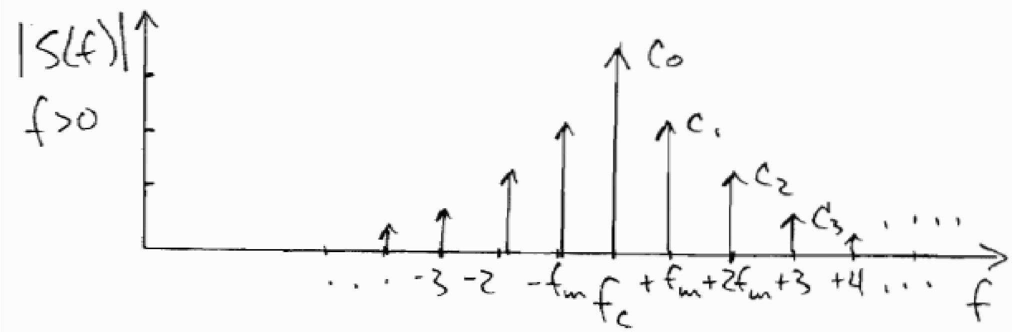
$A_m = 1.2$
$\theta_1 = 146.4°$

$$c_n = \frac{A_c}{2\pi}\left[2\theta_1\left(\frac{\sin(n\theta_1)}{n\theta_1}\right) + 2A_m \left\{ \frac{\cos(n\theta_1)\sin\theta_1 - n\sin(n\theta_1)\cos\theta_1}{1-n^2} \right\} \right]$$

$$S(f) = \frac{1}{2}\left[\sum_{-\infty}^{\infty} c_n\, \delta(f - f_c - nf_m) + \sum_{-\infty}^{\infty} c_n^*\, \delta(-f - f_c - nf_m) \right]$$

5-4 (Continued)

$c_n = c_n^*$ (c_n real)



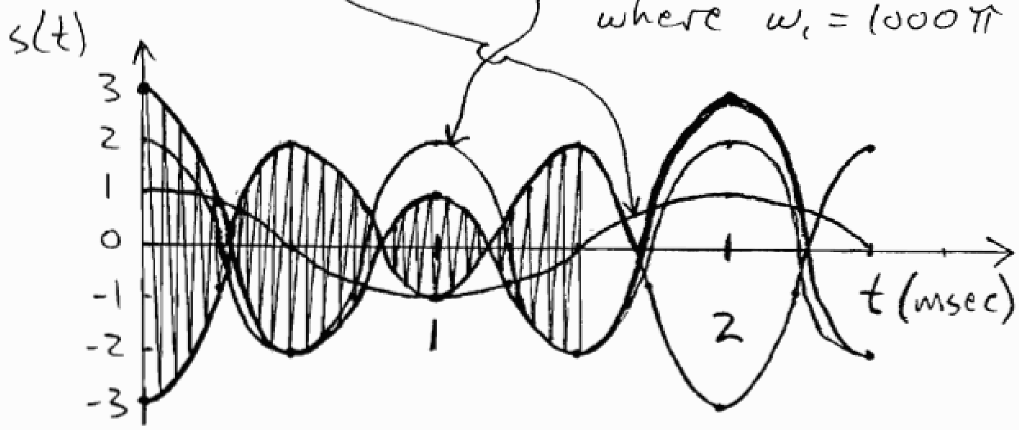
$$c_0 = \frac{A_c}{2\pi}\left[2\theta_1(\text{rad.}) + 2A_m \sin\theta_1\right]$$
$$= \frac{A_c}{2\pi}\left[2(2.56) + 2(1.2)(.553)\right]$$

5-5

(a.) DSB-SC $m(t) = \cos\omega_1 t + 2\cos 2\omega_1 t$

$$s(t) = [\cos\omega_1 t + 2\cos 2\omega_1 t]\cos\omega_c t$$

where $\omega_1 = 1000\pi$

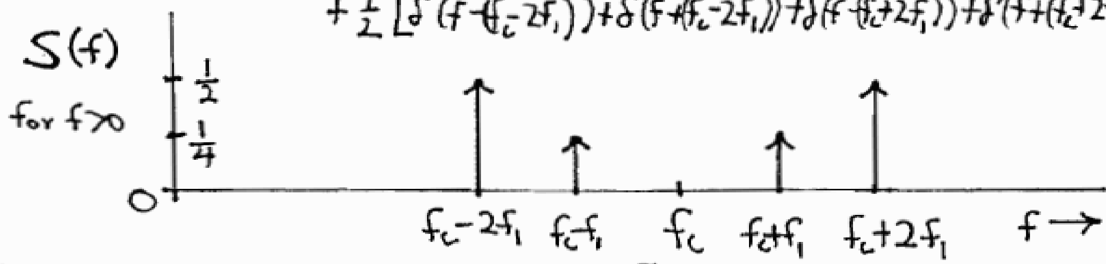


(b.) $$s(t) = \frac{1}{2}\left[\cos(\omega_c - \omega_1)t + \cos(\omega_c + \omega_1)t\right]$$
$$+ \cos(\omega_c - 2\omega_1)t + \cos(\omega_c + 2\omega_1)t$$

5-5 (Continued)

(b) Cont'd $\quad S(-f) = S(f)$ even

$$S(f) = \mathcal{F}[s(t)] = \frac{1}{4}\left[\delta(f-(f_c-f_1)) + \delta(f+(f_c-f_1)) + \delta(f-(f_c+f_1)) + \delta(f+(f_c+f_1))\right]$$
$$+ \frac{1}{2}\left[\delta(f-(f_c-2f_1)) + \delta(f+(f_c-2f_1)) + \delta(f-(f_c+2f_1)) + \delta(f+(f_c+2f_1))\right]$$

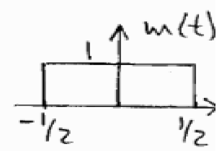


(c.) $P_{AV_{norm}} = \frac{1}{2}\left[(\tfrac{1}{2})^2 + (\tfrac{1}{2})^2 + (1)^2 + (1)^2\right] = \underline{\underline{1.25\ W}}$

(d.) $A_{max} = 3 \quad \Rightarrow \quad PEP_{norm} = \frac{(3)^2}{2} = \underline{\underline{4.5\ W}}$

5-10

$$m(t) = \begin{cases} 1, & |t| < 1/2 \\ 0, & t \text{ elsewhere} \end{cases}$$



(a.) $\hat{m}(t) = m(t) * \frac{1}{\pi t}$

$$= \int_{-1/2}^{1/2} \frac{1}{\pi}\frac{1}{t-\lambda}\, d\lambda \underset{\substack{\lambda_1 = t-\lambda \\ d\lambda_1 = -d\lambda}}{=} \frac{-1}{\pi}\int_{t+1/2}^{t-1/2} \frac{1}{\lambda_1}\, d\lambda_1$$

$$= \int_{t-1/2}^{t+1/2} \frac{1}{\pi}\frac{1}{\lambda_1}\, d\lambda_1 = \frac{1}{\pi}\left(\ln|\lambda_1|\right)\Big|_{t-1/2}^{t+1/2}$$

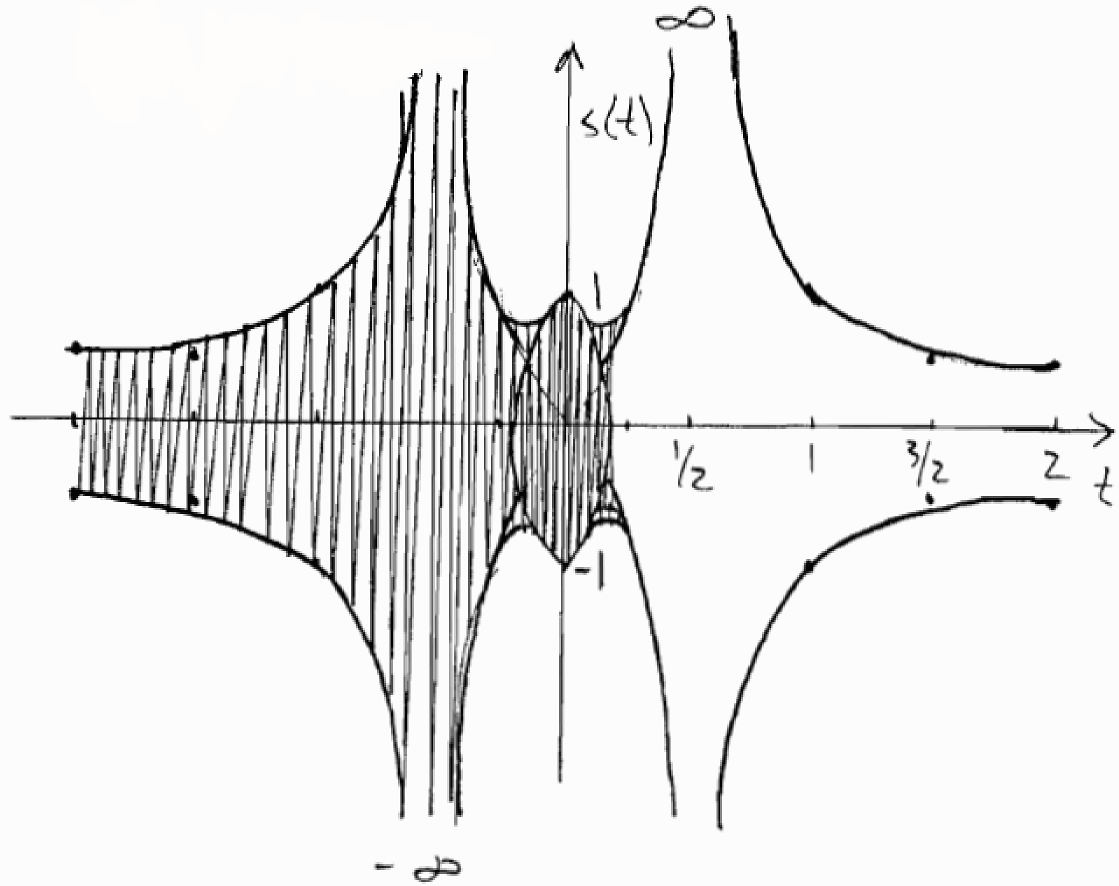
$$\hat{m}(t) = \underline{\underline{\frac{1}{\pi}\ln\left[\frac{|t+\frac{1}{2}|}{|t-\frac{1}{2}|}\right]}}$$

(b.) For USSB:

$$s(t) = m(t)\cos\omega_c t - \hat{m}(t)\sin\omega_c t$$

$$= \underline{\underline{\Pi(t)\cos\omega_c t - \frac{1}{\pi}\ln\left[\frac{|t+1/2|}{|t-1/2|}\right]\sin\omega_c t}}$$

5-10 (Continued)



(c.) $\underline{\underline{s(t)_{max} = \infty}}$

5-11

Note: T has units of Hz.

(a.)

$$m(t)=\frac{\sin(\pi T t)}{\pi T t} \longleftrightarrow M(f)=\frac{1}{T}\Pi\left(\frac{f}{T}\right)=\frac{1}{T}\left[\Pi\left(\frac{f-\frac{T}{4}}{T/2}\right)+\Pi\left(\frac{f+\frac{T}{4}}{T/2}\right)\right]$$

$$\Rightarrow \mathcal{F}[\hat{m}(t)]=M(f)\begin{Bmatrix}-j, & f>0\\ j, & f<0\end{Bmatrix}=\frac{\frac{1}{2}}{\frac{T}{2}}\left[-j\Pi\left(\frac{f-T/4}{T/2}\right)+j\Pi\left(\frac{f+T/4}{T/2}\right)\right]$$

$$\Rightarrow \hat{m}(t)=-j\frac{1}{2}\frac{\sin(\pi\frac{T}{2}t)}{\pi\frac{T}{2}t}e^{j2\pi\frac{T}{4}t}+j\frac{1}{2}\frac{\sin(\pi\frac{T}{2}t)}{\pi\frac{T}{2}t}e^{-j2\pi\frac{T}{4}t}$$

$$=\frac{\sin(\pi\frac{T}{2}t)}{\pi\frac{T}{2}t}\,\frac{e^{j\pi\frac{T}{2}t}-e^{-j\pi\frac{T}{2}t}}{2j}=\frac{\sin(\pi\frac{T}{2}t)}{\pi\frac{T}{2}t}\sin(\pi\tfrac{T}{2}t)=\frac{\sin^2(\pi\frac{T}{2}t)}{\pi\frac{T}{2}t}$$

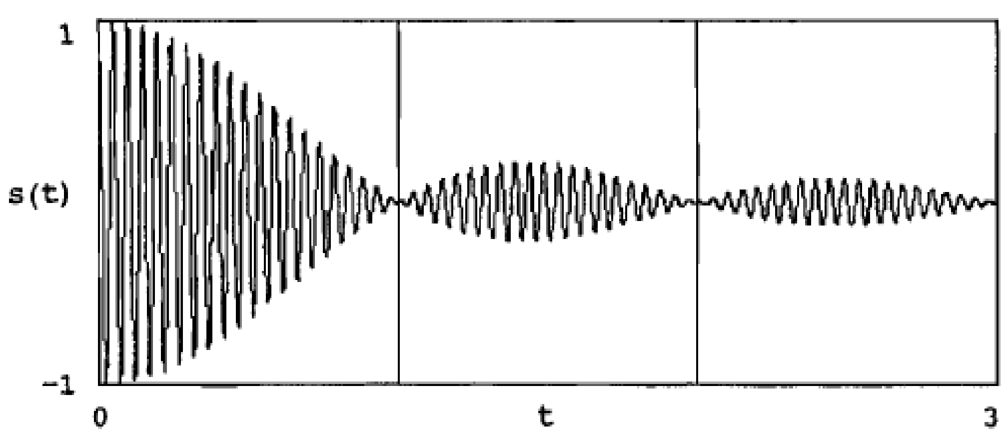
(b)

$t := 10^{-7}, 0.002 .. 3 \qquad T := 2$

$f_c := 20 \qquad \omega_c := 2\cdot\pi\cdot f_c$

$$m(t) := \frac{\sin(\pi\cdot T\cdot t)}{\pi\cdot T\, t} \qquad m_h(t) := \frac{\left[\sin\left[\pi\cdot\frac{T}{2}\,t\right]\right]^2}{\pi\cdot\frac{T}{2}\,t}$$

$$s(t) := m(t)\cdot\cos\left[\omega_c\cdot t\right]-m_h(t)\cdot\sin\left[\omega_c\cdot t\right]$$



5-18

(a.) $\theta(t) = D_p m_p(t) = 20 \cos\omega_1 t$

$\Rightarrow m_p(t) = \frac{20}{D_p} \cos\omega_1 t = \underline{\underline{0.2 \cos(2000\pi t)}}$

$m_p(t)_{peak} = \underline{\underline{0.2\text{ V}}}$; $f_m = \underline{\underline{1\text{ KHz}}}$

(b.) $\theta(t) = D_f \int_{-\infty}^{t} m_f(\lambda)\, d\lambda = 20 \cos\omega_1 t$

$\Rightarrow m_f(t) = \frac{20}{D_f} \frac{d}{dt}\left[\cos\omega_1 t\right]$

$= \frac{-20}{10^6}(2000\pi) \sin\omega_1 t$

$m_f(t) = \underline{\underline{-.1257 \sin\omega_1 t}}$

$m_f(t)_{peak} = \underline{\underline{.1257\text{ V}}}$; $f_m = \underline{\underline{1\text{ KHz}}}$

(c.) $P_{AV} = \frac{V_{rms}^2}{R} = \frac{(500)^2}{2(50)} = \underline{\underline{2.5\text{ KW}}}$

$PEP = \underline{\underline{2.5\text{ KW}}}$

5-22

(a.) $P_T = \frac{1}{2}\langle |g(t)|^2 \rangle = \frac{A_c^2}{2} = \frac{(100)^2}{2} = \underline{\underline{5{,}000 \text{ watts}}}$

(b.) $P_T = \frac{1}{2}\langle |g(t)|^2 \rangle \underset{\text{Using (5-55)}}{=} \frac{1}{2}\langle \sum_{n=-N}^{N} |c_n|^2 \rangle = \frac{1}{2}\sum_{n=-N}^{N} |c_n|^2 \underset{\text{Using (5-57)}}{=} \frac{1}{2}A_c^2 \sum_{n=-N}^{N} J_n(\beta)$

$\Rightarrow P_T = \frac{1}{2}A_c^2\left[J_0^2(\beta) + 2\sum_{n=1}^{N} J_n^2(\beta)\right]$

where $2Nf_m = B_T \Rightarrow N = \frac{B_T}{2f_m} = \frac{56\text{ Hz}}{2(8)} = 3.5 \Rightarrow$ Use $N=3$

Also, $\beta = \frac{\Delta F}{f_m} = \frac{k_d A_m}{f_m} = \frac{(8\text{ Hz/volt})(5\text{ volt})}{8\text{ Hz}} = 5.0$

Using MathCAD: $Ac := 100$ $\quad \beta := 5.0$ $\quad N := 3$ $\quad n := 1..N$

$$PT := 0.5 \cdot Ac^2 \left[J0(\beta)^2 + 2 \cdot \sum_n Jn(n,\beta)^2 \right]$$

$\underline{PT = 2583.485 \text{ watts}}$ (normalized for 1Ω)

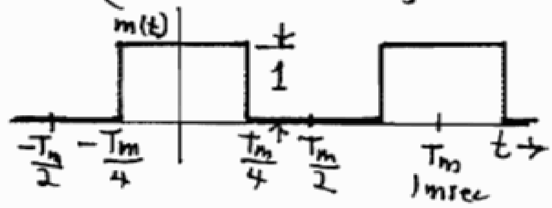
5-26

$$s(t) = \mathrm{Re}\{g(t)\, e^{j\omega_c t}\} = \mathrm{Re}\left\{10\, e^{j\theta(t)}\, e^{j\omega_c t}\right\}$$

$$\theta(t) = \beta\, m(t)$$

$$\beta = 45^\circ\left(\frac{\pi \text{ rad}}{180^\circ}\right) = 0.785 = \pi/4$$

$$g(t) = \sum_{-\infty}^{\infty} c_n\, e^{jn\omega_m t}$$



$$c_n = \frac{1}{T_m}\int_{-T_m/2}^{T_m/2} g(t)\, e^{-jn\omega_m t}\, dt = \frac{10}{T_m}\left[\int_{-T_m/2}^{-T_m/4} e^{j0} e^{-jn\omega_m t}\, dt + \int_{-T_m/4}^{T_m/4} e^{j\beta} e^{-jn\omega_m t}\, dt + \int_{T_m/4}^{T_m/2} e^{j0} e^{-jn\omega_m t}\, dt\right]$$

$$C_n = \frac{10}{T_m}\left[\int_{T_m/4}^{T_m/2} e^{jn\omega_m t}\, dt + \int_{-T_m/4}^{T_m/4} e^{j\beta}\, e^{-jn\omega_m t}\, dt + \int_{T_m/4}^{T_m/2} e^{-jn\omega_m t}\, dt\right]$$

$$= \frac{20}{T_m}\int_{T_m/4}^{T_m/2} \Big(\underbrace{\frac{e^{jn\omega_m t} + e^{-jn\omega_m t}}{2}}_{\cos n\omega_m t}\Big)\, dt + \frac{10\, e^{j\beta}}{T_m}\, \frac{e^{-jn\omega_m t}}{-jn\omega_m}\Bigg|_{-\frac{T_m}{4}}^{\frac{T_m}{4}}$$

$$= \frac{20}{T_m}\left[\frac{\sin(n\omega_m t)}{n\omega_m}\Bigg|_{T_m/4}^{T_m/2} + e^{j\beta}\, \frac{e^{j\pi/2} - e^{-j\pi/2}}{2j\, n\omega_m}\right]$$

$$= \frac{20}{T_m}\left[\frac{\overset{0}{\cancel{\sin(n\pi)}} - \sin\left(\frac{n\pi}{2}\right)}{n\omega_m} + e^{j\beta}\, \frac{\sin\left(\frac{n\pi}{2}\right)}{n\omega_m}\right]$$

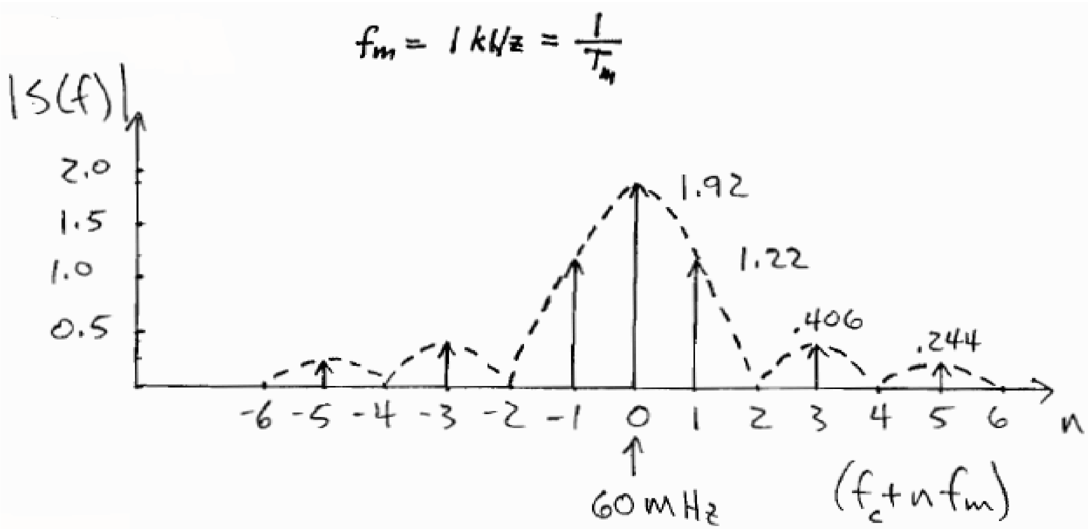
$$C_n = 5\left(e^{j\beta} - 1\right)\left[\frac{\sin\left(\frac{n\pi}{2}\right)}{\frac{n\pi}{2}}\right], \quad \beta = \pi/4$$

$$|C_n| = 5\sqrt{(\cos\beta - 1)^2 + (\sin\beta)^2}\; \left|\frac{\sin\left(\frac{n\pi}{2}\right)}{\frac{n\pi}{2}}\right|$$

$$\Rightarrow |C_n| = 3.83\left|\frac{\sin\left(\frac{n\pi}{2}\right)}{\frac{n\pi}{2}}\right|$$

$$S(f) = \frac{1}{2}\left[\sum_{-\infty}^{\infty} c_n\, \delta(f - f_c - nf_m) + \sum_{-\infty}^{\infty} c_n^*\, \delta(f + f_c + nf_m)\right]$$

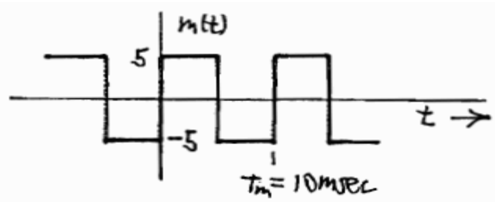
5-26 (Continued)



5-30

NBFM

$$\theta(t) = D_f \int^t m(\lambda)\,d\lambda$$



(a.)

$$\Delta\theta = D_f \int_0^{T_m/2} m(t)\,dt = D_f \int_0^{T_m/2} 5\,dt = D_f\, 5t \Big|_0^{T_m/2} = D_f\, 5\, \frac{T_m}{2} = (10^\circ)\left(\frac{\pi\ \text{rad}}{180^\circ}\right)$$

(Set)

$$\Rightarrow D_f = \frac{10\pi}{180}\left(\frac{2}{5T_m}\right) = \frac{20\pi}{5(180)10^{-2}} = \underline{\underline{6.98\ \frac{\text{rad}}{V\cdot\text{sec}}}}$$

$$(5\text{-}6) \Rightarrow \Delta F = \frac{D_f V_p}{2\pi} = \frac{6.98(5)}{2\pi} = \underline{\underline{5.55\ Hz}}$$

(b.) From (5-26) and (5-27)

$$S'(f) = \frac{A_c}{2}\Big\{ \delta(f-f_c) + \delta(f+f_c) + \frac{D_f}{2\pi}\,\frac{M(f-f_c)}{f-f_c} - \frac{D_f}{2\pi}\,\frac{M(f+f_c)}{f+f_c}$$

$$M(f) = \mathcal{F}[m(t)] = \sum_{-\infty}^{\infty} c_n\,\delta(f - nf_m) \quad \text{where } f_m = \frac{1}{10\,\text{msec}} = \underline{\underline{100\,Hz}}$$

$$\underline{\underline{S'(f) = \frac{A_c}{2}\Big\{ \delta(f-f_c) + \delta(f+f_c) + \frac{D_f}{2\pi} \sum_{\substack{n=-\infty \\ n\neq 0}}^{\infty} \left(\frac{c_n}{nf_m}\right)\Big[\delta(f-f_c-nf_m) - \delta(f+f_c-nf_m)\Big]\Big\}}}$$

5-30 (Continued)

Aside : Evaluate c_n

$$c_n = \frac{1}{T_m}\int_0^{T_m} m(t)\, e^{-jn\omega_m t}\, dt$$

$$= \frac{1}{T_m}\left[\int_0^{T_m/2} 5 e^{-jn\omega_m t}\, dt + \int_{T_m/2}^{T_m} (-5) e^{-jn\omega_m t}\, dt\right]$$

$$= \frac{5}{T_m}\left[\left.\frac{e^{-jn\omega_m t}}{-jn\omega_m}\right|_0^{T_m/2} - \left.\frac{e^{-jn\omega_m t}}{-jn\omega_m}\right|_{T_m/2}^{T_m}\right]$$

$$= \frac{5}{T_m}\left[\frac{e^{-jn\frac{\omega_m T_m}{2}} - e^{-j0} - e^{-jn\omega_m T_m} + e^{-jn\frac{\omega_m T_m}{2}}}{-jn\omega_m}\right]$$

$$= \frac{5}{T_m}\left[\frac{2e^{-jn\pi} - 1 - \overset{1}{\cancel{e^{-jn2\pi}}}}{-jn\omega_m}\right]$$

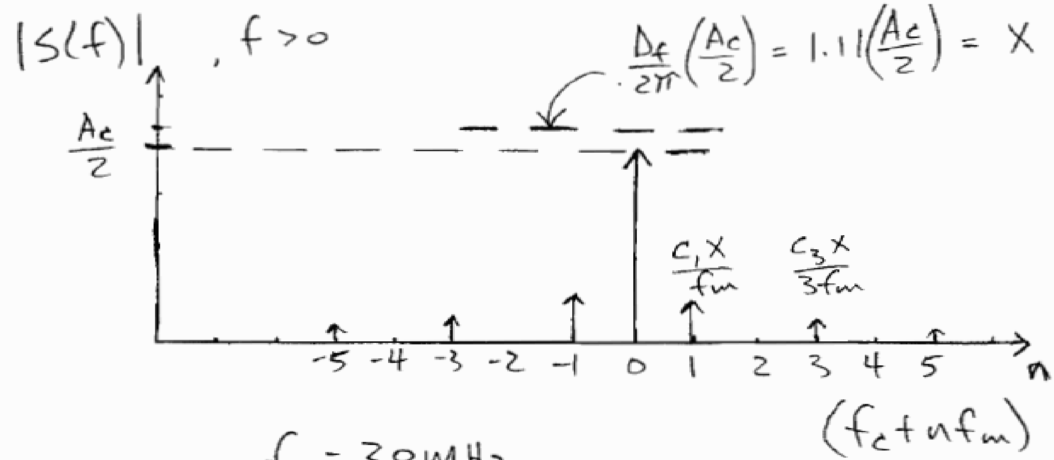
$$= 10\left[\frac{1 - e^{-jn\pi}}{jn\omega_m T_m}\right] = 10\, e^{-j\frac{n\pi}{2}}\left[\frac{e^{j\frac{n\pi}{2}} - e^{-j\frac{n\pi}{2}}}{j2\pi n}\right]$$

$$= \frac{10}{2} e^{-j\frac{n\pi}{2}}\left[\frac{\sin\left(\frac{n\pi}{2}\right)}{n\pi/2}\right]$$

$$c_n = 5(-j)^n\left[\frac{\sin n\pi/2}{n\pi/2}\right],\ n \neq 0\ ;\ c_0 = 0$$

5-30 (Continued)

$$\underline{\underline{c_n = 0, \quad n = \text{even}}}$$



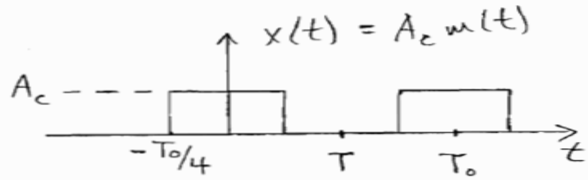
$f_c = 30\text{MHz}$

5-33

(a.) $s(t) = x(t)\cos\omega_c t$, where

$$T = \frac{1}{R} = \frac{1}{24000}$$

$$T_0 = 2T$$



OOK:

$$S(f) = \frac{1}{2}\left[X(f-f_c) + X^*(-f-f_c)\right]$$

$$X(f) = \sum_{-\infty}^{\infty} c_n \delta(f - nf_0) \; ; \; x(t) = \sum_{-\infty}^{\infty} c_n e^{jn\omega_0 t}$$

$$c_n = \frac{1}{T_0}\int_{-T_0/4}^{T_0/4} A_c e^{-jn\omega_0 t}\,dt = \frac{A_c}{T_0}\left.\frac{e^{-jn\omega_0 t}}{-jn\omega_0}\right|_{-T_0/4}^{T_0/4}$$

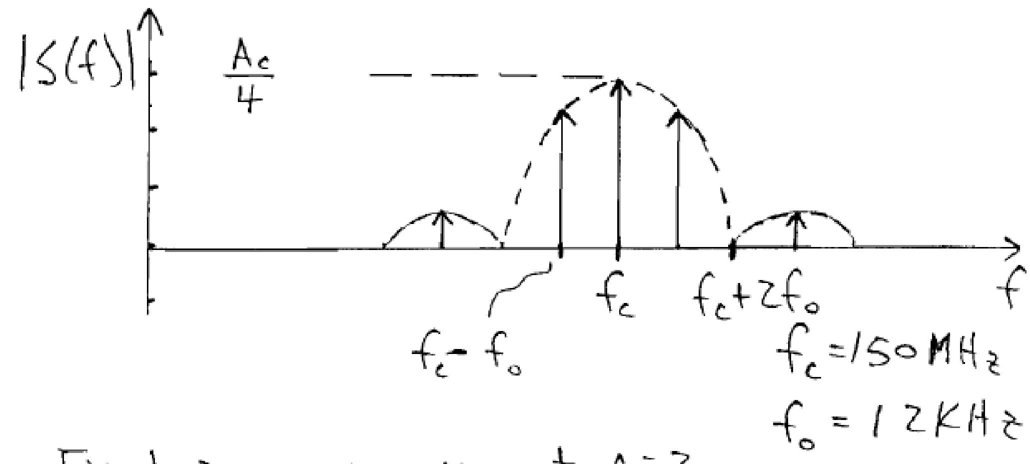
$$= \frac{A_c}{T_0}\,\frac{e^{-jn\pi/2} - e^{jn\pi/2}}{-jn2\pi/T_0} = \frac{A_c}{2}\,\frac{\sin(n\pi/2)}{n\pi/2}$$

$$\underline{\underline{X(f) = \frac{A_c}{2}\sum_{-\infty}^{\infty}\left[\frac{\sin(n\pi/2)}{n\pi/2}\right]\delta(f - nf_0)}}$$

$$f_0 = \frac{1}{T_0} = \frac{1}{2T} = \frac{R}{2}$$

$$\underline{S(f) = \frac{1}{2}\left[X(f-f_c) + X^*(-f-f_c)\right]}$$

5-33 (Continued)



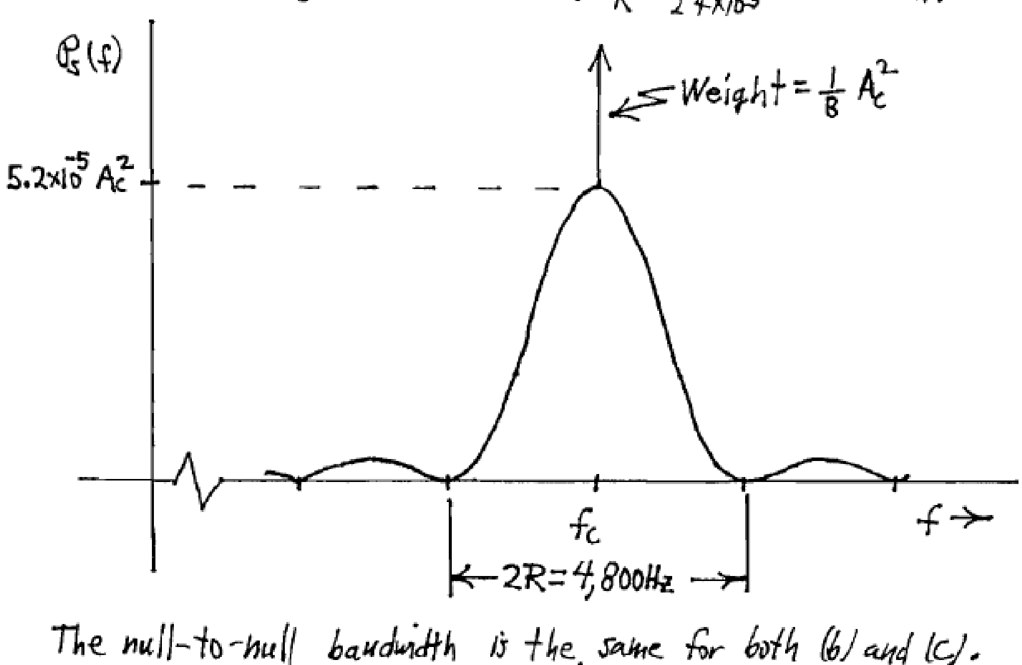
First zero-crossing at $n = 2$

$$BW_T = 2(2f_o) = 2R = \underline{\underline{48 \text{ KHz}}}$$

(c.) Using (5-2b) and (5-72)

$$\mathcal{P}_s(f) = \frac{1}{4}\frac{A_c^2}{2}\left[\delta(f-f_c) + T_b\left(\frac{\sin \pi(f-f_c)T_b}{\pi(f-f_c)T_b}\right)^2 + \delta(f+f_c) + T_b\left(\frac{\sin \pi(f+f_c)T_b}{\pi(f+f_c)T_b}\right)^2\right]$$

where $f_c = 150$ MHz and $T_b = \frac{1}{R} = \frac{1}{2.4\times10^{3}} = 0.0417$ msec



The null-to-null bandwidth is the same for both (b) and (c). Both have $\sin x/x$ type spectral envelope.

5-34

$k := 0 \,..\, 7 \qquad T := 0.0025 \qquad t := 0, 0.00008 \,..\, 8\,T$

$a_k :=$

1
-1
-1
1
-1
1
1
-1

$\omega_c := 1000\,\pi$

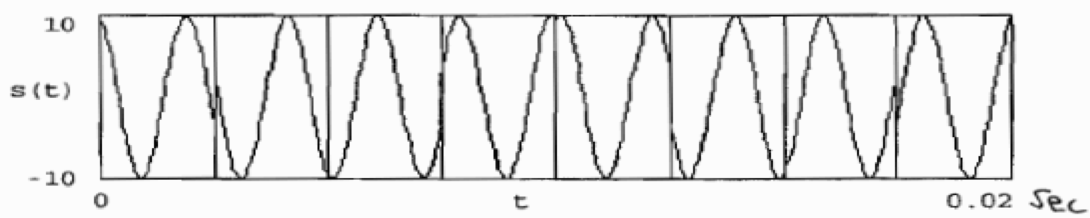
$\mathrm{rect}(t) := \mathrm{if}\left[\left|t - \frac{T}{2}\right| \le \frac{T}{2}, 1, 0\right]$

$m(t) := \sum_k \left[a_k\,\mathrm{rect}(t - k\,T)\right]$

(a) SET INDEX $h := 0.2 \qquad N := 64 \qquad n := 1 \,..\, N - 1 \qquad j := 0 \,..\, \frac{N}{2}$

$D_p := \frac{h\,\pi}{2} \qquad Ts := \frac{0.02}{N} \qquad t1_n := n\,Ts$

$s(t) := 10\,\cos\left[\omega_c\,t + D_p\,m(t)\right]$



$M := 6 \qquad N := 2^M \qquad N = 64 \qquad k := 0 \,..\, N - 1 \qquad T0 := 8\,T$

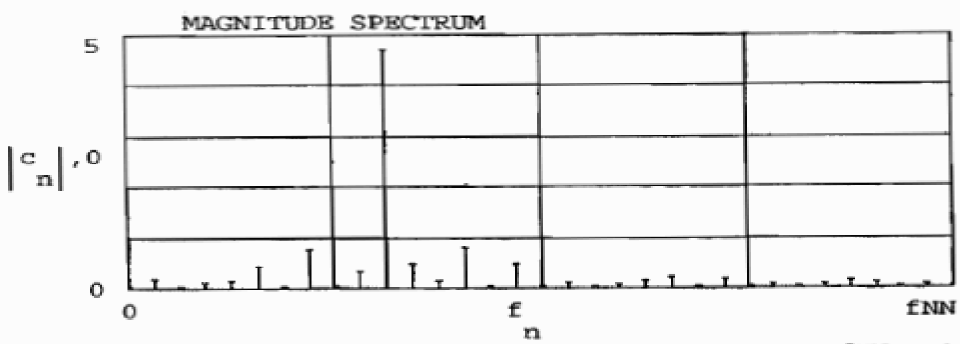
$dt := \frac{T0}{N} \qquad dt = 0 \qquad t_k := k\,dt$

$ss_k := s(k \cdot dt) \qquad n := 0 \,..\, N - 1 \qquad NN := 2^{M-1}$

Assume that the signal is periodic with period T0=8T. The spectrum can be obtained from the complex Fourier series coefficients. Furthermore, the complex Fourier series coefficients may be calculated using the FFT by substituting (2-178) into (2-186). Thus,

$c := \left[\frac{1}{\sqrt{N}}\right] \mathrm{icfft}(ss) \qquad fs := \frac{1}{dt} \qquad fs = 3200$ Hz

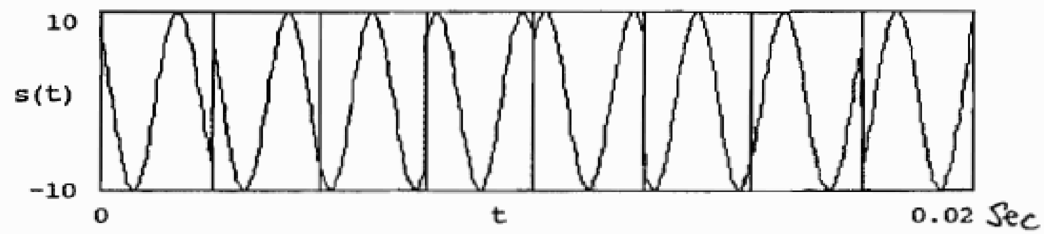
$f_n := \frac{n}{T0} \qquad f_1 = 50 \qquad fNN := NN\,f_1 \qquad fNN = 1600$

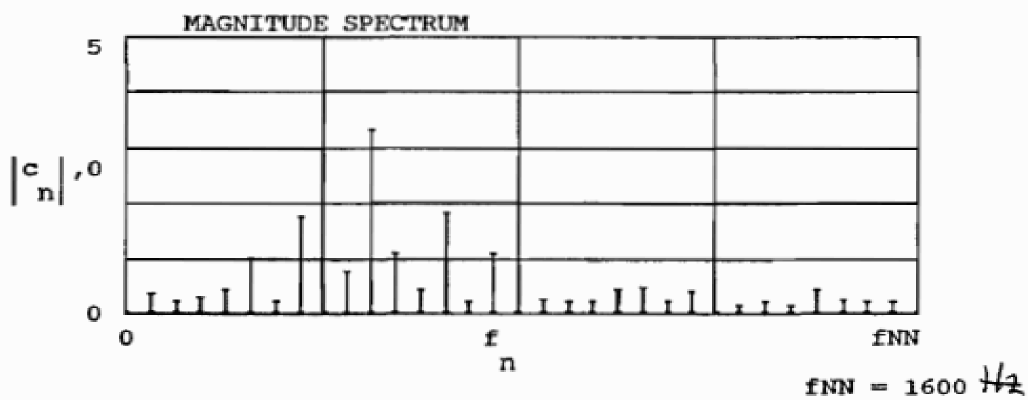


$fNN = 1600$ Hz

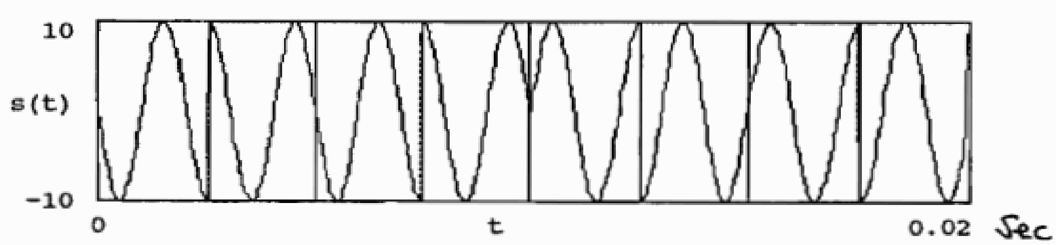
5-34 (Continued)

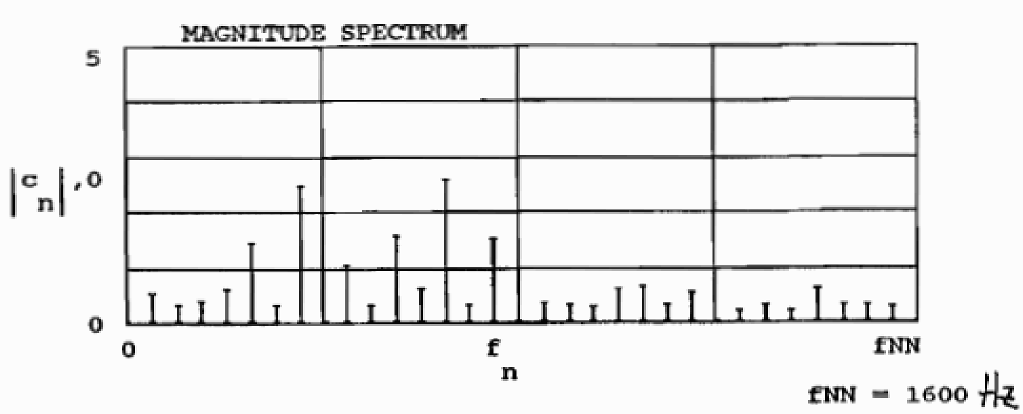
(b.) $h = 0.5$





(c.) $h = 1.0$





5-41

Use (5-106) $B_T = (1+r)\frac{R}{\ell}$ where $\ell = 2$ for QPSK

(a.) $\Rightarrow 24 = (1+r)\frac{30}{2} \Rightarrow (1+r) = \frac{2(24)}{30} = 1.6$

or $\underline{\underline{r = 0.6}}$

(b.) Max R allowed is when $r = 0$

$\Rightarrow R_{max} = \frac{2B_T}{1} = 2(24) = 48$ Mb/sec

$\Rightarrow$ No. A rolloff factor, r, could not be found support 50Mb/s QPSK signaling

5-49

From the description of $\pi/4$ QPSK in Sec. 5-10, use the table shown at the right

Input Bits	$\Delta\theta$
11	$+45°$
01	$+135°$
00	$-135°$
10	$-45°$

Data	10	11	01	00	10	10	10
$\Delta\theta$	$-45°$	$+45°$	$+135°$	$-135°$	$-45°$	$-45°$	$-45°$

(b) From (5-106)

$$B_T = \left(\frac{1+r}{\ell}\right)R \underset{\uparrow}{=} \left(\frac{1+0.5}{2}\right)R = \frac{\frac{3}{2}}{2}R = \frac{3}{4}R$$

$r = 0.5,\ \ell = 2$

$$B_T = \frac{3}{4}R \underset{\uparrow}{=} \frac{3}{4}(1.5) = \underline{\underline{1.13 \text{ Mb/sec}}}$$

$R = 1.5$ Mb/s

5-52

$i := 0 \,..14$ $\quad n := 0 \,..14$ $\quad t := -5, -4.99 \,..5$ $\quad T := 1$ $\quad a_6 := -1$

$a_1 := -1$ $\quad a_2 := -1$ $\quad a_3 := 1$ $\quad a_4 := 1$ $\quad a_5 := 1$ $\quad a0 := -1$

$a_7 := -1$ $\quad a_8 := -1$ $\quad a_9 := 1$ $\quad a_{10} := -1$ $\quad a_{11} := -1$ $\quad a_{12} := 1$

$a_{13} := -1$ $\quad a_{14} := -1$ $\quad tt := 0, 0.2 \,..15$

$h(t) := \Phi(t) - \Phi(t-1)$ $\quad n1 := 0, 2 \,..14$ $\quad n2 := 1, 3 \,..13$

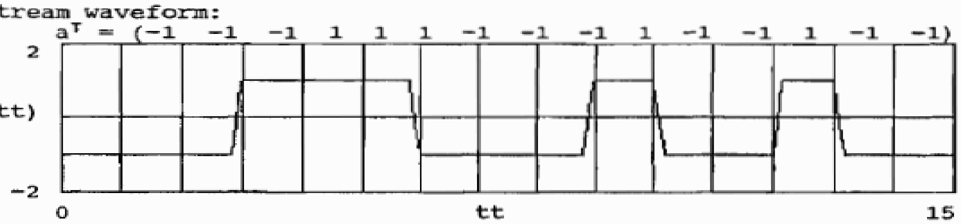
$$hx(t) := \Phi(t) - \Phi(t-2) \qquad m(tt) := \sum_n a_n \cdot h(tt - n\,T)$$

$$x(tt) := \sum_{n1} a_{n1} \cdot hx(tt - n1\,T) \qquad y(tt) := \sum_{n2} a_{n2}\, hx(tt - n2\cdot T)$$

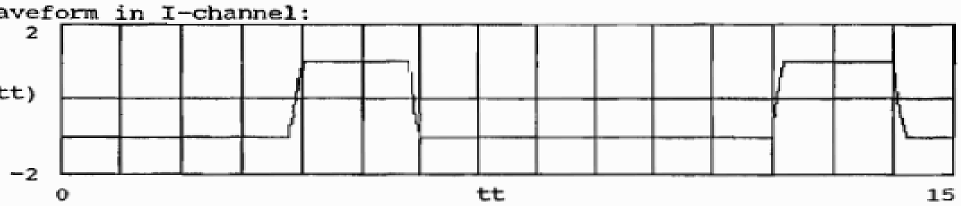
$$yy(tt) := \sum_{n2} a_{n2}\, hx(tt - n2\cdot T)\, \sin\left[\pi\, \frac{tt - n2\cdot T}{2}\right]$$

$$xx(tt) := \sum_{n1} a_{n1}\, hx(tt - n1\,T)\cdot \cos\left[\pi\, \frac{tt - n1\,T - 1}{2}\right]$$

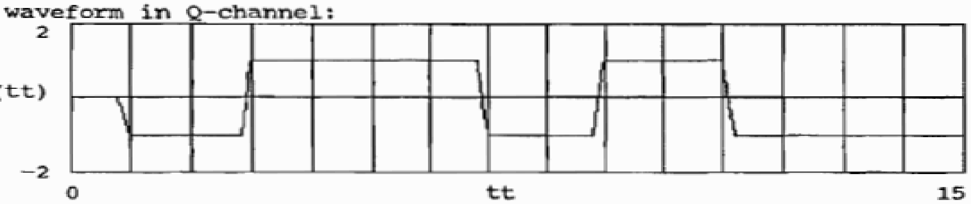
Data stream waveform:



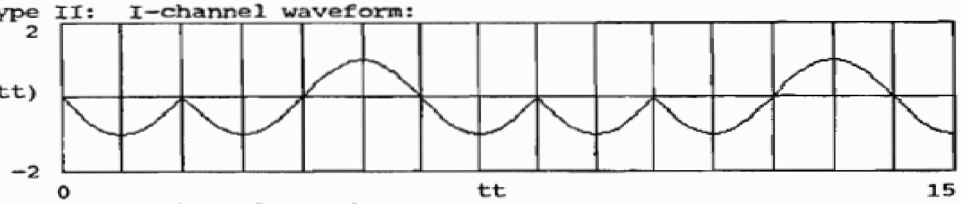
Data waveform in I-channel:



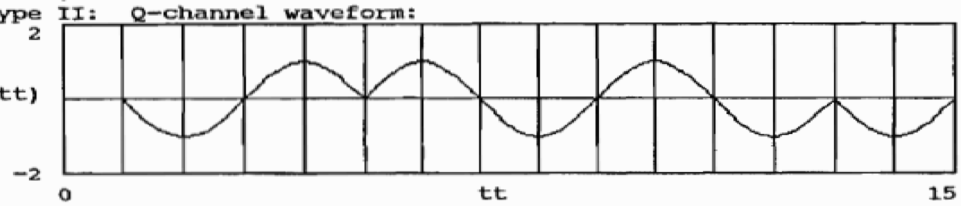
Data waveform in Q-channel:



MSK Type II: I-channel waveform:



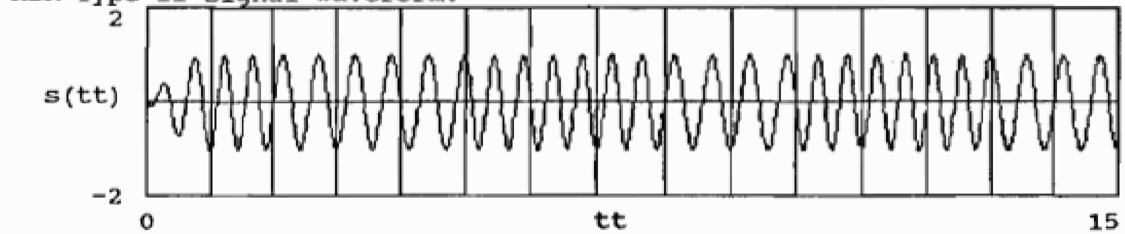
MSK Type II: Q-channel waveform:



5-52 (Continued)

```
tt := 0,0.01 ..15
s(tt) := xx(tt) cos(2 π·2 tt) - yy(tt)·sin(2 π·2 tt)
```

MSK Type II signal waveform:



5-54

(a) $H(f) = e^{-\left(\frac{f}{B}\right)^2\left(\frac{\ln 2}{2}\right)} = \left[e^{-\pi\left(f\sqrt{\frac{\ln 2}{2}}\,\frac{1}{B}\,\frac{1}{\sqrt{\pi}}\right)^2}\right] \Rightarrow h(t) = B\sqrt{\frac{2\pi}{\ln 2}}\; e^{-\pi\left(tB\sqrt{\frac{2\pi}{\ln 2}}\right)^2}$

Table 2-2

$\Pi\left(\frac{t}{T}\right) \longrightarrow \boxed{h(t)} \longrightarrow h_s(t)$ $\qquad$ $\Pi(-t) = \Pi(t)$

$$h_s(t) = \Pi\left(\frac{t}{T}\right) * h(t) = \int h(\lambda)\,\Pi\left(\frac{t-\lambda}{T}\right)d\lambda = \int h(\lambda)\,\Pi\left(\frac{\lambda-t}{T}\right)d\lambda$$

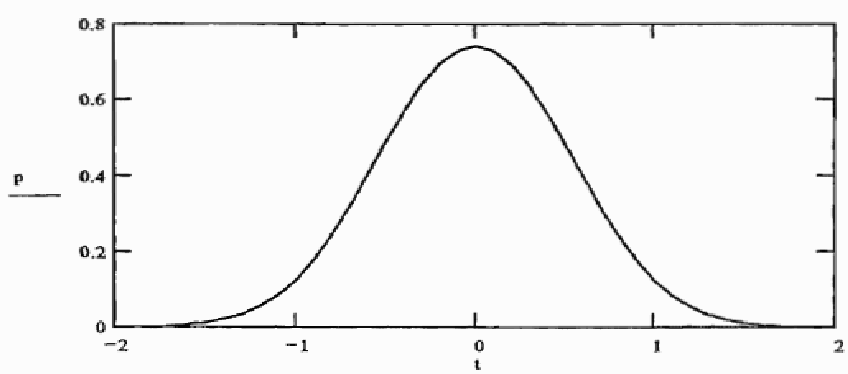
$$= \int_{t-\frac{T}{2}}^{t+\frac{T}{2}} \left(\sqrt{\frac{2\pi}{\ln 2}}\right) B\, e^{-\frac{2\pi^2}{\ln 2}\lambda^2 B^2}\, 1\, d\lambda$$

$$\Rightarrow h_s(t) = \left(\sqrt{\frac{2\pi}{\ln 2}}\right)(BT)\int_{\frac{t}{T}-\frac{1}{2}}^{\frac{t}{T}+\frac{1}{2}} e^{-\frac{2\pi^2}{\ln 2}(BT)^2 x^2}\,dx = p(t)$$

Let $\lambda = Tx$
$d\lambda = T\,dx$
$x = \frac{1}{T}\lambda$

(b) $BTb := 0.3 \quad Tb := 1 \quad N := 20 \quad dt := \frac{2\cdot Tb}{N} \quad n := 0, 1 .. 2\cdot N \quad t_n := (n-N)\cdot dt$

$$p(t) := \left[\sqrt{2\cdot\frac{\pi}{\ln(2)}}\cdot BTb\cdot\int_{\frac{t}{Tb}-0.5}^{\left(\frac{t}{Tb}\right)+0.5} e^{-\left[(2)\cdot\frac{(\pi^2)\cdot(BTb^2)\cdot x^2}{\ln(2)}\right]}dx\right] \qquad p_n := p(t_n)$$



5-60

(a) Referring to Fig 5-42a, the FSK signal is

$$v_1(t) = \cos[\omega_c t + \theta(t)] \text{ where } \theta(t) = D_f \int^t m(\lambda)\,d\lambda$$

The output of the FH spreader is

$$v_2(t) = A_c \cos[\omega_c t + \theta(t)]\cos(\omega_i t)$$

$$= \frac{A_c}{2}\cos[(\omega_c - \omega_i)t + \theta(t)] + \frac{A_c}{2}\cos[(\omega_c + \omega_i)t + \theta(t)]$$

The output of the BPF is the sum frequency part of $v_2(t)$,

$$\Rightarrow \underline{\underline{s(t) = \frac{A_c}{2}\cos[(\omega_c + \omega_i)t + \theta(t)]}}$$

(b) Referring to Fig 5-42b the signal out of the FH spreader

is $v_5(t) = s(t)\,2\cos(\omega_i t) = A_c \cos[(\omega_c + \omega_i)t + \theta(t)]\cos(\omega_i t)$

$$= \underbrace{\frac{A_c}{2}\cos[\omega_c t + \theta(t)]}_{\text{diff term}} + \underbrace{\frac{A_c}{2}\cos[(\omega_c + 2\omega_i)t + \theta(t)]}_{\text{sum term}}$$

$\Rightarrow$ The output of the BPF is $\underline{\underline{v_6(t) = \frac{A_c}{2}\cos[\omega_c t + \theta(t)]}}$ which is FSK.