Chapter 8

8-1

Assuming that the 150 G.Lite subscribers have VF service over the DSL lines, as well as VF service to the 300 VF subscriber lines, we get

$$300 \times 64\ \text{kb/s} + 150 \times 64\ \text{kb/s} + 150 \times 1{,}500\ \text{kb/s}$$
$$= 253{,}800\ \text{kb/s} = \underline{253.8\ \text{Mb/s}}$$

8-7

$$P_{Tx} = 0.1\ \text{W}, \quad f_c = 2\ \text{GHz}, \quad 3.28\ \text{ft/meter}$$

(a.) $$G_A = \frac{7A}{\lambda^2} \approx \frac{7.0\pi\left(\frac{2}{3.28}\right)^2}{\left(\frac{3\times10^8}{2\times10^9}\right)^2} = \underline{\underline{363.14}} = \underline{\underline{25.6\ \text{dB}}}$$

$A = \pi r^2,\ \lambda = c/f$

$10\log(363.4) = 25.6$

(b.) $$P_{EIRP} = P_{Tx}\, G_{AT} = 0.1\,(363.4) = \underline{\underline{36.3\ \text{W}}}$$

(c.) $$P_{Rx} = P_{Tx}\, G_{AT}\, G_{AR}\left(\frac{\lambda}{4\pi d}\right)^2 = (0.1)(363.4)^2\left[\frac{(0.15)(3.28)}{4\pi(15)(5280)}\right]^2$$

$$\Rightarrow P_{Rx} = 3.23\times10^{-9}\ \text{W}$$

or $$(P_{Rx})_{dBm} = 10\log\left(\frac{3.23\times10^{-9}}{10^{-3}}\right) = \underline{\underline{-54.9\ \text{dBm}}}$$

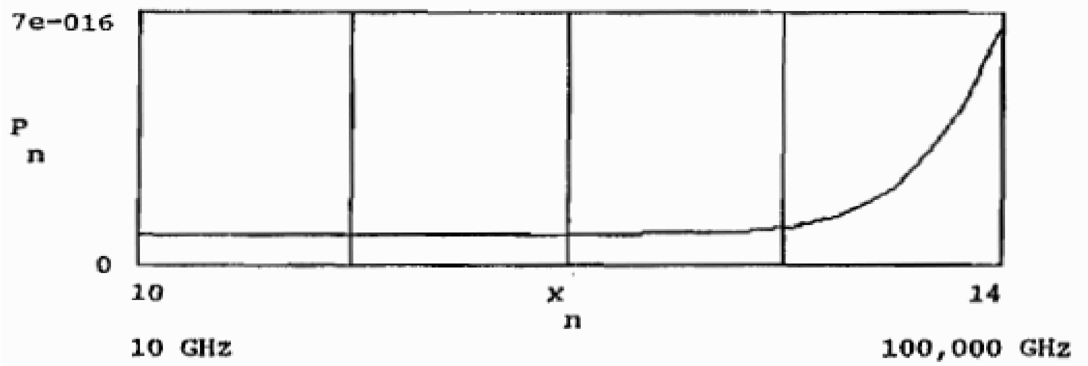
8-8

$n := 100 \,..\, 140$ $\quad h := 6.6252 \cdot 10^{-34}$ $\quad k := 1.381 \cdot 10^{-23}$

$T := 300$

$R := 10000$ $\quad x_n := \dfrac{n}{10}$ $\quad f_n := 10^{x_n}$

$$P_n := 2 \cdot R \left[\frac{h\, f_n}{2} + \frac{h \cdot f_n}{e^{\frac{h \cdot f_n}{k \cdot T}} - 1} \right]$$



8-13

(a.) $T_{eff} = T_o(F-1)$

$= 290(10^{.16} - 1) = \underline{\underline{129^\circ K}}$

(b.) $P_{a_{out}} = K\, T_{IN}\, B\, G_a$

$= (1.38 \times 10^{-23})(30^\circ + 129^\circ)(10 \times 10^6)(10^3)$

$= \underline{\underline{2.2 \times 10^{-11}\ W}}$

$= 10 \log_{10}\left(\dfrac{2.2 \times 10^{-11}}{10^{-3}}\right) = \underline{\underline{-76.6\ dBm}}$

8-15

From Table 7-1 for FSK w/ noncoherent detection:

$$P_e = \frac{1}{2} e^{-\frac{1}{2}(E_b/N_{total})}$$

$$N_{total} = k(T_0 + T_{eff}) = k(T_0 + (F-1)T_0) = kFT_0$$

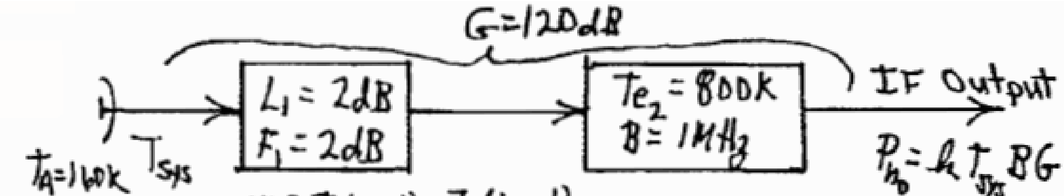
$$T_{eff} = (F-1)T_0$$

$$= (1.38 \times 10^{-23})(10^{6/10})(290)$$

$$\frac{E_b}{N_{total}} = \frac{P_s T}{N_{total}} = \frac{P_s}{N_{tot} R} = \frac{V_s^2/R_A}{k F T_0 R} = 28.53$$

$$P_e = \frac{1}{2} e^{-\frac{1}{2}(28.53)} = \underline{\underline{3.2 \times 10^{-7}}}$$

8-20



$$T_{e_1} = T_0(F_1 - 1) = T_0(L_1 - 1)$$

$$T_{sys} = T_A + T_e = T_A + \left(T_{e_1} + \frac{T_{e_2}}{G_1}\right) = T_A + \left(T_{e_1} + T_{e_2} L_1\right)$$

$$\Rightarrow T_{sys} = T_A + \underbrace{\left[T_0(L_1 - 1) + T_{e_2} L_1\right]}_{T_e}. \quad \text{Also } T_e = T_0(F-1) \Rightarrow F = \frac{T_e}{T_0} + 1$$

(a) Compute the system noise temperature Ts evaluated at the antenna input of the waveguide:

$Ta := 160\ K$ $\quad To := 290\ K$ $\quad Te2 := 800\ K$

$L1 := 10^{0.2}$ $\quad G := 10^{12}$ $\quad B := 10^{6}\ Hz$

$Te := To \cdot (L1 - 1) + Te2\ L1$ $\quad Ts := Ta + Te$ $\quad \underline{\underline{Ts = 1597.534\ K}}$

(b) Noise figure F :

$F := \dfrac{Te}{To} + 1$ $\quad \underline{\underline{F = 5.957}}$ $\quad FdB := 10 \cdot \log(F)$ $\quad \underline{\underline{FdB = 7.75}}$

(c) The available output noise power Pno:

$Pno := 1.38 \cdot 10^{-23} \cdot Ts \cdot B \cdot G$ $\quad \underline{\underline{Pno = 0.022\ Watt}}$

8-22

Assume 4 GHz down link

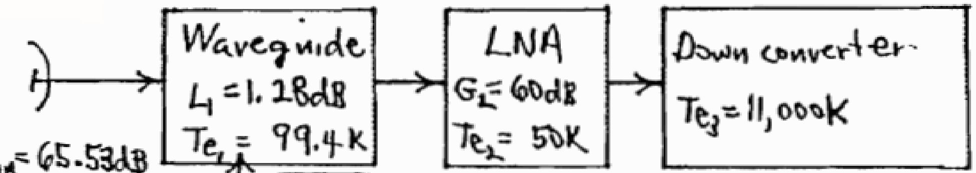
$$\frac{G_{AR}}{T_{sys}} = 10^4 = \frac{4\pi\eta\left[\pi(15)^2\right]}{85\left(3\times10^8/4\times10^9\right)^2} = 1.86\times10^4\eta$$

$$\Rightarrow \underline{\underline{\eta = 54\ \%}} \quad \text{for } 30\text{m antenna}$$

$$10^4 = 1.86\times10^4\eta\left[\frac{(12.5)^2}{(15)^2}\right] = 1.29\times10^4\eta$$

$$\Rightarrow \underline{\underline{\eta = 77.4\ \%}} \quad \text{for } 25\text{m antenna}$$

8-25



$G_{AR} = 65.53$dB
$T_{AR} = 60$K

$T_e = T_0(F_1 - 1) = T_0(L_1 - 1)$
$T_e = (290)(10^{1.28/10} - 1) = 99.4$

(a.) $T_s = (T_{AR} + T_{e_1})G_1 + \left(T_{e_2} + \frac{T_{e_3}}{G_2}\right) = \frac{T_{AR}+T_{e_1}}{L_1} + \left(T_{e_2} + \frac{T_{e_3}}{G_2}\right)$

$G_s = G_{AR}G_1 = \frac{G_{AR}}{L_1}$

(b) $T_s = T_{AR} + T_e = T_{AR} + \left(T_{e_1} + \frac{T_{e_2}}{G_1} + \frac{T_{e_3}}{G_1G_2}\right)$

$\Rightarrow T_s = T_{AR} + \left(T_{e_1} + T_{e_2}L_1 + T_{e_3}\frac{L_1}{G_2}\right)$

$G_s = G_{AR}$

(c.) $T_s = (T_{AR} + T_{e_1})G_1G_2 + T_{e_2}G_2 + T_{e_3} = (T_{AR}+T_{e_1})\frac{G_2}{L_1} + T_{e_2}G_2 + T_{e_3}$

$G_s = G_{AR}G_1G_2 = \frac{G_{AR}G_2}{L_1}$

$Gar := 10^{\frac{65.53}{10}}$ $L1 := 10^{\frac{1.28}{10}}$ $G2 := 10^{\frac{60}{10}}$ $Te3 := 11000$

$Tar := 60$ $Te1 := 290\cdot(L1 - 1)$ $Te2 := 50$

(a.)

$Ts := \frac{Tar + Te1}{L1} + Te2 + \frac{Te3}{G2}$ $\underline{Ts = 168.723}$

$Gs := \frac{Gar}{L1}$ $\underline{Gs = 2.661\cdot 10^6}$ $GTsdB := 10\cdot\log\left(\frac{Gs}{Ts}\right)$ $\underline{\underline{GTsdB = 41.978}}$

(b.)

$Ts := Tar + Te1 + Te2\cdot L1 + Te3\cdot\frac{L1}{G2}$ $\underline{Ts = 226.555}$

$Gs := Gar$ $\underline{Gs = 3.573\cdot 10^6}$ $GTsdB := 10\cdot\log\left(\frac{Gs}{Ts}\right)$ $\underline{\underline{GTsdB = 41.978}}$

(c.)

$Ts := (Tar + Te1)\cdot\frac{G2}{L1} + Te2\cdot G2 + Te3$ $\underline{Ts = 1.687\cdot 10^8}$

$Gs := Gar\cdot\frac{G2}{L1}$ $\underline{Gs = 2.661\cdot 10^{12}}$ $GTsdB := 10\cdot\log\left(\frac{Gs}{Ts}\right)$ $\underline{\underline{GTsdB = 41.978}}$

8-27

$$f_c = 2\text{ GHz} \;;\; \lambda = \frac{c}{f} = \frac{3\times10^8}{2\times10^9} = .15\text{ m}$$

$$\frac{E_b}{N_0} = \frac{P_{Tx}\,G_{AT}\,G_{FS}\,G_{AR}}{K\,T_{sys}\,R}$$

$$G_{AT} = \frac{E_b}{N_0}\,\frac{k\,T_{sys}\,R}{P_{Tx}\,G_{FS}\,G_{AR}}$$

$$G_{FS} = \left(\frac{\lambda}{4\pi d}\right)^2 \cdot L_{incidental} = \left(\frac{0.15}{4\pi(7.5\times10^{12})}\right)^2 (10^{-0.2}) = 1.6\times10^{-30}$$

$$G_{AR} = 7\pi\left(\frac{r}{\lambda}\right)^2 = 7\pi\left(\frac{32}{0.15}\right)^2 = 1\times10^6$$

$$G_{AT} = \frac{10^{0.988}\,(1.38\times10^{-23})(16)(300)}{10\,(1.6\times10^{-30})(10^6)} = 4.03\times10^4 = \frac{7A}{\lambda^2} = \frac{7A}{(0.15)^2}$$

parabolic

$$\Rightarrow A = 129.44\text{ m}^2 = \pi r^2$$

$$\therefore r = \sqrt{\frac{129.44}{\pi}} = 6.42\text{ m} \Rightarrow \underline{\underline{D = 2r = 12.84\text{ m}}}$$ parabolic ant (rather large)

8-29

Using (8-47) and (8-8)

$$P_{dBm}(d) = P_{dBm}(d_0) - 10 n \log\left(\frac{d}{d_0}\right)$$

where $P_{dBm}(d_0) = (P_T)_{dBm} + (G_{TA})_{dBm} - 20\log\left(\frac{4\pi d_0}{\lambda}\right) + (G_{AR})_{dBm}$

$$= 40 + 18 - 20\log\left(\frac{4\pi\,(0.25\,\text{miles})(5280\,\text{ft/mile})\left(\frac{1\,\text{m}}{3.28\,\text{ft}}\right)}{3\times10^8/1.8\times10^9}\right) + 0$$

$\rightarrow 89.64$

$\Rightarrow P_{dBm}(d_0) = -31.64\,\text{dBm}$

	Power Received (dBm)				
Distance (miles)	0.25	1	2	5	10
n=2 (free space)	-31.6	-43.7	-49.7	-57.7	-63.7
n=3	-31.6	-49.7	-58.7	-70.6	-79.7
n=4	-31.6	-55.7	-67.8	-83.7	-95.7

8-32

The available bandwidth is

$$B_T = \frac{1}{2} f_h = \frac{1}{2}(15.734) = 7.867\text{ kHz}$$

Referring to Fig. 8-33, the spectrum of the professional subcarrier (PSC) needs to rolloff fast enough so that it does not interfere with the SAP FM subcarrier and the DSB-SC stereo subcarrier. Since the SAP subcarrier is FM, the capture effect of the FM detector will suppress the PSC interference, when the PSC spectrum is, say, 10 to 15 dB below the SAP spectrum (in the SAP band). Referring to Fig. 5-33, it is seen that these interference specifications are easily satisfied if the first-null bandwidth criterion is used. Thus, for the M-ary signal class,

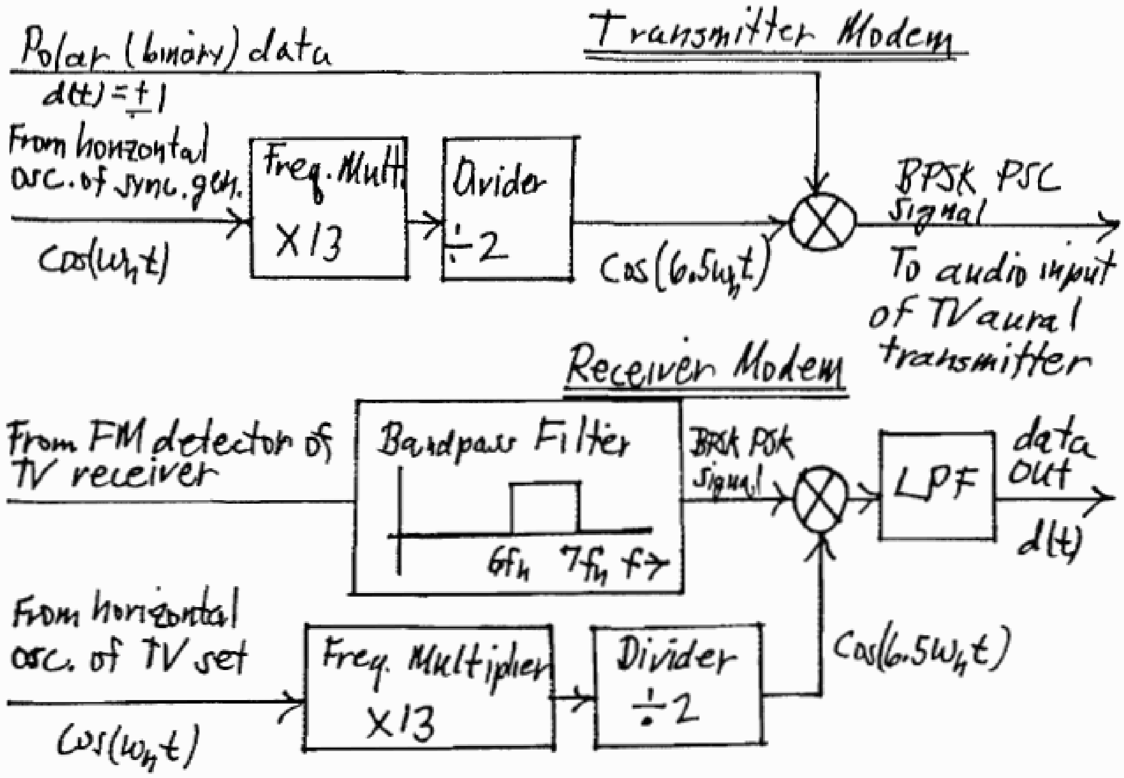
8-32 (Continued)

$$B_T = 2\left(\frac{R}{\ell}\right) \le 7.867 \quad \text{or} \quad \ell \ge \left(\frac{2R}{7.867}\right)$$

(a) For $R = 1.2$ kb/s, $\ell \ge \left(\frac{2(1.2)}{7.867}\right) = 0.305$.

$\Rightarrow$ Choose $\ell = 1$ $\Rightarrow$ Use BPSK signaling

A $R = 1200$ b/s BPSK system is shown below.



(b) For $R = 9.6$ kb/s, $\ell \ge \left(\frac{2(9.6)}{7.867}\right) = 2.44$

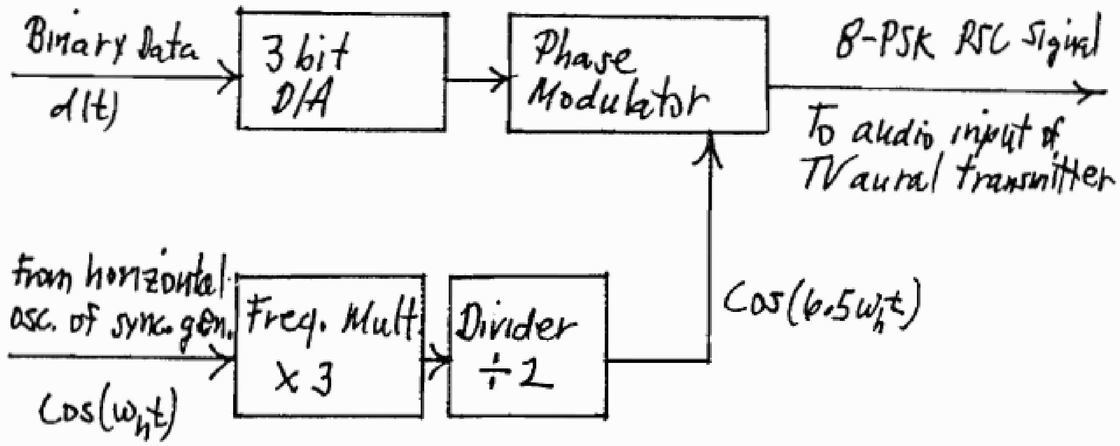
$\Rightarrow$ Choose $\ell = 3$ $\Rightarrow$ $M = 2^3 = 8$

$\Rightarrow$ Use 8-PSK

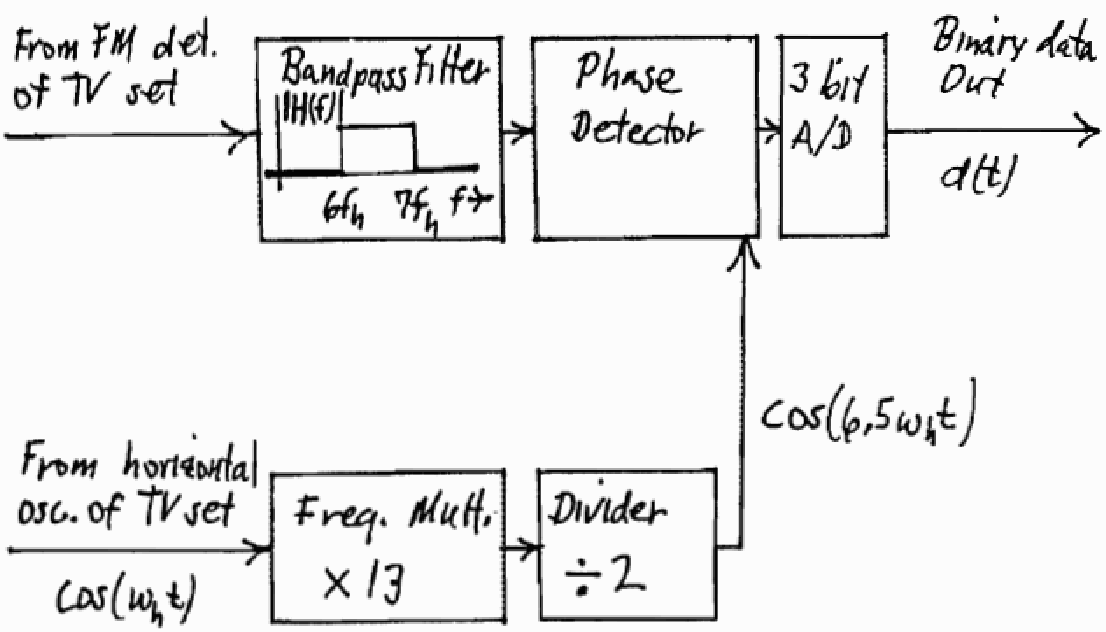
8-32 (Continued)

A $R = 9600$ b/s 8-PSK system is shown below

Transmitter Modem



Receiver Modem



8-34

$$R_{\text{with Coding}} = (R_{\text{without coding}})\left(\frac{1}{R_{TCM}}\right)\left(\frac{1}{R_{RS}}\right) = 19.39\left(\frac{3}{2}\right)\left(\frac{207}{187}\right)$$

$$\Rightarrow R_{\text{withCoding}} = 32.20 \text{ Mb/s}$$

$$\Rightarrow D_{\text{withcoding}} = \frac{R_{\text{withcoding}}}{\ell} = \frac{32.2}{3} = 10.73 \text{ Mbaud}$$

($\ell = 3$ for 8 levels)

The segment sync replaces the payload sync at the beginning of each segment. One segment of training data is added after 312 segments.

Thus,

$$D_{\text{overall}} = (D_{\text{withcoding}})\left(\frac{312+1}{312}\right) = 10.73\left(\frac{312+1}{312}\right) = \underline{\underline{10.76 \text{ Mbaud}}}$$

Appendix B

B-1

$$P(1) = \frac{n_1}{n} = \frac{1428}{1428+2668} = \underline{\underline{0.3486}}$$

B-3

(a.) $P(1+3+5) = P(1) + P(3) + P(5) = \frac{3}{6} = \underline{\underline{\frac{1}{2}}}$

(b.) $P(4/E) = \frac{P(4\cdot E)}{P(E)} = \frac{P(4)}{P(E)} = \frac{1/6}{1/2} = \underline{\underline{\frac{1}{3}}}$

B-8

(a.) $\int_{-\infty}^{\infty} f(x)\,dx = 1 = \int_{0}^{\infty} k e^{-bx}\,dx$

$= \frac{k e^{-bx}}{-b}\Big|_0^{\infty} = \frac{k}{b}\left[e^{-\infty} - e^{0}\right] = \frac{k}{b} = 1 \Rightarrow \underline{\underline{k=b}}$

(b.) $f(x) = b e^{-bx}$

$m = \bar{x} = \int_{-\infty}^{\infty} x f(x)\,dx = \int_{0}^{\infty} b x e^{-bx}\,dx$

$= b\left[\frac{-x e^{-bx}}{b}\Big|_0^{\infty} + \int_0^{\infty} \frac{e^{-bx}}{b}\,dx\right] = b\left[\frac{e^{-bx}}{-b^2}\Big|_0^{\infty}\right]$

$\boxed{\begin{array}{ll} \text{Let } u = x & dv = e^{-bx}dx \\ du = dx & v = -e^{-bx}/b \end{array}}$

$\Rightarrow m = b\left[-\frac{1}{b^2}(e^{-\infty} - e^{0})\right] = \underline{\underline{\frac{1}{b}}} = m$

(c.) $\sigma^2 = \overline{x^2} - (\bar{x})^2$ where $\overline{x^2} = \int_{-\infty}^{\infty} x^2 b e^{-bx}\,dx$

Using Sec. A-5 $\overline{x^2} = b e^{-bx}\left[\frac{x^2}{-b} - \frac{2x}{b^2} - \frac{2}{b^3}\right]\Big|_0^{\infty} = -b e^{-0}\left(\frac{-2}{b^3}\right) = \frac{2}{b^2}$

$\Rightarrow \sigma^2 = \frac{2}{b^2} - \left(\frac{1}{b}\right)^2 = \underline{\underline{\frac{1}{b^2}}} = \sigma^2$

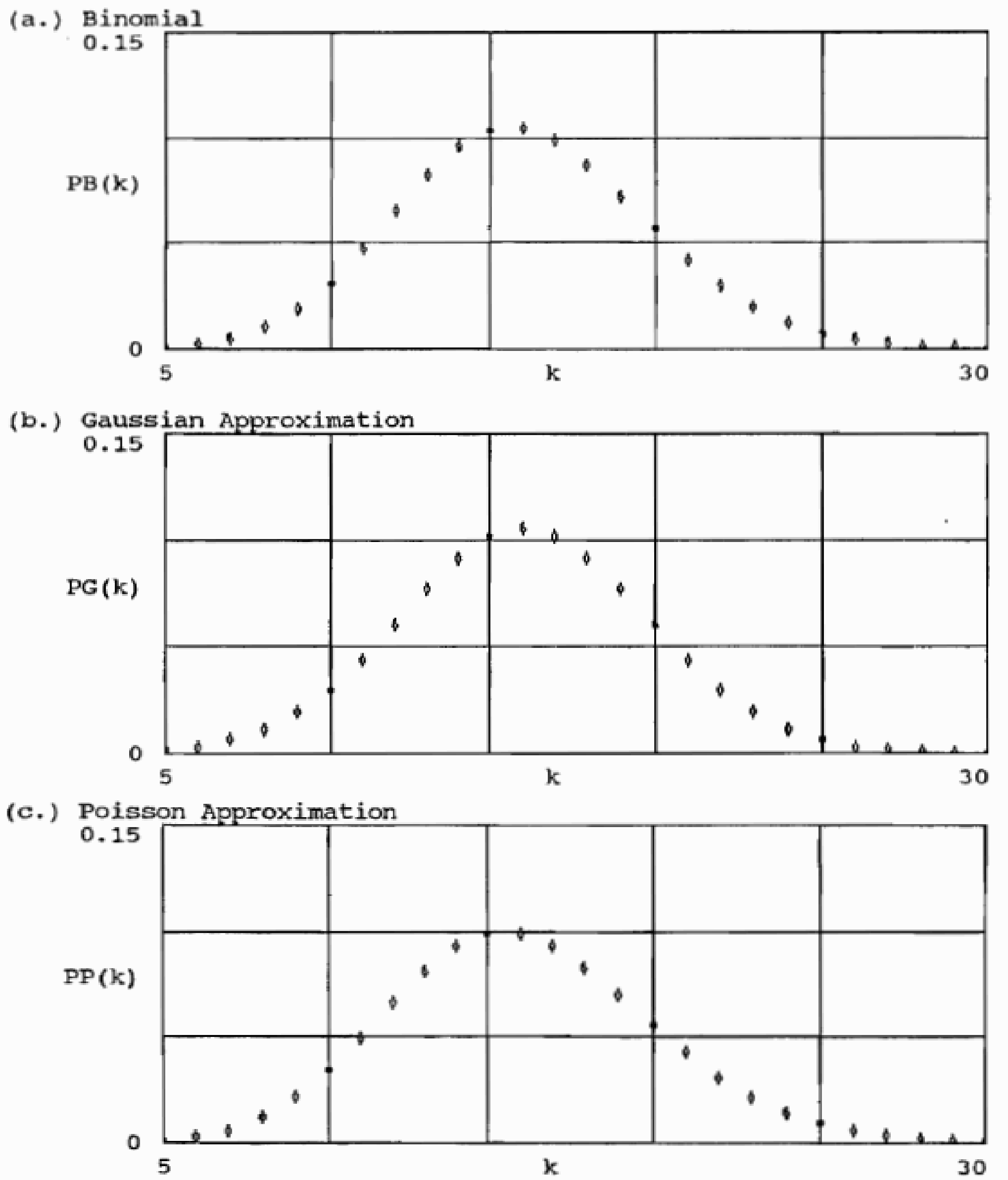
B-12

$n := 160 \quad p := 0.1 \quad q := 1 - p \quad \lambda := n \cdot p$

$m := n\,p \quad \sigma := \sqrt{n\,p \cdot q} \quad k := 0\,..2\,\lambda \quad m = 16$

$$PB(k) := \frac{n!}{k!\,(n-k)!}\,p^{k}\,q^{n-k} \quad \text{Binomial}$$

$$PP(k) := e^{-\lambda} \cdot \frac{\lambda^{k}}{k!} \quad \text{Poisson} \qquad PG(k) := \frac{1}{\sigma \cdot \sqrt{2 \cdot \pi}}\,e^{\frac{-(k-m)^2}{2 \cdot \sigma^2}}$$



B-16

Let $f(x)$ = pdf of R values where x = R value

$$\Rightarrow \int_{.9\bar{x}}^{1.1\bar{x}} f(x)\,dx \overset{\text{set}}{=} .95$$

$$\Rightarrow \int_{.9\bar{x}}^{1.1\bar{x}} \frac{1}{\sqrt{2\pi}\sigma} e^{-\frac{(x-\bar{x})^2}{2\sigma^2}} dx = .95$$

Let $x_1 = x - \bar{x}$; $dx_1 = dx$

$$= \int_{-.1\bar{x}}^{.1\bar{x}} \frac{1}{\sqrt{2\pi}\sigma} e^{-x_1^2/2\sigma^2} dx = .95 = 1 - 2Q\left(\frac{.1\bar{x}}{\sigma}\right)$$

$$\Rightarrow Q\left(\frac{.1\bar{x}}{\sigma}\right) = \frac{1.-.95}{2} = .025 \overset{\text{A-10}}{\Rightarrow} \frac{.1\bar{x}}{\sigma} = 1.96$$

$$\Rightarrow \sigma = \frac{.1\bar{x}}{1.96} = \frac{(.1)(1000)}{1.96} = \underline{\underline{51.0 \text{ ohms} = \sigma}}$$

B-25

The input is $x(t) = A \sin \omega_m t$ where $A = 8$.
The output consists of a quantized sinusoid similar to that shown in Fig. 3-8b. The PDF of the output, $y(t)$, will consist of δ functions at the quantized values.
Thus,
$$\underline{\underline{f(y) = \sum_{k=1}^{M} P_k\, \delta(y - y_k)}}$$
where $M = 8$, the step size is $\delta = \frac{2A}{M} = \frac{16}{8} = 2$, and the quantized values are: $\underline{\underline{y_k = \frac{(2k-M-1)}{2}\delta}}$

$$P_k = \int_{y_k-\delta/2}^{y_k+\delta/2} f_x(x)\,dx = \int_{y_k-\delta/2}^{y_k+\delta/2} \frac{1}{\pi\sqrt{A^2 - x^2}}\,dx = \int_{y_k-\delta/2}^{y_k+\delta/2} \frac{\frac{1}{A}}{\pi\sqrt{1 - \left(\frac{x}{A}\right)^2}}\,dx$$

Using (B-67)

$$= \frac{1}{\pi}\sin^{-1}\left(\frac{x}{A}\right)\Bigg|_{y_k-\delta/2}^{y_k+\delta/2} = \frac{1}{\pi}\left[\sin^{-1}\left(\frac{y_k+\delta/2}{A}\right) - \sin^{-1}\left(\frac{y_k-\delta/2}{A}\right)\right]$$

Using (A-29)

or

$$P_k = \frac{1}{\pi}\left[\sin^{-1}\left(\frac{(2k-M-1+1)\delta}{2A}\right) - \sin^{-1}\left(\frac{(2k-M-1-1)\delta}{2A}\right)\right]$$

$$P_k = \frac{1}{\pi}\left[\sin^{-1}\left(\frac{(2k-M)\frac{2A}{M}}{2A}\right) - \sin^{-1}\left(\frac{(2k-M-2)\frac{2A}{M}}{2A}\right)\right] = \underline{\underline{\frac{1}{\pi}\left[\sin^{-1}\left(\frac{2k-M}{M}\right) - \sin^{-1}\left(\frac{2k-M-2}{M}\right)\right]}}$$

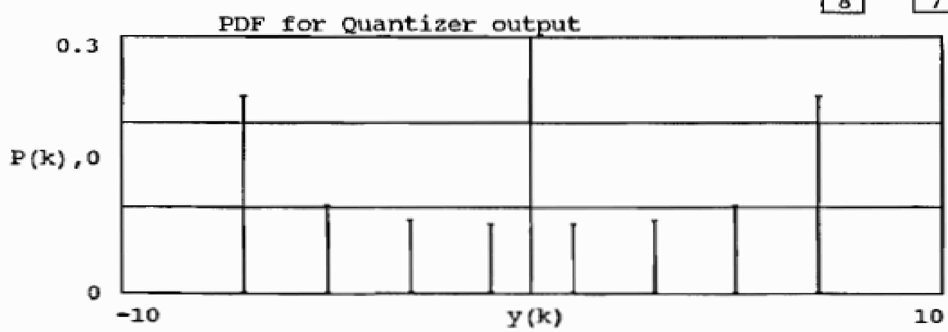
$A := 8$ $\quad M := 8$ $\quad \delta := 2\,\frac{A}{M}$ $\quad \delta = 2$ <--Step size

$k := 1 \,..\, M$

$y(k) := (2\,k - M - 1)\;0.5\cdot\delta$

$$P(k) := \frac{1}{\pi}\left[\operatorname{asin}\left[\frac{2\cdot k - M}{M}\right] - \operatorname{asin}\left[\frac{2\,k - M - 2}{M}\right]\right]$$

k	y(k)
1	−7
2	−5
3	−3
4	−1
5	1
6	3
7	5
8	7



B-27

$$\bar{y} = \int_{-\infty}^{\infty} y f(y)\, dy = \int_0^{\infty} \frac{y}{\sqrt{2\pi}\, \beta\Delta} e^{-y^2/2\beta^2\Delta^2} dy + \frac{1}{2}\int_{-\infty}^{\infty} \cancel{y\,\delta(y)}\, dy \xrightarrow{} 0$$

$$= \left(\frac{-\beta\Delta}{\sqrt{2\pi}}\right) \int_0^{\infty} e^{-y^2/2\beta^2\Delta^2} \left(\frac{-y}{\beta^2\Delta^2}\right) dy$$

$$= \left(\frac{-\beta\Delta}{\sqrt{2\pi}}\right) \int_0^{\infty} e^{z}\, dz = \left(\frac{-\beta\Delta}{\sqrt{2\pi}}\right) e^{z}\Big|_0^{\infty}$$

$$\boxed{\text{Let } z = \frac{-y^2}{2\beta^2\Delta^2} \qquad dz = \frac{-y}{\beta^2\Delta^2}\, dy}$$

$$= \frac{\beta\Delta}{\sqrt{2\pi}} = \bar{y}$$

B-34

$$mx := \begin{bmatrix} 2 \\ -1 \end{bmatrix} \qquad Cx := \begin{bmatrix} 5 & \frac{-2}{\sqrt{5}} \\ \frac{-2}{\sqrt{5}} & 4 \end{bmatrix} \qquad T := \begin{bmatrix} 1 & \frac{1}{2} \\ \frac{1}{2} & 1 \end{bmatrix}$$

(a.) Compute the mean vector for y:

$$my := T\, mx \qquad my = \begin{bmatrix} 1.5 \\ 0 \end{bmatrix}$$

(b.) Compute the covariance matrix, Cy:

$$Cy := T \cdot Cx \cdot T^T \qquad Cy = \begin{bmatrix} 5.106 & 3.382 \\ 3.382 & 4.356 \end{bmatrix}$$

B-34 (Continued)

(c.) Compute the correlation coefficient for y1 and y2:

$$\rho := \frac{Cy_{0,1}}{\left[\sqrt{Cy_{0,0}}\right] \left[\sqrt{Cy_{1,1}}\right]} \qquad \rho = 0.717$$

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