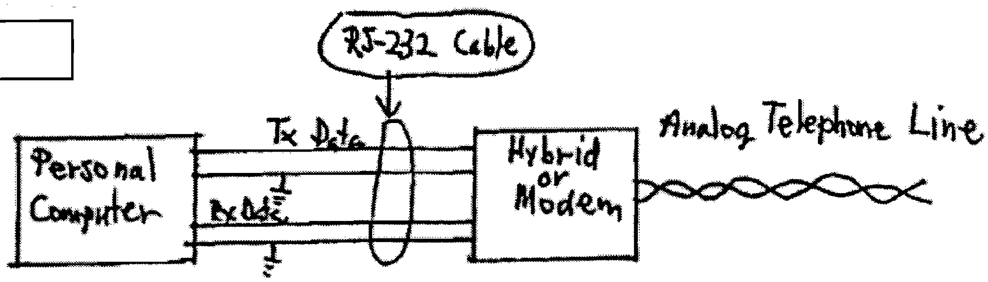
Chapter 8

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

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

8-5



Suppose the serial data port on a PC is interfaced to the VF telephone line without a modem. The transmit (Tx) and receive (Rx) serial data from the PC are each represented by a Polar NRZ line code as described by the RS-232 serial port standard in Appendix C. A hybrid (4 wire to 2 wire) circuit could be used to couple the Tx and Rx line-code signals to a single twisted-pair VF telephone line. However, the spectrum of the polar line-code is not compatible with the frequency response of the VF telephone line. That is, as shown in Fig. 3-16b, the dominant frequencies in the Polar NRZ line code are near zero (i.e. baseband) but the telephone line is a bandpass channel with a frequency response from 300 to 2700 Hz. Thus, the Polar NRZ waveform would be distorted by the telephone line so that the data could not be detected at the receiving end. Thus, a modem is needed to provide a bandpass signal that is generated by some sort of modulation technique, such as QAM. That is, the baseband line-code waveform is modulated onto a carrier. This produces a bandpass signal with a spectrum that falls within the bandpass of the VF telephone line.

8-9 $P_{Tx} = 0.1\,W$, $f_c = 2\,GHz$, $3.28\,ft/meter$

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

$A = \pi r^2,\ \lambda = c/f$ $\qquad$ $10\log(363.4) = 25.6$

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

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

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

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

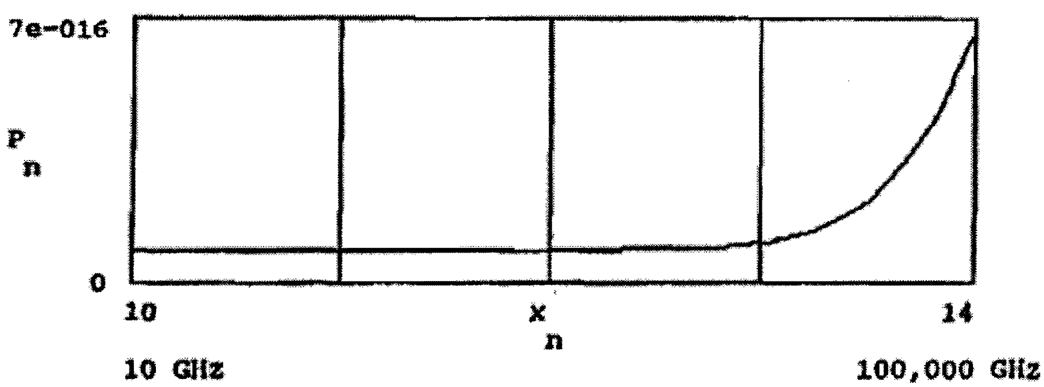
8-14

$n := 100\,..140$ $\qquad h := 6.6252\cdot10^{-34}$ $\qquad k := 1.381\cdot10^{-23}$

$T := 300$

$R := 10000$ $\qquad x_n := \frac{n}{10}$ $\qquad f_n := 10^{x_n}$

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



8-17

$$(P_a)_{in} = R_s\left(\frac{E_s}{2R_s}\right)^2 = \frac{E_s^2}{4R_s}, \quad (P_a)_{out} = \frac{V_{out}^2}{R_{out}} \quad \text{where } R_L = R$$

$$V_{out} = (h_{fe}\, i)\frac{R}{2} = \frac{h_{fe}}{2}\left(\frac{E_s}{R_s + h_{ie}}\right)R$$

$$i = E_s/(R_s + h_{ie}) \qquad R = 1/h_{oe}$$

$$\Rightarrow (P_a)_{out} = \frac{\left(\frac{h_{fe}}{2}\right)^2\left(\frac{E_s}{R_s + h_{ie}}\right)^2 R^2}{R} = \left(\frac{h_{fe}}{2}\right)^2\left(\frac{E_s}{R_s + h_{ie}}\right)^2\left(\frac{1}{h_{oe}}\right)$$

$$\Rightarrow G_a = \frac{(P_a)_{out}}{(P_a)_{in}} = \frac{\frac{1}{4}h_{fe}^2\frac{1}{h_{oe}}\left(\frac{1}{R_s + h_{ie}}\right)^2 E_s^2}{\frac{1}{4}E_s^2/R_s}$$

$$\Rightarrow \underline{\underline{G_a = \frac{h_{fe}^2 R_s}{h_{oe}(R_s + h_{ie})^2}}}$$

8-21 (a.)

$$T_{eff} = T_0(F-1)$$
$$= 290(10^{.16} - 1) = \underline{\underline{129^\circ}}\,K$$

(b.)

$$P_{a_{out}} = k\, T_{in}\, B\, G_a$$
$$= (1.38 \times 10^{-23})(30^\circ + 129^\circ)(10 \times 10^6)(10^3)$$
$$= \underline{\underline{2.2 \times 10^{-11}\ W}}$$
$$= 10\log_{10}\left(\frac{2.2 \times 10^{-11}}{10^{-3}}\right) = \underline{\underline{-76.6\ dBm}}$$

8-23

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

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

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

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

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

$$\frac{E_b}{N_{total}} = \frac{P_s T}{N_{total}} = \frac{P_s}{N_{tot} R} = \frac{V_s^2/R_n}{kFT_0 R} = 28.53$$

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

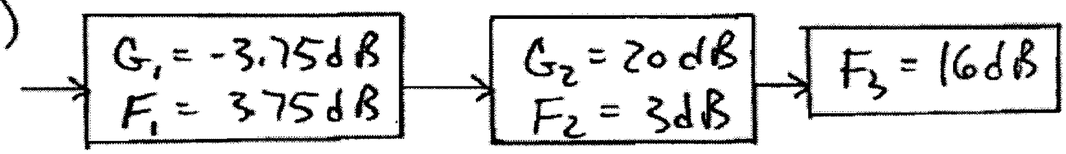
8-26 (a.) $F = F_1 + \dfrac{F_2 - 1}{G_1}$

$$F_1 = 125\,ft\left(\frac{3\,dB}{100\,ft}\right) = 3.75\,dB = 10^{.375} = 2.37$$

$$F = 2.37 + \frac{10^{1.6} - 1}{1/2.37} = \underline{\underline{94.4}} \implies \underline{\underline{19.8\,dB}}$$

8-26 Cont'd.

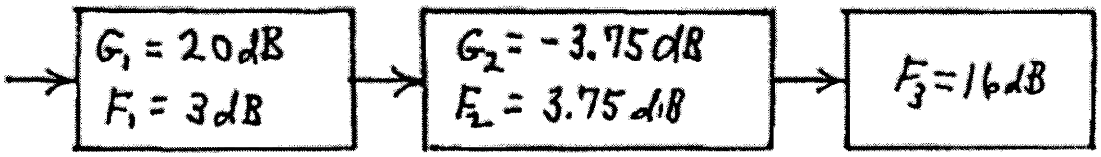
(b)



$$F = F_1 + \frac{F_2 - 1}{G_1} + \frac{F_3 - 1}{G_1 G_2}$$

$$= 2.37 + \frac{(10^{.3} - 1)}{1/2.37} + \frac{(10^{1.6} - 1)}{10^2/2.37}$$

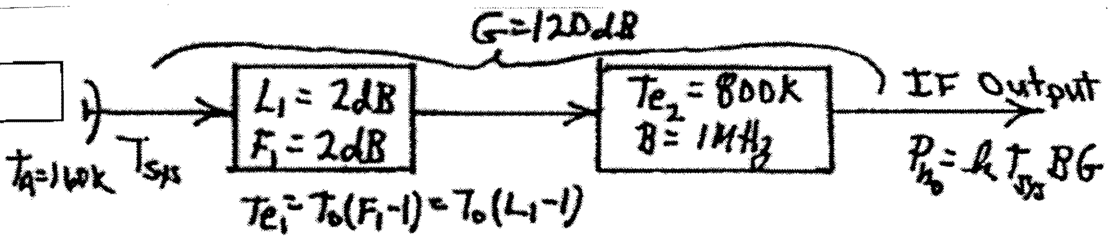
$$= 2.37 + 2.36 + 0.92 = \underline{\underline{5.65}} \Rightarrow \underline{\underline{7.52\text{ dB}}}$$



$$F = 2 + \frac{2.37 - 1}{100} + \frac{10^{1.6} - 1}{\frac{100}{2.37}}$$

$$\Rightarrow F = 2 + 0.0137 + 0.92 = \underline{\underline{2.93}} = \underline{\underline{4.67\text{ dB}}}$$

8-30



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

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

8-30 Cont'd.

(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 :

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

(c) The available output noise power Pno:

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

8-32 Assume 4 GHz down link

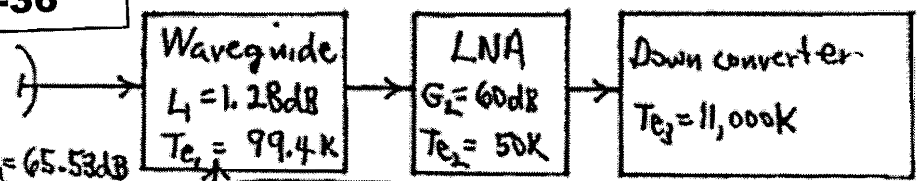
$$\frac{G_{AR}}{T_{sys}} = 10^4 = \frac{4\pi\eta\left[\pi(15)^2\right]}{85\left(3\times10^8/4\times10^9\right)^2} = 1.86\times10^4\eta$$

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

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

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

8-36



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

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

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

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

$G_s = G_{AR}$

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

$G_s = G_{AR} G_1 G_2 = \frac{G_{AR} G_2}{L_1}$

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

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

(a.)

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

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

(b.)

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

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

(c.)

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

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

8-38

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

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

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

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

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

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

parabolic

$$\Rightarrow A = 129.44\,m^2 = \pi r^2$$

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

8-42 Using (8-47) and (8-8)

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

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

$$= 40 + 18 - \underbrace{20\log\left(\frac{4\pi(0.25\,\text{miles})(5280\,\text{ft/mi})\left(\frac{1\,\text{m}}{3.28\,\text{ft}}\right)}{3\times10^8/1.8\times10^9}\right)}_{\to 89.64} + 0$$

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

	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

8-46 First determine the value of K by using the average power reading:

$s(t) = m(t)\cos\omega_c t$; $m(t)$ shown in figure P8-46

$$S_{rms}^2 = \frac{1}{2}\langle m^2(t)\rangle$$

$$= \frac{1}{2T}\int_0^T m^2(t)\,dt$$

$$\left\{\begin{array}{l} T = 63.5\,\mu\text{sec} \\ 0.835\,T = 53\,\mu\text{sec} \\ 0.165\,T = 10.5\,\mu\text{sec} \\ .075\,T = 4.76\,\mu\text{sec} \end{array}\right.$$

$$= \frac{1}{2T}\left[(0.75k)^2(0.165T - 0.075T) + k^2(0.075T) + (0.5k)^2(0.835T)\right]$$

8-46 Cont'd.

$$= \frac{K^2}{2}\left[(.75)^2(.09) + 1(.075) + (.5)^2(.835)\right]$$

$$= \frac{K^2}{2}\left[.0506 + .075 + .2087\right] = \frac{K^2}{2}(.3343)$$

$$\Rightarrow S_{rms}^2 = 0.1672\,K^2$$

$$P_{AV} = 6.9\times10^3 = \frac{.1672K^2}{50} = \frac{S_{rms}^2}{50}$$

$$\Rightarrow K = \sqrt{\frac{50(6.9\times10^3)}{.1672}} = 1436.6$$

$$P_{PEP} = \frac{V_{max}^2}{2(50)} = \frac{K^2}{100} = \frac{(1436.6)^2}{100} = \underline{\underline{20.64\text{ kW}}}$$

8-49

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

$$\Rightarrow R_{with\,Coding} = 32.20\text{ Mb/s}$$

$$\Rightarrow D_{with\,coding} = \frac{R_{with\,coding}}{\ell} = \frac{32.2}{3} = 10.73\text{ Mbaud}$$

($\ell = 3$ 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,

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