Problem Solutions for Chapter 12

12-1. We need to evaluate P_{in} using Eq. (12-11). Here $F_c = 0.20$,

$C_T = 0.05$, $F_i = 0.10$, $P_0 = 0.5$ mW, and $A_0 = e^{-2.3(3)/10} = 0.933$

Values of P_{in} as a function of N are given in the table below. P_{in} in

dBm is found from the relationship $P_{in}(\text{dBm}) = 10 \log \frac{P_{in}(\text{mW})}{1 \text{ mW}}$

N	P_{in}(nW)	P_{in}(dBm)		N	P_{in}(nW)	P_{in}(dBm)
2	387	-34.1		8	5.0	-53.0
3	188	-37.3		9	2.4	-56.2
4	91	-40.4		10	1.2	-59.2
5	44.2	-43.5		11	0.6	-62.2
6	21.4	-46.7		12	0.3	-65.5
7	10.4	-49.8				

(b) Using the values in the above table, the operating margin for 8 stations is

-53 dBm - (-58 dBm) = 5 dB

(c) To have a 6-dB power margin, we can transmit over at most seven stations.

The dynamic range with N = 7 is found from Eq. (12-13):

$$DR = -10(N-2)\ \log\ \left[.933(.8)^2(.95)^2(.9)\right] = -50\ \log\ (0.485) = 15.7\ \text{dBm}$$

12-2. (a) Including a power margin, we have from Eq. (12-16)

$$P_S - P_R - \text{power margin} = L_{excess} + \alpha(2L) + 2L_c + 10\log N$$

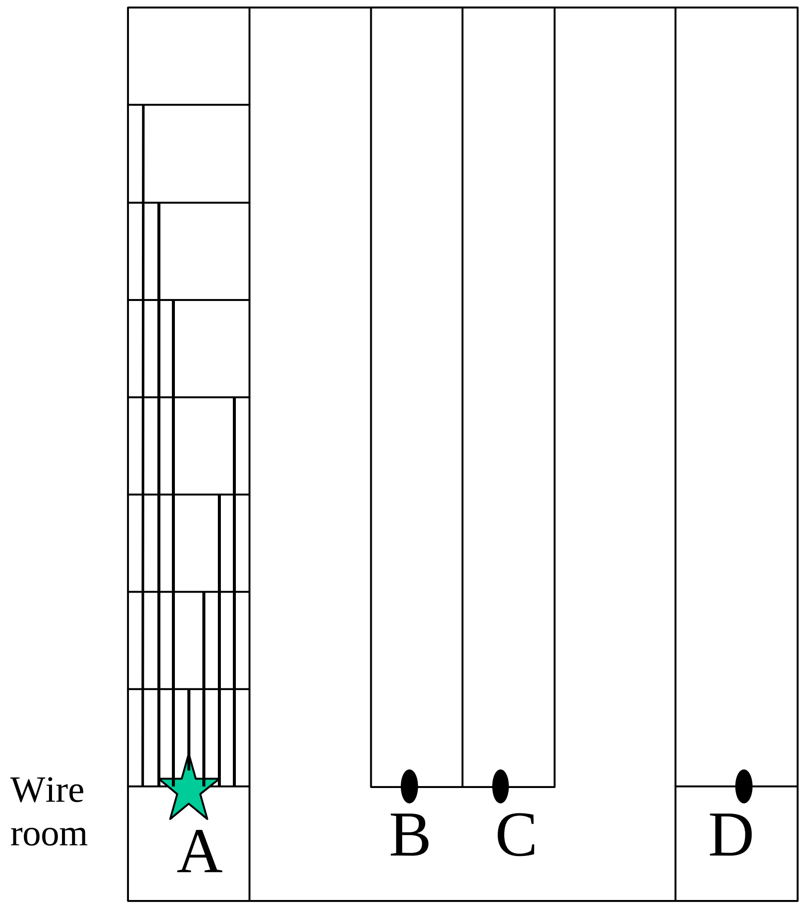
Thus

0 – (-38 dBm) – 6 dB = 3 dB + (0.3 dB/km)2(2 km) + 2(1.0 dB) + 10 log N

so that 10 log N = 25.8. This yields N = 380.1, so that 380 stations can be attached.

(b) For a receiver sensitivity of –32 dBm, one can attach 95 stations.

12-3. (b) Let the star coupler be located in the ceiling in the wire room, as shown in the figure below.



For any row we need seven wires running from the end of the row of offices to each individual office. Thus, in any row we need to have (1+2+3+4+5+6+7)x15 ft = 420 ft of optical fiber to connect the offices. From the wiring closet to the second row of offices (row B), we need 8(10 + 15) ft = 200 ft; from the wiring closet to the third row of offices (row C), we need 8(10 + 30) ft = 320 ft; and from the wiring closet to the fourth row of offices (row D), we need 8(20 + 45) ft = 520 ft of cable. For the 28 offices we also need 28x7 ft = 196 ft for wall risers.

Therefore for each floor we have the following cable needs:

(1) 4 x 420 ft for row runs

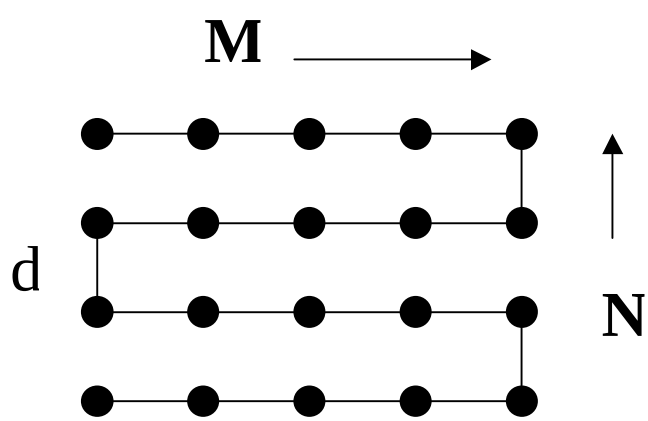
(2) 200 + 320 + 520 ft = 1040 for row connections

(3) 196 ft for wall risers

Thus, the total per floor = 2916 ft

<u>Total cable in the building</u>: 2x9 ft risers + 2916 ft x 2 floors = 5850 ft

12-4. Consider the following figure:



(a) For a bus configuration:

Cable length = N rows×(M-1)stations/row + (N-1) row interconnects

$$= N(M-1)d + (N-1)d = (MN-1)d$$

(b) The ring is similar to the bus, except that we need to close the loop with one cable of length d. Therefore the cable length = MNd

(c) In this problem we consider the case where we need individual cables run from the star to each station. Then the cable length is

L = cables run along the M vertical rows + cables run along the N horizontal rows:

$$= \; Md\sum_{i=1}^{N-1} i + Nd\sum_{j=1}^{M-1} j = \; M\,\frac{N(N-1)}{2}d + N\,\frac{M(M-1)}{2}d \; = \; \frac{MN}{2}(M+N-2)d$$

12-5. (a) Let the star be located at the relative position (m,n). Then

$$L = \left[N\sum_{j=1}^{m-1} j + N\sum_{j=1}^{M-m} j + M\sum_{i=1}^{n-1} i + M\sum_{i=1}^{N-n} i\right]d$$

$$= \left\{N\left[\frac{m(m-1)}{2} + \frac{(M-m)(M-m+1)}{2}\right] + M\left[\frac{n(n-1)}{2} + \frac{(N-n)(N-n+1)}{2}\right]\right\}d$$

$$= \left[\frac{MN}{2}(M+N+2) - Nm(M-m+1) - Mn(N-n+1)\right]d$$

(b) When the star coupler is located in one corner of the grid, then

m = n= 1, so that the expression in (a) becomes

$$L = \left[\frac{MN}{2}(M+N+2) - NM - MN\right]d = \frac{MN}{2}(M+N-2)d$$

(c) To find the shortest distance, we differentiate the expression for L given in (a) with respect to m and n, and set the result equal to zero:

$$\frac{dL}{dm} = N(m - 1 - M) + Nm = 0 \qquad \text{so that} \quad m = \frac{M+1}{2}$$

Similarly

$$\frac{dL}{dn} = M(n - 1 - N) + nM = 0 \qquad \text{yields} \quad n = \frac{N+1}{2}$$

Thus for the shortest cable runs the star should be located in the center of the grid.

12-6. (a) For a star network, one cannot reuse wavelengths. Thus, since each node must be connected to N – 1 other nodes through a central point, we need N – 1 wavelengths.

For a bus network, these equations can easily be verified by drawing sample diagrams with several even or odd stations.

For a ring network, each node must be connected to N – 1 other nodes. Without wavelength reuse one thus needs N(N – 1) wavelengths. However, since each wavelength can be used twice in the network, the number of wavelengths needed is N(N-1)/2.

12-7. From Tables 12-4 and 12-5, we have the following:

OC-48 output for 40-km links: –5 to 0 dBm; α = 0.5 dB/km; P_R = -18 dBm

OC-48 output for 80-km links: –2 to +3 dBm; α = 0.3 dB/km; P_R = -27 dBm

The margin is found from: $\text{Margin} = (P_s - P_R) - \alpha L - 2L_c$

(a) Minimum power at 40 km:

Margin = [-2 – (-27)] – 0.5(40) –2(1.5) = +2 dB

(b) Maximum power at 40 km:

Margin = [0 – (-27)] – 0.5(40) –2(1.5) = +4 dB

(c) Minimum power at 80 km:

Margin = [-2 – (-27)] – 0.3(80) –2(1.5) = -2 dB

(d) Maximum power at 80 km:

Margin = [3 – (-27)] – 0.3(80) –2(1.5) = +3 dB

12-8. Expanding Table 12-6:

# of λs	P_1(dBm)	$P = 10^{P_1/10}$ (mW)	P_{total}(mW)	P_{total}(dBm)
1	17	50	50	17
2	14	25	50	17
3	12.2	16.6	49.8	17
4	11	12.6	50.4	17
5	10	10	50	17

6	9.2	8.3	49.9	17
7	8.5	7.1	49.6	17
8	8.0	6.3	50.4	17

12-9. See Figure 20 of ANSI T1.105.01-95.

12-10. See Figure 21 of ANSI T1.105.01-95.

12-11. The following wavelengths can be added and dropped at the three other nodes:

Node 2: add/drop wavelengths 3, 5, and 6

Node 3: add/drop wavelengths 1, 2, and 3

Node 4: add/drop wavelengths 1, 4, and 5

12-12. (b) From Eq. (12-18) we have

$$N_{\lambda} = kp^{k+1} = 2(3)^3 = 54$$

(c) From Eq. (12-20) we have

$$\overline{H} = \frac{2(3)^2(3-1)(6-1) - 4(3^2-1)}{2(3-1)[2(3^2)-1]} = 2.17$$

(d) From Eq. (12-21) we have

$$C = \frac{2(3)^3}{2.17} = 8.27$$

12-13. See Hluchyj and Karol, Ref. 25, Fig. 6, p. 1391 (*Journal of Lightwave Technology*, Oct. 1991).

12-14. From Ref. 25:

In general, for a (p,k) ShuffleNet, the following spanning tree for assigning fixed routes to packets generated by any given user can be obtained:

h	**Number of users h hops away from the source**
1	p

2	p^2
.	
.	
.	
k – 1	p^{k-1}
k	$P^k - 1$
k + 1	$P^k - p$
k + 2	$P^k - p^2$
.	
.	
.	
2k – 1	$P^k - p^{k-1}$

Summing these up results in Eq. (12-20).

12-15. See Li and Lee (Ref 40) for details.

12-16. The following is one possible solution:

(a) Wavelength 1 for path A-1-2-5-6-F

(b) Wavelength 1 for path B-2-3-C

(c) Wavelength 2 for the partial path B-2-5 and Wavelength 1 for path 5-6-F

(d) Wavelength 2 for path G-7-8-5-6-F

(e) Wavelength 2 for the partial path A-1-4 and Wavelength 1 for path 4-7-G

12-17. See Figure 4 of Barry and Humblet (Ref. 42).

12-18. See Shibata, Braun, and Waarts (Ref. 67).

(a) The following nine 3rd-order waves are generated due to FWM:

$\nu 113 = 2(\nu 2 - \Delta\nu) - (\nu 2 + \Delta\nu) = \nu 2 - 3\Delta\nu$

$\nu 112 = 2(\nu 2 - \Delta\nu) - \nu 2 = \nu 2 - 2\Delta\nu$

$\nu 123 = (\nu 2 - \Delta\nu) + \nu 2 - (\nu 2 + \Delta\nu) = \nu 2 - 2\Delta\nu$

$\nu 223 = 2\nu 2 - (\nu 2 + \Delta\nu) = \nu 2 - \Delta\nu = \nu 1$

$\nu 132 = (\nu 2 - \Delta\nu) + (\nu 2 + \Delta\nu) - \nu 2 = \nu 2$

$\nu 221 = 2\nu 2 - (\nu 2 - \Delta\nu) = \nu 2 + \Delta\nu = \nu 3$

$\nu 231 = \nu 2 + (\nu 2 + \Delta\nu) - (\nu 2 - \Delta\nu) = \nu 2 + 2\Delta\nu$

$\nu 331 = 2(\nu 2 + \Delta\nu) - (\nu 2 - \Delta\nu) = \nu 2 + 3\Delta\nu$

$\nu 332 = 2(\nu 2 + \Delta\nu) - \nu 2 = \nu 2 + 2\Delta\nu$

(b) In this case the nine 3rd-order waves are:

$\nu 113 = 2(\nu 2 - \Delta\nu) - (\nu 2 + 1.5\Delta\nu) = \nu 2 - 1.5\Delta\nu$

$\nu 112 = 2(\nu 2 - \Delta\nu) - \nu 2 = \nu 2 - 2\Delta\nu$

$\nu 123 = (\nu 2 - \Delta\nu) + \nu 2 - (\nu 2 + 1.5\Delta\nu) = \nu 2 - 2.5\Delta\nu$

$\nu 223 = 2\nu 2 - (\nu 2 + 1.5\Delta\nu) = \nu 2 - 1.5\Delta\nu$

$\nu 132 = (\nu 2 - \Delta\nu) + (\nu 2 + 1.5\Delta\nu) - \nu 2 = \nu 2 + 0.5\Delta\nu$

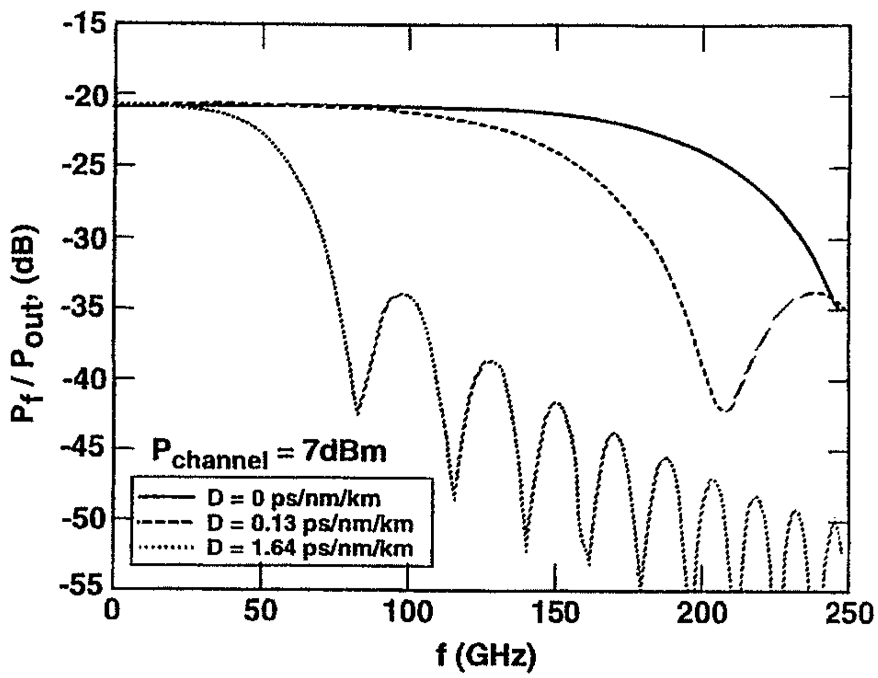
$\nu 221 = 2\nu 2 - (\nu 2 - \Delta\nu) = \nu 2 + \Delta\nu$

$\nu 231 = \nu 2 + (\nu 2 + 1.5\Delta\nu) - (\nu 2 - \Delta\nu) = \nu 2 + 2.5\Delta\nu$

$\nu 331 = 2(\nu 2 + 1.5\Delta\nu) - (\nu 2 - \Delta\nu) = \nu 2 + 4\Delta\nu$

$\nu 332 = 2(\nu 2 + 1.5\Delta\nu) - \nu 2 = \nu 2 + 3\Delta\nu$

12-19. Plot: from Figure 2 of Y. Jaouën, J-M. P. Delavaux, and D. Barbier, "Repeaterless bidirectional 4x2.5-Gb/s WDM fiber transmission experiment," Optical Fiber Technology, vol. 3, p. 239-245, July 1997.



12-20. (a) From Eq. (12-50) the peak power is

$$P_{peak} = \left(\frac{1.7627}{2\pi}\right)^2 \frac{A_{eff}\lambda^3}{n_2 c} \frac{D}{T_s^2} = 11.0 \text{ mW}$$

(b) From Eq. (12-49) the dispersion length is

L_{disp} = 43 km

(c) From Eq. (12-51) the soliton period is

$$L_{period} = \frac{\pi}{2} L_{disp} = 67.5 \text{ km}$$

(d) From Eq. (12-50) the peak power for 30-ps pulses is

$$P_{peak} = \left(\frac{1.7627}{2\pi}\right)^2 \frac{A_{eff}\lambda^3}{n_2 c} \frac{D}{T_s^2} = 3.1 \text{ mW}$$

12-21. Soliton system design.

12-22. Soliton system cost model.

12-23. (a) From the given equation, L_{coll} = 80 km.

(b) From the given condition, $L_{amp} \le \frac{1}{2} L_{coll} = 40 \text{ km}$

12-24. From the equation and conditions given in Prob. 12-23, we have that

$$\Delta\lambda_{max} = \frac{T_s}{DL_{amp}} = \frac{20 \text{ ps}}{[0.4 \text{ ps/(nm}\cdot\text{km)}](25 \text{ km})} = 2 \text{ nm}$$

Thus 2.0/0.4 = 5 wavelength channels can be accommodated.

12-25 Plot from Figure 3 of Ref. 103.

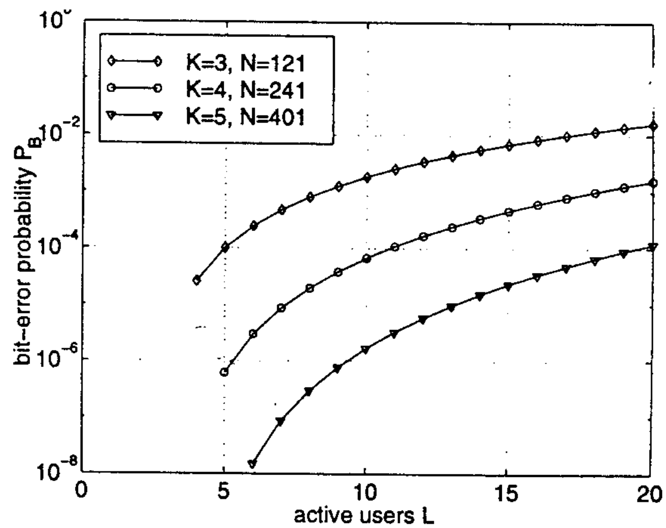


Fig. 3. BER vs. active users for different K, $M = 20$