Book Problem Solutions

Chapter 3 problem solutions

3.4:
Simplex channel = 25kHz => Duplex channel = 50kHz
So 20MHz/50kHz = 400 channels.
If N=4, using omnidirectional antennas => 400/4 = 100 channels per cell site

3.5:
We must compute Q^n/i_0 for each case with $Q=(3N)^{1/2}$ and n=4. This simplifies to $(3N)^2/i_0$. The 15 db criteria means we need $(3N)^2/i_0 > 31.62$

a) For omnidirectional, i_0 =6, so solving for N we get N>4.5 => N=7
b) For 3 sectored, we check N=4 and N=3 (N>=7 will work but we want the smallest N)
   For N=4: i_0=2, so $(3N)^2/i_0$= 144/2=72 >31.62. so N=4 will work with 3 sectors
   For N=3: i_0=3, so $(3N)^2/i_0$= 81/3=27 <31.62. so N=3 will NOT work with 3 sectors.
   So N=4 with 3 sectors is the answer
c) For 6 sectors we only need to check N=3 (since N>=4 will work)
   For N=3 and i_0=2 (for N=3 or 12 or when i-j we must be careful of i_0)
   So $(3N)^2/i_0$= 81/2=40.5 >31.62. so N=3 WILL work with 6 sectors….. theoretically…..

NOTE: as for which one is the best, you would need to check which provided the highest capacity per basestation. This is tricky. For a large number of channels (e.g. 108 total) you get:
N=7 => 15 ch/bstn => 8.1E per bstn
N=4 with 3 sectors => 27ch/bstn => 9 ch/sector => 3.75E/sector=> 11.25E/bstn
N=3 with 6 sectors => 36ch/bstn => 6 ch/sector =>1.9E/sector => 11.4E/bstn
So N=3 wins…. But just barely and (it turns out) not if there are fewer channels (e.g. try 64 ch).

3.8:
As above with n=3 we need $(3N)^{1.5}/i_0 > 31.62$:

a) i_0 =6, so N>11.006 => N=12
b) i_0 =2, so N> 5.29 => N=7
c) i_0 =1, so N> 3.33 => N=4

Now it makes more sense to use 60 degree sectoring (i.e. six sector cells) since we get a better value for N.

3.10:
Duplex channel = 60kHz so 24MHz/60kHz = 400 channels. Au=0.1 E.

a) 400/4=100 per cell. Assuming old style AMPS/DAMPS we need 1 cntl channel per cell so that leave 99 tch per cell.
b) Perfect scheduling would be 99 circuits in use on each cell. 90% of that means 89.1 circuits in use so we have 99 channels serving 89.1E of users. Now if Au=.1E this means we can serve 891 users per cell
c) From the chart I gave in class 99 channels gives ~89.1E with GOS =0.03. or 3% blocking probability (roughly)

d) With 120 degree sectoring, we get 33 channels per cell/sector on two sectors and 34 on the third for each basestation. So we have 32 TCH and one CNTL per sector for two sectors and 33 TCH one CNTL for the third on each basestation. So from the Erlang B chart: for 32 TCH channels at a 0.03 GOS we get 24.9E or 249 users and for 33 channels at 0.03 GOS we get 25.8E or 258 users. This give a total of 756 users that each basestation can support.

e) 50x50 = 2500square km so if each basestation covers 5square km, this give 500 basestations. So in the omnidirectional case we can serve 500*891 = 445500 customers

f) 500*756 = 378000 customers.

3.11:

I am interpreting 57 channels as meaning 57 channels per cell/basestation in the omnidirectional case (If all you have is 57 channels for a system, I'd quit now and take up knitting) I will also assume that (like AMPS) control channels are in a separate part of the spectrum and the 57 refers to traffic channels only. GOS=0.01 so in the omnidirectional case each cell can handle 44.22E. H=2min and λ =1/hr so Au= 1/30 = 0.0333 E. Thus each cell can handle 44.22/.0333 = 1326.6 users (on average). With 60 degree sectoring we get 3 sectors with 10 channels and 3 with 9.
10 channels => 4.46E => 133.8 users while 9channels => 3.78E =>113.4 So the total users declines to 741.6 with sectoring.

3.13:

300 traffic channels (we assume control channels are handled separately) with N=4 => 75 channels cell. 0.01 GOS => 60.73E per cell. Au=0.04E => 1518.25 users per cell. For 84 cells =>127533 total users on the system
N=7 => 43 channels per cell for 6 cells (one has 42). 0.01GOS => 31.66 (30.77 for one).
Au=0.04 => 791.5 (769.25) => 66219 users on the system
N=12 => 25 channels per cell. 0.01 GOS => 16.125 E per cell. Au=0.04 => 403.125 users per cell => 33862.5 users on the system.

3.15 is not a good problem.

3.16:

We use $P/P_0 = (d/d_0)^{-n}$ where P_0 = 1 mW, d_0 = 1m, n=3, and P=-100dBm = 10^{-10}mw. So we get $10^{10} = d^3$ => d= $10^{3.333}$ = 2154.4 m =2.1544km. Now the ratio between the distance between cells and the major cell radius D/R = Q=$(3N)^{1/2}$. So: R = 2.1544 / $(3N)^{1/2}$ km so
N=7 => R = ~470 m
N=4 => R = ~622m

Chapter 4 problem solutions

4.1

Linear version:

Pr = Pt (λ/(4πd))^2 GtGr. λ=(300m/μs)/900MHz=0.333m d=1000m. Gt=Gr=1

So: Pr = 10 (0.333/4000π)^2 =7.022x10^{-9} W

Decibel version:

Pr = Pt +Gt +Gr –FSL. Pt=40 dBm, FSL=20log(900) + 20log(1) + 32.45 =91.53

So Pr = 40 – 91.53 = -51.53 = 7.023x10^{-6}mw=7.023x10^{-9}W

4.3

The gain of an antenna is given by G = Aη4π/(λ^2) where Aη is the effective aperture (as I mentioned briefly when deriving the FSL equations). A is the area and η is the efficiency (usually between .4 and .8) For the sake of this problem we can guess that η= ~0.5

f=60GHz so λ=(0.3m/ns)/60GHz = 0.005m.

This gives G = (0.046*0.035)*0.5*4* π /(0.005)^2=404.637= ~26 dB. Forget the HPBW.

For the Fraunhoffer distance: the largest dimension of the antenna is 0.046m.

So 2D^2/λ = 2(0.046)^2/(0.005) = 0.846m =84.6 cm

4.4

1W = 30 dBm. Given the gain is 26 db (above), EIRP = 56dBm.

FSL = 20log(d_{km}) +20log(60000) + 32.45. RSL = EIRP – FSL + Gr =82 - FSL

So:

d=1m= 0.001km: FSL= 20log(0.001)+20log(60000) +32.45 = 68.01 RSL= 82 - 68=14dBm

d=100m=0.1km: FSL = 20log(0.1)+20log(60000) +32.45 = 108.01 RSL = 82 – 108= -26 dBm

d=1000m=1km: FSL = 20log(1)+20log(60000) +32.45 = 128.01 RSL = 82 – 128= -46 dBm

4.14:

50W =47 dBm. Gt=0dB, Gr= 3dB. f=1900MHz. d=10km.

FSL = 20log(10)+20log(1900)+32.45=118.03dB.

a) Pr= Pt + Gt –FSL + Gr = 47 +0 -118 +3 = -68dBm
d) FEL = 40log(10000) – 20log(50) – 20log(1.5) = 130.46 so
   Pr= Pt + Gt – FEL +Gr = 47 – 130.46 +3 = - 80.46 dBm

4.19:

Pt=10W=40dBm. Gt=10dB, Gr=3dB, L=1dB. So EIRP = 49dB and RSL = EIRP – PL + Gr (normally I take Gr to be zero for the usual cellular situation. However in this case, they are assuming a car with a whip antenna, which will give an extra 3dB gain…).

f=900MHz so λ=.3333

We will do this backwards: Total distance= 5 km. So:

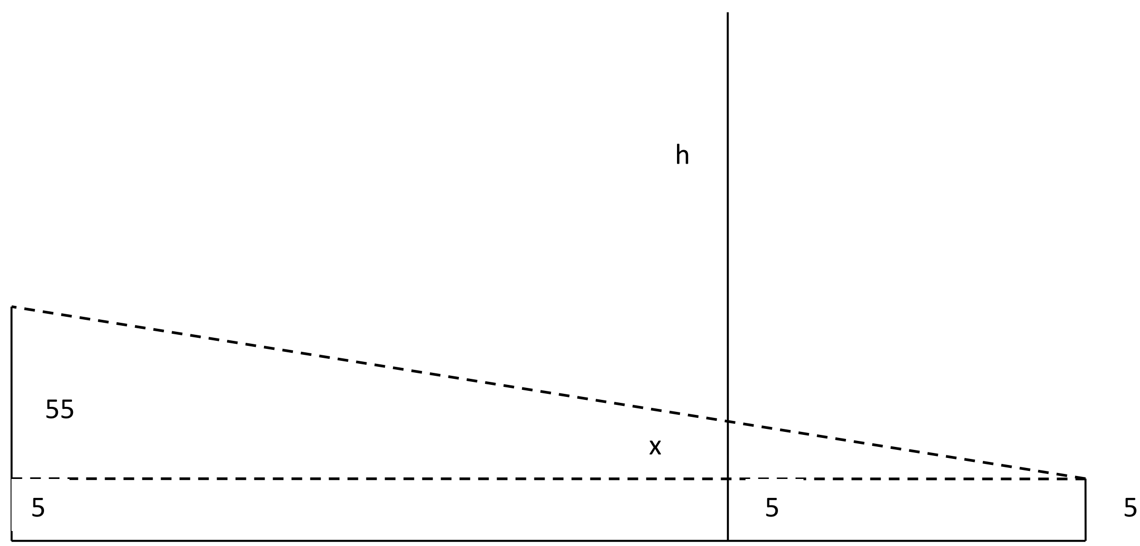
FSL = 20log(900)+ 20log(5)+32.45=105.51 dB

So, RSL without diffraction = 49 – 105.51 + 3 = - 53.51dBm

For diffraction, we do the usual geometry stunt and get

400 = 5 + x + h

where 5 is the height of the mobile, h is the height of the obstruction above line of sight, and x is given by 55/5 = x/2. So x = 22m and h =373m See the drawing below



Now $\nu = h\,[\,2(5000)/(\lambda(2000)(3000))\,]^{1/2} = 373\,(1/200)^{1/2} = 26.375$

Using 4.61e we get

Gd = 20log(0.225/ν)= -41.38 dB

So RSL with diffraction = -53.51 – 41.38 = -94.89 dBm

4.20: We use the same equations:

a) f=50MHz => λ=6m FSL = 20log(50)+ 20log(5) +32.45 = 80.41dB
   RSL without diffraction = 49 – 80.41 +3 = -28.41 dBm
   ν= 373[2(5000)/(6(2000)(3000)) $]^{1/2}$= 6.2167
   Gd=20log(0.225/ν)= -28.83 dB
   RSL with diffraction = -28.41 -28.83 = -57.24 dBm

b) f=1900MHz => λ=0.15789m FSL=20log(1900)+20log(5)+32.45=112 dB
   RSL without diffraction = 49 – 112 +3 = -60 dBm
   ν= 373[2(5000)/((0.15789)(2000)(3000)) $]^{1/2}$= 38.3221
   Gd=20log(0.225/ν)= -44.63 dB
   RSL with diffraction = -60 – 44.63 = -104.63 dBm

4.23:

This is a challenging (and confusing) exercise in using $P/P_0 = (d/d_0)^{-n}$ where P_0= 1µW, d_0 = 1km and d=2, 5, 10, and 20 km. The value of n varies with the model:

a) Free space => n=2
b) n=3
c) n=4
d) for the approximate equation for FEL, n=4 as well
e) n will be the coefficient of the log(d) term (divided by 10) =
   [44.9- 6.55log(h)]/10 = 4.49 -.655log(40) = 3.44

P for d=	2km	5km	10km	20km
a) n=2	0.25 µW	0.04 µW	10nW	2.5nW
b) n=3	0.125 µW	8nW	1nW	0.125nW
c) n=4	62.5nW	1.6nW	0.1nW	6.25pW
d) FEL	62.5nW	1.6nW	0.1nW	6.25pW
e) N=3.44	92.1nW	3.94nW	0.363nW	33.45pW

Chapter 5 problem solutions

5.1:
The Doppler shift is given by $f_d = (v/\lambda)\cos(\theta)$. The maximum will be when cos = +1 and the minimum will be at cos = -1 so we need only compute $f_m = v/\lambda$ and then add and subtract. We must be careful of the units, however: 1km/hr = 0.2778 m/s . Also: $\lambda = 3\times10^8/1.95\times10^9$ =0.1538m and watch the significant digits:

a) 1km/hr = 0.2778 m/s => fm = 1.8056 Hz => maxf = 1950.000002MHz minf = 1949.999998MHz
b) 5km/hr = 1.3889 m/s => fm = 9.0278 Hz => maxf = 1950.000009MHz minf = 1949.999991MHz
c) 100km/hr = 27.78 m/s => fm = 180.56 Hz => maxf = 1950.000181MHz minf = 1949.999819MHz
d) 1000km/hr = 277.8 m/s => fm = 1805.6 Hz => maxf = 1950.001806MHz minf = 1949.998179MHz

5.8:
For P5.6a:
We have 4 components so

$\overline{\tau}$ = [0(1) + 50(1) +75(.1) +100(.01)]/[1+1+.1+.01]=58.5/2.11 = 27.725 ns

$\overline{\tau^2}$ =[0(1) + 50^2(1) + 75^2(.1) + 100^2(.01)]/2.11 = 3162.5/2.11=1498.915 ns^2

$\sigma = (\overline{\tau^2} - (\overline{\tau})^2)^{1/2} = (1498.915 – 768.682)^{1/2}$= 27.02 ns

So for 90% Bc = 1/(50*27.02) = 7.4×10^{-4} GHz = 740KHz (NB: t in ns => f in GHz)
For 50% Bc = 1/(5*27.02) = 7.4×10^{-3} GHz = 7.4 MHz

For P5.6b:
We have 3 components:

$\overline{\tau}$ = [0(.01) + 5(.1) +10(1)]/[1 +.1+.01]=10.5/1.11 = 9.459 μs

$\overline{\tau^2}$ =[0(.01) + 5^2(.1) + 10^2(1)]/1.11 = 102.5/1.11=92.3423 μs^2

$\sigma = (\overline{\tau^2} - (\overline{\tau})^2)^{1/2} = (92.3423 – 89.4814)^{1/2}$= 1.691 μs

So for 90% Bc = 1/(50*1.691) = .0118 MHz = 11.8KHz
For 50% Bc = 1/(5*1.691) = .118 MHz = 118KHz

5.9:
Binary modulated 25kbps signal => bit duration T = 1/25000 = 40 μs
To run without an equalizer, we need to be in a flat fading environment, which means we need $\sigma \ll T$ = 40 μs The book uses a rule of thumb which says “<<” is about a factor of 10 so they get a max σ of about 4 μs
For 8PSK modulated at 75kbps we get 3 bits in every symbol. Thus the symbol rate is 25ksps so T is again 40 μs so the answer is the same as above.

5.13:

f = 900MHz so λ=1/3 =0.333 m. We don't know v, but we can find it if we get the Doppler frequency from the afd. The afd = 1ms for a signal level (by which I assume they mean power level) of 10 dB below the rms level. So ρ = -5dB = .316

afd =($e^{\rho 2}$- 1)/[$\rho f_m(2\pi)^{1/2}$] = 1ms = 0.001 s

So f_m = ($e^{0.1}$ -1)/[$\rho(2\pi)^{1/2}$(0.001)] = 132.68 Hz

So v = f_m/λ = 44.23 m/s

So in 10s the vehicle travels 442.3 m

To find the number of fades we need the level crossing rate: N= $\rho f_m(2\pi)^{1/2}$ $e^{-\rho 2}$=95.16 or about 95

5.28:

a) $\overline{\tau}$ = [0(1) + 1(.1) +2(1)]/[1 +.1+1]=2.1/2.1 = 1 μs

$\overline{\tau^2}$ =[0(1) + 1^2(.1) + 2^2(1)]/2.1 = 4.1/2.1=1.9524 μs^2

σ= ($\overline{\tau^2}$ - ($\overline{\tau}$ $)^2)^{1/2}$ = (1.9524 - 1$)^{1/2}$= 0.9759 μs

b) all components are > 20db below so after 2 μs we get everything so $\tau_{max\ 20dB}$= 2 μs

c) So we require T > 10σ = 9.759 μs => Symbol rate < 1/(10σ) = 102.47 ksps

d) We must compute the coherence time so we need the maximum Doppler shift.
v = 30km/hr = 8.333 m/s, f = 900 MHz => λ=c/f = 1/3 m so f_m=v/ λ=8.333/.3333= 25Hz. Using the conservative value of Tc we get 7.16 ms. Using the practical value we get 16.92ms. So depending on what " highly correlated" means, you should get one of these values

5.29:

f = 6GHz => λ = 0.05 m. Since v = 80kph = 22.222 m/s, f_m=v/λ= 444.44 Hz

a) Zero crossings about the rms value => ρ =1 so the lcr = N = $\rho f_m(2\pi)^{1/2}$ $e^{-\rho 2}$ = 409.839 per second
So over 5 seconds you get 2049.19
b) Afd =($e^{\rho 2}$- 1)/[$\rho f_m(2\pi)^{1/2}$] = 1.54 ms (NB: so on average the signal spends about 63.2% of its time below the rms level. This is consistent with the Rayleigh fading model)
c) Again, I assume 20 dB is a power level estimation so ρ = 0.1
then afd =($e^{\rho 2}$- 1)/[$\rho f_m(2\pi)^{1/2}$] =90.2 μs

5.30:

We look at each scenario:

a) Urban environment => slow mobiles, e.g. v<30mph < 50kph < 14 m/s so f_m < 46.33 < 50Hz so even the conservative value of Tc is 3.58 ms. Data rate = 500kbps => Ts = 2 μs so the fading is definitely not fast. However, to pass a 500kbps signal, the channel would need a coherence bandwidth (using the 50% coherence) of 500kHz so σ< 0.4 μs. This is not likely in an urban fading environment (see , e.g. problem 5.28 or 5.8b above) Thus this should be frequency selective fading scenario.
b) For a highway environment v is much larger, so say v = 60mph so f may be 100Hz. Using the practical value give Tc = 4.23 ms (conservative gives 1.8ms). Data rate of 5kbps => Ts = 0.2 ms so the environment is still pretty slow (i.e. not a fast fading

environment). However a 5 kHz signal requires only that σ< 40 μs. This is a pretty easy requirement to meet for most channels. Thus this is likely to be a flat fading scenario.

c) At 10bps, Ts = 100ms. Tc is going to be much less than this (as describe in b and a above) so the environment is clearly fast fading. (the requirement on σ will be on the order of milliseconds so the environment will also be flat)

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