Chapter 3

1. A wireless receiver with an effective diameter of 250 cm is receiving signals at 20 GHz from a transmitter that transmits at a power of 30 mW and a gain of 30 dB.
   (a) What is the gain of the receiver antenna?
   (b) What is the received power if the receiver is 5 km away from the transmitter?

   [Solution]

   Given

   d_e = Effective diameter = 250 cm.

   f_c = Carrier frequency = 20 GHz.

   P_t = Transmitter power = 30 mW

   G_t = Transmitter gain = 30 dB = 1000.

   d = Distance of receiver = 5 km.

   A_e = Effective area = $(\frac{\pi d_e^2}{4})$ = 4.91 m^2

   λ = Wavelength = $\frac{c(speed - of - light)}{f_c}$ = 0.015 m

   (a) G_r = Receiver antenna gain $= \frac{4\pi A_e}{\lambda^2} = 2.74 * 10^5 = 54.38$ dB.

   (b) P_r = Received power at distance of 5 km $= \frac{A_e G_t P_t}{4\pi d^2} = 4.69 * 10^{-7}$ Watts.

4. The transmission power is 40 W, under a free-space propagation model,
   (a) What is the transmission power in unit of dBm?
   (b) The receiver is in a distance of 1000 m; what is the received power, assuming that the carrier frequency f_c = 900 MHz and $G_t = G_r$ = 1 dB?
   (c) Express the free space path loss in dB.

   [Solution]

   (a) $10 \times \log(40 \times 1000)$ = 46 dBm.

   (b)

$$Pr = \frac{G_t G_r P_t}{(\frac{4\pi d}{\lambda})^2}$$

$$= \frac{40 \times 1 \times 1 \times (\frac{1}{3})^2}{(4 \times \pi \times 1000)^2}$$

$$= 2.82 \times 10^{-8} \text{ W.}$$

(c) L_f(dB)=32.45+20log$_{10} f_c$+20log$_{10}d = 91.5349dB$

11. How is radio propagation on land different from that in free space?

[Solution]

Propagation in free space does not have any obstacles and hence it characterizes the most ideal situation for propagation. Whereas, radio propagation on land may take place close to obstacles which cause reflection, diffraction, scattering.

12. What is the difference between fast fading and slow fading?

[Solution]

Slow fading is caused by movement over distances large enough to produce gross variations in overall path length between base station and mobile station. In other words, the long term variation in the mean level is known as slow fading. Rapid fluctuations caused by local multipath are known as fast fading. It is short-term fading.

14. A BS has a 900 MHz transmitter and a vehicle is moving at the speed of 50 mph. Compute the received carrier frequency if the vehicle is moving

(a) Directly toward the BS.

(b) Directly away from the BS.

(c) In a direction which is 60 degree to the direction of arrival of the transmitted signal.

[Solution]

Given

f_c = Carrier frequency = 900 MHz

λ = Wavelength = $\dfrac{c}{f_c}$ = 0.3333 m

v = Velocity = 50 mph = 22.22 m/s.

Let Doppler shift frequency be denoted by f_d.

(a) θ = 180, (direction is towards BS.)

$$f_d = \frac{v}{\lambda}\cos\theta = -67.06$$

Received carrier frequency:

$$f_r = f_c - f_d = 900*10^6 + 67.06 = 900.000067*10^6 \text{ MHz.}$$

(b) θ = 0, (direction away from BS.)

$$f_d = \frac{v}{\lambda}\cos\theta = 67.06$$

Received carrier frequency:

$$f_r = f_c - f_d = 900*10^6 - 67.06 = 899.99993*10^6 \text{ MHz.}$$

(c) θ = 60, (direction is towards BS.)

$$f_d = \frac{v}{\lambda}\cos\theta = -33.53$$

Received carrier frequency:

$$f_r = f_c - f_d = 900*10^6 + 33.53 = 900.000033*10^{10} \text{ MHz.}$$

Chapter 5

3. Two adjacent BSs ***i*** and ***j*** are 30 kms apart. The signal strength received by the MS is given by the following expressions.

$$P(x) = \frac{G_t G_r P_t}{L(x)}$$

Where

$$L(x) = 69.55 + 26.16 \log_{10} f_c(\text{MHz}) - 13.82 \log_{10} h_b(\text{m}) - \alpha\,[hm(\text{m})]$$
$$+ [44.9 - 6.55 \log_{10} h_b(\text{m})] \log_{10}(x),$$

and ***x*** is the distance of the MS from BS ***i***. Assume unity gain for G_r and G_t, given that $P_i(t) = 10$ Watts, = 100 Watts, $f_c = 300$ MHz, $h_b = 40$ m, $h_m = 4$ m, $\alpha = 3.5$, $x = 1$ km, and $P_j(t)$ is the transmission power of BS *j*.

(a) What is the power transmitted by BS ***j***, so that the MS receives signals of equal strength at ***x***?

(b) If the threshold value $E = 1$ dB and the distance where handoff is likely to occur is 2 km from BS *j*, then what is the power transmitted by BS ***j*** ?

[Solution]

(a)Assume that the distance of the MS from base station ***i*** is ***x***. Since

$G_t = G_r = 1$. Since $G_R = G_T = 1$,

$$\frac{Pi}{L(x)} = \frac{Pj}{L(30-x)} \qquad (1)$$

$$P_i = 10 \log(10) = 10 \text{ dB}$$

By substituting data given in $L(x)$, we get

$$L(x) = 69.55 + 64.801 - 22.140 - 14 + 34.406 \log(x)$$
$$= 98.211$$

$$L(30-x) = 98.211 + 34.406 \log(30-x)$$
$$= 98.211 + 50.315$$
$$= 148.526$$

Substituting in Equation (1), we have

$$\frac{10}{98.211} = \frac{P_j}{148.526}$$

Solving for P_j , we get

$$P_j = 15.123 \text{ dB} = 32.512 \text{ Watts}$$

(b) Assume that the distance of the MS from the BS ***i*** is ***x***, and if E = 1 dB then the point of hand off will be when

$$P_m(i) + 1\text{dB} = P_m(j)$$

$$P_m(i) = 10 \log_{10} 10 = 10 \text{ dB}$$

Similar to (a), we get

$$L(\boldsymbol{x}) = 69.55 + 64.801- 22.140 – 14 + 34.406 \log_{10}(\boldsymbol{x})$$

$$= 98.211 + 34.406 \log_{10}(\boldsymbol{x})$$

$$= 98.211 + 34.406 \log_{10} 2$$

$$= 108.5682$$

$$L(30 – x) = 98.211 + 34.406 \log_{10}(30 – \boldsymbol{x})$$

$$= 98.211 + 34.406 \log_{10}(28)$$

$$= 148.0019.$$

Using Equation (1), we get

$$(10 + 1) * 148.0019 = 108.5682 * P_m(\boldsymbol{j})$$

Thus,

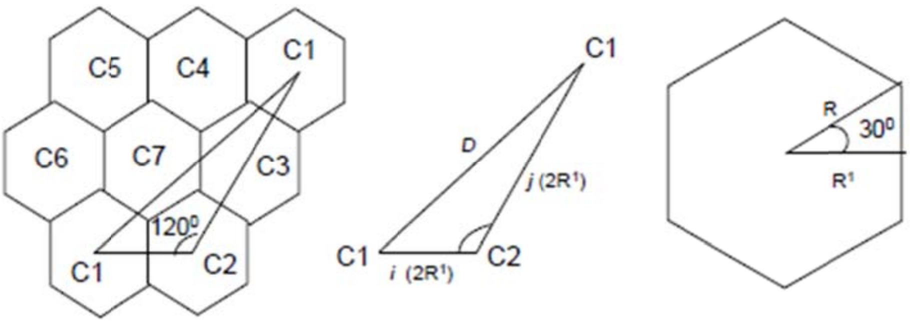
$$P_m(\boldsymbol{j}) = 14.995 \text{ dB} = 31.589 \text{ Watts.}$$

5. Prove that $D = R\sqrt{3N}$.

[Solution]

To prove that $D = R\sqrt{(3N)}$

Let R be the radius of the cell and D the reuse distance.



where *i* and *j* are the number of cells in the corresponding directions. In the figure as we traverse from C1-C2-C1, we .first move 1 cell in the *i* direction, from C1 to C2 and then 2cells in the *j* direction from C2 to C1.

We have

$$R^1 = R\cos 30 = \frac{\sqrt{3}}{2}R \qquad (2)$$

The distance D can be found using the cosine law,

$$D^2 = (i(2R^1))^2 + (j(2R^1))^2 - 2i(2R^1)j(2R^1)\cos 120$$
$$= (i^2 + j^2)(2R^1)^2 + ij(2R^1)^2$$
$$= (2R^1)^2(i^2 + j^2 + ij)$$
$$= (2R^1)^2(N),$$

where *N* is the number of cells in the cluster.

Using Equation (2) described above, we get

$$D^2 = 3NR^2 \Rightarrow D = \sqrt{3N}R.$$

9. For the following cell pattern,

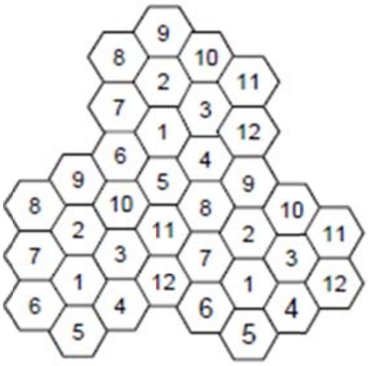


Figure for problem 5.9

(a) Find the reuse distance if radius of each cell is 2 kms.

(b) If each channel is multiplexed among 8 users, how many calls can be simultaneously processed by each cell if only 10 channels per cell are reserved for control, assuming a total bandwidth of 30 MHz is available and each simplex channel consists of 25 kHz ?

(c) If each user keeps a traffic channel busy for an average of 5% time and an average of 60 requests per hour are generated, what is the Erlang value ?

[Solution]

(a) $D = \sqrt{3N}R \Rightarrow D = 2*(3*12)^{0.5}$

The reuse distance = 12 kms

(b) One duplex channel = 2 (BW of one simplex channel) = 2 * 25 = 50 kHz

Number of channels = $(\frac{30*10^3}{50}) - 10*12 = 600 - 120 = 480$ channels

Number of channels per cell = $\frac{480}{12} = 40$ /cell

Total number of calls per cell = 8 * 40 = 320 calls/cell

(c) The request rate $\alpha = \frac{60}{3600} = \frac{1}{60}$ requests/second

Holding time = 5% = 0.05 * 3600 = 5 * 36 = 180 seconds

Therefore the offered traffic load in Erlangs is

α =request rate * holding time = $(\frac{1}{60})$ *180 = 3 Erlangs.

10. A TDMA-based system shown in the Figure, has a total bandwidth of 12.5 MHz and contains 20 control channels with equal channel spacing of 30 kHz. Here, the area of each cell is equal to 8 km^2, and cells are required to cover a total area of 3600 km^2. Calculate the following:

    (a)Number of traffic channels/cell

    (b)Reuse distance

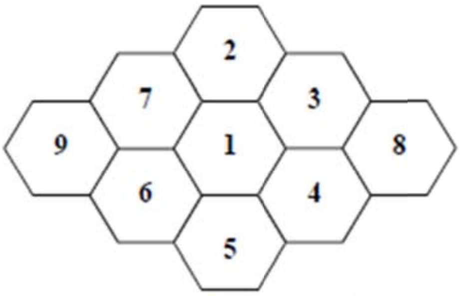


Figure of Problem 5.10.

[Solution]

(a)

$$\frac{\frac{12.5\times10^6}{30\times10^3}-20}{9} \approx 44 \text{ traffic channels/cell}$$

(b)

$$D = \sqrt{3N}R$$
$$= \sqrt{3\times9}\times1.75$$
$$= 9.12 \text{ Km}$$