1. A mobile phone user is making a call in a digital AMPS system. The cells are approximately 5 [km] in radius, and all of equal size. Assume a path loss model of \( r^{-2} \), an uplink carrier frequency of 830 [MHz], a transmit power (from the cell phone) of 1 [W], a reuse factor of 4, and that the user is at the extreme boundary of his current cell.

a) Assuming 10 [dB] antenna gains at both the cell phone and base station, estimate the average power of the signal received by the communicating base station.

b) Estimate the noise power (in the form of co-channel interference from users in the first tier of interfering cells) received by the communicating base station.

(a) This will be a direct application of the link equation:

First:

\[
\lambda = \frac{c}{f} = \frac{3 \times 10^8 \text{m/sec}}{\text{830 MHz}} = 0.361 \text{ m}
\]

User is at \( d = 5 \text{ km} \)

\( P_r = 1 \text{ W} = 30 \text{ dBm} \)

\[
P_R = P_T + G_T + G_a + 20 \log \left( \lambda \right) - 20 \log \left( 4\pi \right) - 10 \log \left( d \right) - L_c
\]

\[
= 30 + 10 + 10 + 20 \log \left( 0.361 \right) - 21.98 - 30 \log \left( 5000 \right) \text{ assume } \frac{\text{dbm}}{\text{db}} = 0
\]

\[
= 50 - 8.85 - 21.98 - 110.96 \text{ dB}
\]

\[
= -91.83 \text{ dBm} = 0.66 \text{ puW}
\]

Note, just how large the path loss is and how really weak the received signal actually is!

(b) From notes: \( \frac{c}{I} = \left( \frac{\sqrt{3} K}{M} \right)^3 \)

\( M = 6 \) for hexagonal cells

\( K = 7 \) from problem data

\[ n = 3 \]

\[ 16.04 \Rightarrow 12.05 \text{ dB} \]

Actual interference power:

\[ I = \frac{c}{16.04} \left( c = 0.66 \text{ puW} \right) \]

\[ I = 91.3 \text{ femto watts} \]
2. In a certain CDMA cellular system, the voice signals are compressed to a binary bit rate of 20 [kb/s], which includes all overhead for signaling and error correction. To spread their spectrum, these baseband signals are multiplied by a binary code with chip rate 1.1 [MHz].
   a) Calculate the processing gain. If the minimum required signal to noise ratio at the base station receiver is 12 [dB], estimate the maximum number of simultaneous users.
   b) Assume that the orthogonal code words used for the system in part a. are 100 'chips' long, and that the carrier frequency is 2.4 [GHz]. Further assume that the received power should not vary significantly in the time corresponding to ten code words. Estimate the maximum mobile user velocity, in [m/s].

(a) bit rate = 20 [kb/s]  chip rate = 1.1 [MHz]

\[ \text{processing gain} = \frac{1.1 \times 10^6}{20 \times 10^3} = 55 \quad N = 85 \]

(b) The question asks us to consider the "coherence time" of the channel.

- for 10 words; 10 x 100 chips → \( T_c = \frac{1000}{1.1} = 0.909 \text{ m/sec} \),

  \[ T_c \approx \frac{9c}{16 \pi f_c} \]

From notes:

\[ T_c = \frac{9c}{16 \pi f_c} \approx \frac{9 \times 10^8 \text{ m/sec}}{16 \pi (0.909 \times 10^3 \text{ Hz})} = 29.6 \text{ m/sec or } 88 \text{ km/h} = v_{\text{max}} \]

\[ \text{Max # simultaneous users:} \]

- Set by 12 dB SNR requirement (after depadding)

Assuming adequate adaptive power control (all users same power at BS receiver) and assuming that interference from other users is the main source of noise:

\[ \text{SNR} = 2 \frac{B}{P_N} = \frac{P_s}{P_i} \quad \text{implies} \quad \text{SNR} = \frac{2N}{m-1} \]

\[ \text{after depadding} \quad 12 \text{dB} \]

\[ \text{SNR before depadding} = \frac{15.85}{15.85} = 1 \]

\[ m = 7.99 \approx 8 \text{ users} \]
6. Measurements on a certain radio channel in the 800 [MHz] frequency band indicate that the coherence bandwidth is approximately 100 [KHz]. Assume that multipath effects should not spread digital symbols by more than 10% of their nominal symbol period. What is the maximum symbol rate?

\[
\frac{f_c}{B_c} = 800 \text{ MHz} \quad \Rightarrow \quad B_c = 100 \text{ kHz}
\]

- Coherence bw is related to the rms delay spread in the time domain:

\[
B_c \approx \frac{1}{\Delta \tau} = \frac{1}{T_m}
\]

So, 100 kHz = \frac{1}{0.10(T_{\text{symbol}})}

\[T_{\text{symbol}} \leq 0.1 \text{ msec}\]

Maximum symbol rate = 10 kb/s
3. You are assigned to design an adaptive power (gain) control circuit for a CDMA cellular system, such that power adjustments are made often enough that the channel doesn't change significantly between adjustments. What is the minimum rate of power adjustments (expressed in [Hz]) to accommodate a mobile user traveling at 110 km/hr? Assume the system is centered at 1.9 GHz.

This is a direct application of the coherence-time expression:

\[ v = 110 \text{ km/hr}, \quad f_m = \text{max doppler shift} \]

\[ \Rightarrow v/\lambda = \frac{v f}{c} \]

\[ \Rightarrow 110 \text{ km} = \frac{30.56 \text{ m/sec}}{\text{hr}} \]

\[ f_m = \frac{30.56 \text{ m/sec} \cdot 1.9 \text{ GHz}}{3 \times 10^8 \text{ m/sec}} \]

\[ = 193.5 \text{ Hz} \quad \text{max doppler frequency} \]

\[ T_c = \frac{9}{16\pi f_m} = 0.93 \text{ msec} \]

or in other words power control has to make adjustments at \(1081\) times a second \((1081 \text{ Hz})\).