ECE 257B: Principles of Wireless Networks
Solution of Homework assignment # 1

1. Some advantages of using digital systems:

   - improved noise immunity
   - more efficient transmission and better quality of service – error correction codes, bandwidth efficient modulation schemes, efficient source coding, joint source and channel coding
   - can easily perform data encryption and other security provisions
   - flexibility (variable bit-rate sources can be accommodated easily, newer coding schemes can be easily incorporated)
   - lower power consumption (unless lots of processing needed)
   - can easily allow for different Quality of Service guarantees – can specify priorities
   - easier to network, compatible with current wireline standards
   - easier to use signal processing
   - easily implementable in VLSI (low-cost)
   - software receivers which can be upgraded
   - possibility of using various multiple access techniques (CDMA/TDMA) and TDD
   - needed for efficient data transmission

   Some disadvantages of using digital systems:

   - intersymbol interference if high data rates – need for equalization
   - analog systems already in place; replacement by digital systems involves new investments

- voice quality may not be good – quality degradation of compressed voice in the presence of channel errors is perceptually worse than for analog
- complex algorithms, control procedures and protocols may need to be used
- need for synchronization

2. Some techniques which can be used to increase the spectral efficiency:

   - cellular structure
   - better receivers which tolerate lower SIR
   - bandwidth efficient modulation
   - decreased protocol overhead
   - use of speech compression
   - antenna sectorization
   - diversity and power control
   - interference suppression techniques
   - interference-robust schemes (e.g., spread spectrum)
   - digital transmission
   - dynamic channel allocation
   - multilevel modulation techniques

3. From equation (3.40), we have

$$\begin{aligned}\Delta &= d'' - d' = \sqrt{(h_t + h_r)^2 + d^2} - \sqrt{(h_t - h_r)^2 + d^2} \\ &= d\left(\sqrt{1 + (h_t + h_r)^2/d^2} - \sqrt{1 + (h_t - h_r)^2/d^2}\right) \qquad (1)\end{aligned}$$

If $(h_t + h_r) \ll d$ (as it usually is), we use the expansion $\sqrt{1+x} \simeq 1 + x/2$ to obtain

$$\Delta \simeq d\left(1 + \frac{(h_t + h_r)^2}{2d^2} - 1 - \frac{(h_t - h_r)^2}{2d^2}\right) = d\frac{4h_t h_r}{2d^2} = \frac{2h_t h_r}{d} \qquad (2)$$

The accuracy of this approximation can be assessed by noting that $\sqrt{1+x}$ is approximated by $1+x/2$ to within 0.1% for $x = 0.1$.

4. The average signal power at $d = 10$ m is 35 dB below its level at $d_0 = 1$ m, i.e., its is equal to -35 dBm (0 dBm = 1 mW). Since with probability 10% the signal level exceeds the average by 10 dB or more, we must have $Q(10/\sigma) = 0.1$, i.e., $10/\sigma \simeq 1.3$ and $\sigma \simeq 7.7$ dB.

5. Taking into account that $10 \log 2 = 3$ and $10 \log 5 = 7$, we have

distance	free space	$n = 3$	$n = 4$
1 km	-30 dBm	-30 dBm	-30 dBm
2 km	-36 dBm	-39 dBm	-42 dBm
5 km	-44 dBm	-51 dBm	-58 dBm
10 km	-50 dBm	-60 dBm	-70 dBm

On a logarithmic plot, these curves are straight lines with different slopes.

6. A SNR of 20 dB is provided with probability 0.95 in the presence of log-normal shadowing with $\sigma = 8$ dB if its average, SNR_0, is at least $20 + \ell\sigma$ where $Q(\ell) = 0.05$, i.e., $\ell = 1.65$ and SNR_0 = 33 dB.

The thermal noise power at the receiver is computed as $P_n = kT_0B = 1.38 \times 10^{-23} \times 290 \times 30000 = -129.2$ dBm, which becomes -121.2 dBm when the noise figure of 8 dB is taken into account.

The radiated power is 53.76 dBm (15 W = 41.76 dBm). The value of SNR_0 at $d_0 = 1$ km is given by the free-space expression and is about 80 dB. In order to guarantee the required performance, the additional loss due to distance must not exceed $80 - 33 = 47$ dB. The maximum distance d is then found from $40 \log(d/d_0) = 47$, i.e., $d \simeq 15$ km.

7. For channel 1, we have

$$\overline{\tau} = \frac{1 \times 0 + 1 \times 50 + 0.1 \times 75 + 0.01 \times 100}{1 + 1 + 0.1 + 0.01} = 27.7ns \tag{3}$$

$$\overline{\tau}^2 + \sigma_\tau^2 = \frac{1 \times 0^2 + 1 \times 50^2 + 0.1 \times 75^2 + 0.01 \times 100^2}{1 + 1 + 0.1 + 0.01} = 1500ns^2 \tag{4}$$

$$\sigma_\tau = 27ns \tag{5}$$

For channel 2, we have

$$\overline{\tau} = \frac{0.01 \times 0 + 0.1 \times 5 + 1 \times 10}{1 + 0.1 + 0.01} = 9.46\mu s \tag{6}$$

$$\overline{\tau}^2 + \sigma_\tau^2 = \frac{0.01 \times 0^2 + 0.1 \times 5^2 + 1 \times 10^2}{1 + 0.1 + 0.01} = 92.3\mu s^2 \tag{7}$$

$$\sigma_\tau = 1.7\mu s \tag{8}$$

The maximum data rate which can be supported with adequate performance is $0.1/\sigma_\tau$, i.e., about 4 Mbps in channel 1 and about 60 kbps in channel 2.

8. Note: signal level 10 dB below the rms value corresponds to $\rho = 0.316$ (not 0.1!). A fade duration of 1 ms corresponds to a Doppler frequency of 132 Hz, i.e., a mobile speed of 44 m/s at 900 MHz. The mobile therefore travels 440 m. With $\rho = 1$, we have a fading rate of $\sqrt{2\pi} f_D e^{-1} = 122$ fades per second, and therefore the number of crossings in 10 s is about 1220.

9. (a) time difference is 8μs and speed of light is 3×10^8 m/s, so that length difference is 2.4 km.
   (b) $\overline{\tau} = 1.5\mu$s and $\sigma_\tau = 2\mu$s.
   (c) using the estimate $1/(5\sigma_\tau)$ we have a coherence bandwidth of about 101 kHz.
   (d) IS-54 uses a channel bandwidth of 30 kHz, and experiences flat fading in this case. GSM has a channel bandwidth of 200 kHz and experiences some frequency selective fading. IS-95 uses channels with 1.25 MHz bandwidth and therefore the channel is frequency selective.