



Sirindhorn International Institute of Technology
Thammasat University at Rangsit
School of Information, Computer and Communication Technology

ECS 455: Problem Set 1

Semester/Year: 2/2016

Course Title: Mobile Communications

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Course Web Site: <http://www2.siiit.tu.ac.th/prapun/ecs455/>

Due date: February 8, 2017 (Wednesday), 4:30 PM

Instructions

1. (1 pt) Write your first name and the last three digit of your student ID on the upper-right corner of every submitted sheet.
2. (1 pt) For each part, write your explanation/derivation and answer in the space provided.
3. (8 pt) It is important that you try to solve all non-optional problems.
4. Late submission will be heavily penalized.

Questions

1. Cellular communication in the USA was limited by the Federal Communication Commission (FCC) to one of three frequency bands, one around 0.9 GHz, one around 1.9 GHz, and one around 5.8 GHz [Tse and Viswanath, 2005, p. 11]. Find the corresponding **wavelengths**.

2. Under the free-space PL model, how much received power is lost when the operating frequency (carrier frequency) is changed from $f_c = 700\text{MHz}$ to $f_c = 1,800\text{ MHz}$?

3. Consider a cellular system with operating frequencies around $f_c = 900\text{ MHz}$, cells of radius 100 m , and *nondirectional* antennas.
 - a. Under the ***free-space path loss model***, what transmit power is required at the base station such that all mobile devices within the cell receive a minimum power of $10\text{ }\mu\text{W}$?

 - b. How does this change if the system frequency is 5 GHz ?

[Example 2.1 in Goldsmith, 2005]

4. Let us take a look at the microwave ultra-wideband (UWB) impulse radio. UWB is a power-limited technology in the unlicensed band of 3.1–10.6 GHz. For the multiband OFDM (MB-OFDM) UWB systems, there are 5 band groups whose centers are provided in Table 1 below

Table 1: Relationship between center frequencies and coverage range for MB-OFDM UWB systems.

Band Group	Center frequency (MHz)	Range (meter)
1	3,960	10
2	5,544	
3	7,128	
4	8,712	
5	10,032	

According to the Friis equation, given the same transmitted power, propagation attenuation will be different for each band because they use different frequency. (This variation of received signal strength can be a bothering factor.) If band group 1 can cover 10 meters, estimate the coverage ranges for other band groups in Table 1.

Show your calculation and explanation here but put your answers in Table 1.

Extra Questions

Here are some optional questions for those who want more practice.

5. Consider the set of empirical measurements of P_r/P_t given in Table 2 below for a system operating around 900 MHz.

Table 2 Path Loss Measurements

Distance from Transmitter	P_r/P_t
10m	-70 dB
20m	-75 dB
50m	-90 dB
100m	-110 dB
300m	-125 dB

- a. Find the path loss exponent γ that minimizes the sum of square differences between the calculated dB power ratio using the simplified path loss model and the empirical dB power ratio measurements, assuming that $d_0 = 1$ m and K is determined from the free space path gain formula at this d_0 .

Hint: Recall that $10\log_{10} \frac{P_r}{P_t} = (10\log_{10} K) + \gamma 10\log_{10} \frac{d_0}{d}$, where $K = \left(\frac{\lambda}{4\pi d_0} \right)^2$. The

values of f and d_0 can be used to determine K and hence b . So, the only unknown parameter is γ .

Here, we are given 5 values of d which we will denote by d_1, d_2, \dots, d_5 . For a chosen value of γ , we can plug these distance values into the formula above to calculate

$10\log_{10} \frac{P_r}{P_t}$ which will be close to (but not exactly the same as) the $10\log_{10} \frac{P_r}{P_t}$

provided in the table. Our task, then, is to find the best γ that minimize their (average) difference; that is, we want to minimize

$$\sum_{i=1}^5 \left(r_i - \left((10\log_{10} K) + \gamma 10\log_{10} \frac{d_0}{d_i} \right) \right)^2$$

where r_i is the empirical power ratio measurements provided in the table.

To find the best γ , simply find the root of the derivative wrt. γ .

- b. Find the received power at 150 m for the simplified path loss model with the path loss exponent found in part (a) and a transmit power of 1 mW (0 dBm).

[Example 2.3 in Goldsmith, 2005]

6. [Calculus*] Consider the random variable R whose $k \ln R \sim \mathcal{N}(\mu, \sigma^2)$ for some constant μ and positive constants k and σ . (An example of this is the random attenuation factor that models the path loss and shadowing effect in wireless communication.)

- Find the pdf $f_R(r)$ of R .
- Find the expected value $\mathbb{E}R$. (Hint: Let $z = \frac{k \ln(r) - \mu}{\sigma}$. Then, use the fact that the integration of any pdf will always give 1.)
- Find the median of R . (This is the value of r at which $F_R(r) = \frac{1}{2}$.)