UNIVERSITY OF TEXAS AT DALLAS
Department of Electrical Engineering

EE 6391 - Signaling and Coding for Wireless Communication Systems
Solutions to Problem Set #1:

Date assigned:
Date due:

Reading: "Propagation measurements and models for wireless communication channels," J. Andersen. T. Rappaport, S. Yoshida, IEEE Comm. Mag, Han. 1995.

Solution 1.1

A program to plot the figures is shown below. From the plots that you can obtain with the program it can be seen that as G_r (gain of reflected path) is decreased, the asymptotic behavior of P_r tends toward d^{-2} from d^{-4}, which makes sense since the effect of reflected path is reduced and it is more like having only a LOS path. Also the variation of power before and around dc is reduced because the strength of the reflected path decreases as G_r decreases. Also note that the the received power actually increases with distance up to some point. This is because for very small distances (i.e. $d = 1$), the reflected path is approximately two times the LOS path, making the phase difference very small. Since $R = -1$, this causes the two paths to nearly cancel each other out. When the phase difference becomes 180 degrees, the first local maxima is achieved. Additionally, the lengths of both paths are initially dominated by the difference between the antenna heights (which is 35 meters). Thus, the powers of both paths are roughly constant for small values of d, and the dominant factor is the phase difference between the paths.

```
clear all;
close all;
ht=50;
hr=15;
f=900e6;
c=3e8;
lambda=c/f;
GR=[1,.316,.1,.01];
Gl=1;
R=-1;
counter=1;
figure(1);
d=[1:1:100000];
l=(d.^2+(ht-hr)^2).^.5;
r=(d.^2+(ht+hr)^2).^.5;
```

```
phd=2*pi/lambda*(r-1);
dc=4*ht*hr/lambda;
dnew=[dc:1:100000];
for counter = 1:1:4,
Gr=GR(counter);
Vec=Gl./l+R*Gr./r.*exp(phd*sqrt(-1));
Pr=(lambda/4/pi)^2*(abs(Vec)).^2;
subplot(2,2,counter);
plot(10*log10(d),10*log10(Pr)-10*log10(Pr(1)));
hold on;
plot(10*log10(dnew),-20*log10(dnew));
plot(10*log10(dnew),-40*log10(dnew));
end
hold off
```

Solution 1.2 Outage Prob. = Prob. [received power$_dB \leq T_{p_{dB}}$] $T_p = 10$dB

(a)

$$\textit{outage prob} = 1 - Q\left(\frac{T_p - \mu_\psi}{\sigma_\psi}\right) = 1 - Q\left(\frac{-5}{8}\right) = Q\left(\frac{5}{8}\right) = 26\%$$

(b) $\sigma_\psi = 4$ dB, outage prob $< 1\%$

$$Q\left(\frac{T_p - \mu_\psi}{\sigma_\psi}\right) > 99\% \Rightarrow \ \frac{T_p - \mu_\psi}{\sigma_\psi} < -2.33$$

$$\mu_\psi \geq 19.32\text{dB}$$

(c)

$$\sigma_\psi = 12\text{dB}, \frac{T_p - \mu_\psi}{\sigma_\psi} < -6.99 \ \Rightarrow \ \mu_\psi \geq 37.8\text{dB}$$

(d) For mitigating the effect of shadowing, we can use macroscopic diversity. The idea in macroscopic diversity is to send the message from different base stations to achieve uncorrelated shadowing. In this way the probability of power outage will be less because both base stations are unlikely to experience an outage at the same time, if they are uncorrelated.