Habib University
Spring 2018

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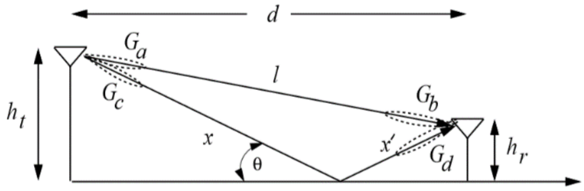
EE 422 – Wireless & Mobile Communication
Assignment # 03
Dr. Aamir Hasan

<u>Problem 01</u> –For a two-path propagation model with transmitter-receiver separation d = 100 m, ht = 10m, and hr =2 m, find the delay spread between the two signals.

- d = 100m
- ht = 10m
- hr = 2m

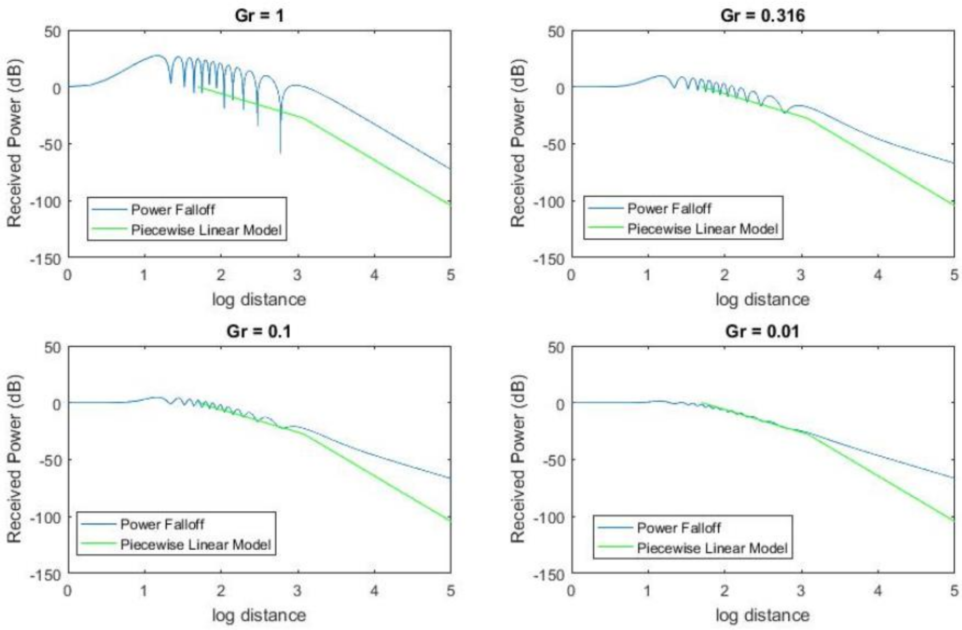


The delay spread between the two signals is given by: $x + x' - l = \sqrt{(h_t + h_r)^2 + d^2} - \sqrt{(h_t - h_r)^2 + d^2}$.
Therefore;
Delay spread = sqrt [$(12)^2$+100^2] – sqrt [$(8)^2$+100^2]
Delay spread = 0.3979 m

<u>Problem 02</u> – Directional antennas are a powerful tool to reduce the effects of multipath as well as interference. In particular, directional antennas along the LOS path for the two-ray model can reduce the attenuation effect of the ground wave cancellation, as will be illustrated in this problem. Plot the dB power (10log10 Pr) versus log distance (log10 d) for the two-ray model with the parameters f = 900MHz, R=-1, ht = 50m, hr =2m, Gl =1, and the following values for Gr: Gr =1,.316,.1, and .01 (i.e. Gr =0 ,−5,−10, and −20 dB, respectively). Each of the 4 plots should range in distance from d =1m tod = 100,000m. Also calculate and mark the critical distance dc =4 hthr/λ on each plot, and normalize the plots to start at approximately 0dB. Finally, show the piecewise linear model with flat power falloff up to distance ht, falloff 10log10(d−2) for ht <d<d c, and falloff 10log10(d−4) for d ≥ dc. (on the power loss versus log distance plot the piecewise linear curve becomes a set of three straight lines with slope 0, 2, and 4, respectively). Note that at large distances it becomes increasingly difficult to have Gr << Gl since it requires extremely precise angular directivity in the antennas.

The following is the Matlab code and plots for the 2 ray model exhibiting reduced attenuation effect with varying parameters[1];

```
ht=50;
hr=15;
f=900e6;
c=3e8;
w=c/f;
GR=[1, 0.316, 0.1, 0.01];
Gl=1;
R=-1;
i=1;
d=[1:1:1000000];
l=(d.^2+(ht-hr)^2).^0.5;
r=(d.^2+(ht+hr)^2).^0.5;
p=2*pi/w*(r-1);
dc=4*ht*hr/w;
dn=[dc:1:999995];
for i=1:1:4,
   Gr=GR(i);
   Vec=Gl./1+R*Gr./r.*exp(p*sqrt(-1));
   Pr=(w/4/pi)^2*(abs(Vec)).^2;
   subplot(2,2,i);
   plot(10*log10(d),10*log10(Pr)-10*log10(Pr(1)));
   hold on;
   plot(10*log10(dn), -20*log10(dn));
   plot(10*log10(dn), -40*log10(dn));
end
```



[1] https://www.slideshare.net/Engdpak/goldsmith-wireless-communication

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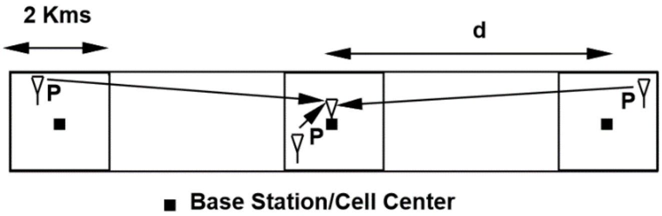
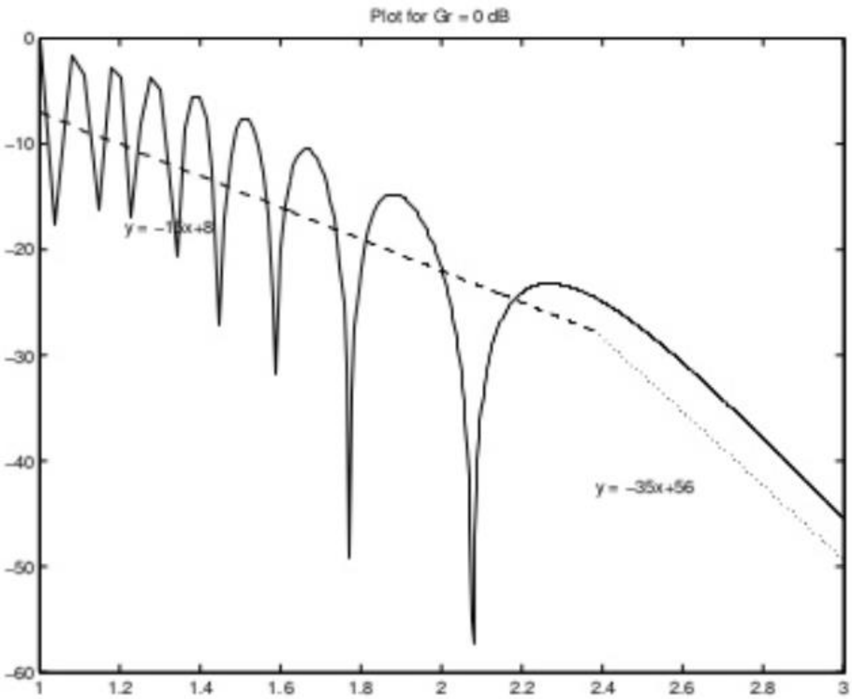
<u>Problem 03</u> – (Computer plots) Find parameters for a piecewise linear model with three segments to approximate the two path model path loss (2.4.1) over distances between 10 and 1000 meters, assuming ht=10m and hr=2m. Plot the path loss and the piecewise linear approximation using these parameters over this distance range.



- d = ranging from 10-1000 m
- h_t = 10m
- h_r = 2m

Following is the path loss & piecewise linear model for a 2 path ray model;



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<u>Problem 04</u> – Consider a cellular system operating at 900 MHz where propagation follows free space path loss with variations from log normal shadowing with σ =6dB. Suppose that for acceptable voice quality a signal-to-noise power ratio of 15 dB is required at the mobile. Assume the base station transmits at 1 W and its antenna has a 3 dB gain. There is no antenna gain at the mobile and the receiver noise in the bandwidth of interest is -10 dBm. Find the maximum cell size so that a mobile on the cell boundary will have acceptable voice quality 90% of the time.

Assuming free space path loss parameters;

- *fc = 900MHz*
- *lambda = 1/3m; lambda=c/f*
- *SNRreceived = 15dB*
- *Ptx = 1W*
- *Gtx = 3dB*
- *Pnoise = -40 dB ; Preceived = -35 dB*
- *Cell radius = d*
- $\sigma_{\psi dB} = 6$

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Problem 05 – In this problem we will explore the impact of different log-normal shadowing parameters on outage probability. Consider a cellular system where the received signal power is distributed according to a log-normal distribution with mean μ dBm and standard deviation σ_ψ dBm. Assume the received signal power must be above 10 dBm for acceptable performance.

(a) What is the outage probability when the log-normal distribution has μ_ψ = 15dBm and σ_ψ = 8dBm?

Outage probability = Probability $[\text{received } power_{dB} \leqslant Tp_{dB}]$
Tp = 10dB

$$outageprob. = 1 - Q\left(\frac{Tp-\mu_\psi}{\sigma_\psi}\right) = 1 - Q\left(\frac{-5}{8}\right) = Q\left(\frac{5}{8}\right) = 26\%$$

(b) For σ_ψ =4dBm, what value of μ_ψ is required such that the outage probability is less than 1%, a typical value for high-quality PCS systems?

σ_ψ = 4 dBm & Outage probability = 0.01

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

$$\mu_\psi \geq 19.32dB$$

(c) Repeat (b) for σ_ψ = 12dBm.

σ_ψ = 12 dBm & Outage probability = 0.01

$$\frac{Tp-\mu_\psi}{\sigma_\psi} < -6.99$$

$$\mu_\psi \geq 37.8dB$$

(d) One proposed technique to reduce outage probability is to use macro diversity, where a mobile unit's signal is received by multiple base stations and then combined. This can only be done if multiple base stations are able to receive a given mobile's signal, which is typically the case for CDMA systems. Explain why this might reduce outage probability.

For the migrating of the effect of shadowing, we may use the macroscopic diversity. Diversity is a powerful communication receiver technique that provides wireless link improvement at relatively low cost. Diversity exploits the random nature of radio propagation by finding independent (or at least highly uncorrelated) signal paths for communication. By receiving more than one copy of the transmitted received signal and then selecting one (or multiple) of them intelligently, both the instantaneous and average SNRs at the receiver may be improved, often by as much as 20 dB to 30 dB. 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.