PROBLEM SET 5
ECE 5010 Autumn 2018

Assigned: October 10th
Quiz: October 22nd
Instructor: Joel Johnson

Problem 1
A cellular phone user in a rural area transmits at 835 MHz in a bandwidth of 30 kHz on the link from the handset to the basestation. Assume the handset at 1.5 m height has an antenna gain of 1.5 dBi, a transmit power of 0.5 W, and is located 10 km from the basestation. The basestation at height 50 m has an antenna gain of 6 dBi in the direction of the receiver, and a receiver noise figure of 6.1. The system operates in a 290K external noise environment, and requires a signal to noise ratio at the receiver of 6 in order to function. Assume the transmitter and receiver are polarization and impedance matched.

(a) Find the power received at the base station assuming (i) free space propagation (ii) direct plus reflected (flat-Earth) propagation.
(b) Find the power received at the base station using the (i) Hata and (ii) Lee models. How do these predictions compare with each other and with those from part (a)?
(c) It is known that slow fading effects are present with a standard deviation of 5 dB in path loss. Estimate the percentage of time that the system will fail due to slow fading effects under the Hata model.
(d) Now neglect slow fading effects and assume the received power follows the Hata model. It is known that the fast fading power level at the receiver (i.e. \( P_f \)) is 20% of the power received (in Watts) when fast fading effects are neglected. Estimate the percentage of time that the system will fail due to fast fading effects in these conditions.

Problem 2
A PCS basestation operates in a “medium city” environment at 1950 MHz, with a base station antenna height of 60 m and a receiver antenna height of 2 m.

(a) Estimate the path loss at ranges 1 km, 5 km, and 10 km using the Cost-231 model.
(b) Given a slow fading loss standard deviation of 10 dB, what is the probability of obtaining a signal fade of 10 dB from the power level neglecting slow fading effects?
(c) The receiver is now placed in a location where there is no direct line of site reception, only a fast fading power level of 0.1 microWatts is received. (i) Find the power level that will be exceeded 90% of the time. (ii) Find the power level that will be exceeded 10% of the time.
Problem 3
A radio station transmits 10 kW of vertically polarized power at 1460 KHz. This results in the constant $2E_0 = 993$ millivolts/m for this system when $\frac{2E_0}{d}$ is expressed with $d$ in km. A listener has a very sensitive receiver that will produce an understandable output for received field strengths greater than $10 \, \mu$Volts/m (note this is a way of specifying required signal to noise ratios and receiver noise figures simultaneously.) Assume the soil properties for the region of interest are $\varepsilon_r = 15$ and $\sigma = 1$ mmhos/m. Neglect any effects of transmit or receive antenna heights in parts (a)-(d).

(a) Write a relationship between the amplitude of the numerical distance $|\rho|$ and the distance to the receiver in km.

(b) Find $b$ (the phase of the numerical distance) in degrees.

(c) Find the distance to which the planar Earth theory should be valid, and the corresponding value of $|\rho|$.

(d) Estimate the received field strength at the distance in part (c). Is the listener still able to receive the transmission?

(e) Now consider a transmit antenna height of 45 m. How does the received field strength in part (d) change?

(f) Neglecting antenna height effects again, find $\tau$ in the spherical Earth groundwave theory, and write an equation relating the distance in km to the spherical Earth distance $x$. Assume an effective Earth radius multiplier of 4/3.

(g) Neglecting antenna height effects, find the received field strength at distance 250 km from the transmitter. Can the listener still receive the transmissions?