Mobile Communications

Problems on Wireless Transmission

The problems will have to be solved individually, so every student has to solve all the problems. The problems should be solved by hand (not using a text editor) and the resolutions should be digitalized and submitted as single pdf file via moodle.

1. Using *Google* find out the typical sensitivity of receivers for GSM, WLAN and Bluetooth receivers. Indicate these values both in dBm and W. Indicate also the web links from where the information was retrieved.

2. The IEEE 802.11g technology enables the transmission of data using multiple bitrates. Some manufacturers provide the receiver sensivity required for each bitrate for their receivers. Using Google again, try to find an example of it. Please provide the link and indicate the sensitivity values both in dBm and W.

3. Assume two antennas, one antenna is 100 m high and the other is at ground level.
   a) Calculate the maximum Line-Of-Sight (LOS) distance between these antennas.
   b) Assume that one antenna is 10 m high. How high must be the second antenna to obtain the same LOS distance?

4. Consider a square city of 100 km^2. Suppose you design a cellular system for this city with square cells, where every cell (regardless of cell size) has 100 channels and can support 100 active users (in practice the number of users that can be supported per cell is mostly independent of cell size as long as the propagation model and power scale appropriately). What is the total number of active users that your system can support for a cell size of 1 km^2? What cell size would you use if you require that your system support 250 000 active users?

5. Consider an indoor wireless LAN with f_c=900 MHz, cells of radius 100 m, and omnidirectional antennas. Under the free-space path loss model (Friis model), what transmit power is required at the access point such that all terminals within the cell receive a minimum power of 10 nW? Consider G_l=1.

6. Suppose a pedestrian is moving in an urban environment that has a wireless channel with a coherence time T_c= 70 ms and a coherence bandwidth B_c=150 kHz. Assume we would like to consider the channel as slow fading ($T_{symbol} < 0.1*T_c$) and no-frequency selective ($B < 0.1* B_c$)
   a) Indicate the baudrate interval, in symbol/s or baud, at which the information could be transmitted through this channel. Assume that T_{symbol}=1/B.
   b) Calculate the velocity the pedestrian is moving, in km/h. Assume f_c=1 GHz and θ=0º.

7. Consider the set of empirical measurements of P_r/P_t given in the table below for an indoor system at 900 MHz.

Distance from Transmitter (d)	$M_{dB} = Pr_{dB} - Pt_{dB}$
10 m	-70 dB
20 m	-75 dB
50 m	-90 dB
100 m	-110 dB
300 m	-125 dB

   a) Find the path loss exponent γ that minimizes the Mean Square Error (MSE) between the simplified model [$Pr_{dB} = Pt_{dB} + K_{dB} - 10.\gamma.\log(d/d_0)$] and the empirical dB power measurements, assuming $d_0 = 1$ m. The MSE is given by the Equation represented below; try to find the γ which minimizes F(γ).

$$F(\gamma) = \sum_{i=1}^{5} [M_{measured}(d_i) - M_{model}(d_i)]^2$$

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

8. Assume in the previous example that the exponent for the simplified path loss model that best fits the measurements of the table was γ = 3.7. Assuming the simplified path loss model with this exponent and K = - 31.5 dB, find $\sigma^2_{\psi\ dB}$, the variance of log-normal shadowing about the mean path loss based on these empirical measurements. Please remember that $Var(X)=E[(X-\mu)^2]$.

9. Consider a channel with Rayleigh fading and a receiver receiving an average power P_r = 20 dBm.
   a) Find the probability that the received power is below 10 dBm. As discussed, the power received along the time in this situation is exponentially distributed having a p.d.f. given by

$$p_{Z^2}(x) = \frac{1}{P_r} e^{-x/P_r}$$

   where P_r represents the average power of the signal received, i. e. the power received based on path loss and shadowing alone.
   a) Find the probability that the received power is below 20 dBm (the average power). Compare this probability with the probability obtained using a Gaussian distribution.

10. Consider 4 transmitters, ------T1------T2------T3------T4------, separated by distances of 2 km. The transmitters are transmitting continuously information at powers P_t= 20dBm. T1 and T3 operate in channel 1; T2 and T4 operate in channel 2. Channel 1 is characterized by a carrier of 5 GHz and a bandwidth B= 40 MHz. Consider 2 receivers, R1 and R2, located respectively at left and right sides of T3 at distances of 1 km from T3.

------T1------T2---R1---T3---R2---T4------

Receivers R1 and R2 receive information from T3, have thermal noise ($N=N_0.B$), as well as interference power (I) generated by T1. Using the Shannon law, C/B=

$\log_2(1+P_r/(N+I))$, and assuming the Friis propagation model, estimate the maximum spectral efficiency (bit/s/Hz), obtainable at R1 and R2.

11. Suppose a signal encoding technique requires E_b/N_0=8.4 dB for a Bit Error Ratio (BER), BER=10^{-4}. If the effective noise temperature is 290 K (room temperature) and the bitrate is 100 kbit/s, what received signal power is required to overcome the thermal noise?

12. Using the Shannon Law, $C= B*\log_2(1+S/N)$, C in bit/s, B in Hz, and S and N in W, find the minimum E_b/N_0 required to achieve a spectral efficiency of 6 bit/s/Hz.