Extra problems – ETI051
Batch 1

2007-11-06

1. We are analyzing a radio communication system with the following properties. A base station (BS) antenna is placed at an elevation of 150 m and communication is taking place in a large-city environment at 900 MHz. The BS is communicationg with a mobile station (MS) whose antenna is at elevation 5 m. The distance between the BS and the MS is 5 km and both are equipped with $\lambda/2$-dipole antennas. We are going to focus on the down link, from BS to MS. The noise temperature of the MS antenna is estimated to 1000 K. A low-noise amplifier (LNA) with noise figure 3.8 dB and 10 dB gain is placed directly after the antenna. After the LNA, there is a feeder connecting the LNA to the rest of the receiver. The feeder has a 3 dB attenuation and the rest of the receiver has a noise figure of 5 dB. The data rate is 271 kbit/sec and the required (minimal) E_b/N_0 is 10 dB. Due to fading, a 12 dB fading margin is required. The fading margin is given relative to the median propagation loss (50% of the area and 50% of the time).
   Select a suitable (narrowband) propagation model and determine the required input power to the BS antenna. *Motivate* your choice of propagation model!

2. Assume that we have a receiving system operating in a Rayleigh-fading environment.The receiving system has access to K antennas with independent fading. The system uses RSSI-selection to connect the antena with the best instantaneous SNR to the receiver. Assuming that the instantaneous received power from antenna k is C_k and that N_0 is fixed, then the instantaneous C/N_0 after RSSI selection is $C_{\max}/N_0$, where $C_{\max} = \max_{k=1..K} C_k$. Assume that all antennas have the same average received power $\overline{C}$ and that we require that the SNR to the receiver is below $(C/N_0)_{\min}$ only with probability p_0 (the outage probability). Using the fact that a Rayleigh-fading environment leads to an exponential distribution of received power, $pdf\ (C) = \exp\left(-C/\overline{C}\right)/\overline{C}$, where $\overline{C}$ is the average received power, perform the following calculations:

   (a) Derive an expression for the required $\overline{C}/N_0$, as a function of $(C/N_0)_{\min}$ and p_0, when only one antenna is used.

   (b) Derive an expression for the required $\overline{C}/N_0$,as a function of K, $(C/N_0)_{\min}$ and p_0, when K antennas and RSSI-selection are used.

   (c) Defining the diversity gain as the reduction in required $\overline{C}/N_0$ (in dB) when going from one to K antennas, use the results from (a) and (b) to derive a general expression for the diversity gain of K antennas, depending only on K and p_0.

Hint: The cumulative distribution function of the maximum $x_{\max} = \max_{i=1..K}(x_i)$ of K independent and indentically distributed stochastic variables x_i is given as $cdf\,(x_{\max}) = (cdf\,(x_i))^K$.

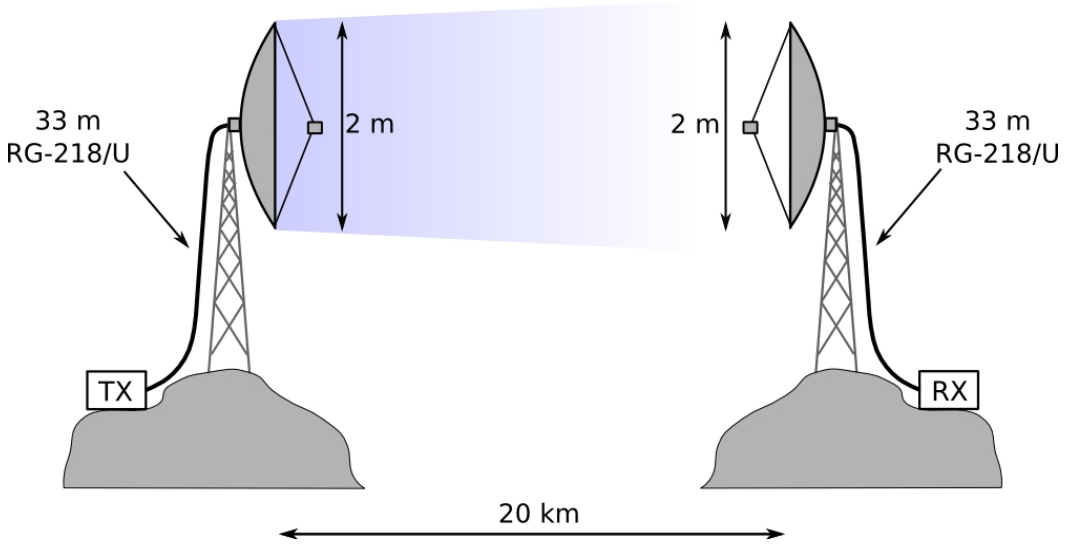
3. In a digital radio link we use 8PSK modulation and maximum-likelihood detection of the received symbols. The bandwidth of the radio signal is measured as the symbol rate (1 symbol/sec = 1 Hz bandwidth). The information rate to be transmitted is 10 kbit/sec and a BER of 10^{-4} is required. To make the calculations simple, we assume that there is no fading and we therefore have an additive white Gaussian noise channel. Determine the required C/N_0 at the receiver input.

4. A mobile radio link, subjected to Rayleigh fading, is carrying an information data-rate of 10 kbit/sec. The specified quality is expressed as an average bit-error probability of 10^{-3}. The noise temperature of the receiver system is 1000 Kelvin (the noise source placed at the receiver input) and 2ASK is used.

   (a) What signal strength (average power) is required at the receiver input, if no countermeasures are used against the fading?

   (b) To improve the system, two antennas and RSSI selection diversity is employed. The distance between the antennas is chosen so that their fading is uncorrelated. How large is the diversity gain and what is the required signal strength (average power) at the receiver input?

5. A radio link is being established between two mountain tops in Republic of Utopia. Circular parabolic antennas with narrow main lobes are used to avoid multipath propagation caused by ground reflections.



In addition to what is shown in the figure, the system has the following parameters:

Carrier frequency	$f_c = 1$ GHz
RX antenna noise temperature	$T_a = 250$ K
RX noise figure	$F_r = 8$ dB
RX bandwidth	$B = 20$ MHz
Carrier to noise requirement	$C/N = 30$ dB
Effective area of RX antenna	55% of opening area
RG-218/U feeder attenuation at 1 GHz	12 dB/100m

Calculate the required transmit power, under the above (not too realistic) conditions. Ignore any mismatch losses.