Georgia Institute of Technology
School of Electrical and Computer Engineering

ECE6604 Personal & Mobile Communications

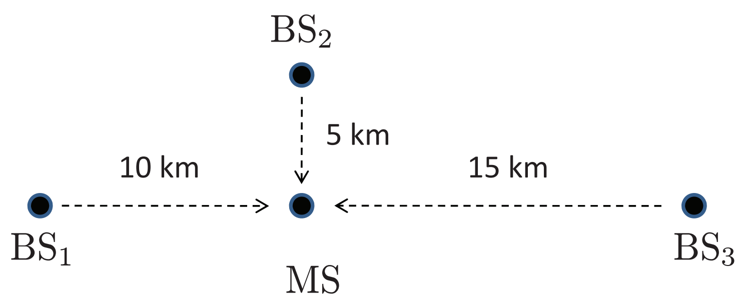
Final Exam

Fall 2016

Thursday December 8, 2:50pm - 5:40pm

- Attempt all questions.
- All questions are of equal value.
- Open book, open notes, exam.

1) Consider the simulcast broadcast system shown in the figure below. A mobile station lies at a distance of 5 km, 10 km and 15 km from three base stations. The simulcast system is GPS synchronized so that the same waveform is transmitted from the three base stations simultaneously.



Neglect shadowing and fading, and assume that the propagation path loss follows the model

$$\mu_{\Omega_p\ (\mathrm{dBm})}(d) = \mu_{\Omega_p\ (\mathrm{dBm})}(d_o) - 10\beta \log_{10}(d/d_o) \quad (\mathrm{dBm})$$

where $\beta = 3.5$, and $\mu_{\Omega_p\ (\mathrm{dBm})}(d_o) = 1$ microwatt at $d_o = 1$ km.

a) 5 marks: Find a mathematical expression for the frequency correlation function of the channel. You do not have to plot it.

b) 5 marks: Find the mean delay and rms delay spread of the channel.

Extra sheet

Extra sheet

2) Suppose that a mobile station is at distance 2 km from its serving base station and at distances 4 km and 5 km from two co-channel base stations. The path loss is described by the model

$$\mu_{\Omega_p \text{ (dBm)}}(d) = \mu_{\Omega_p \text{ (dBm)}}(d_o) - 10\beta\log_{10}\left(\frac{d}{d_o}\right)$$

where $\mu_{\Omega_p \text{ (dBm)}}(d_o) = -70$ dBm, $d_o = 1.6$ km, and $\beta = 3.68$. Each link experiences independent log-normal shadowing with shadow standard deviation $\sigma_\Omega = 8$ dB.

a) 5 marks: Using the Fenton-Wilkinson method find the probability density function of the total interfering power in decibel units.

b) 3 marks: What is the probability density function of the carrier-to-interference ratio in decibel units?

c) 2 marks: If the carrier-to-interference ratio must be greater than 10 dB, what is the probability of outage?

Extra sheet

Extra sheet

3a) 5 marks: A mobile operating at a carrier frequency of 900 MHz is experiencing Rayleigh with 2-D isotropic scattering. Calculate the number of fading events per second having the instantaneous received power 10 and 20 dB lower than the average received power for vehicle speeds of 10 and 100 km/h. Calculate the average duration of these fading events.

3b) 5 marks: Consider two propagation paths that are identical except that each experiences independent log-normal shadow fading. Write down an expression for the probability density of the shadow fading *in decibel units* at the output of the selector function.

Extra sheet

Extra sheet

4) Suppose that an unmodulated 900 MHz carrier is transmitted from a fixed base station over a hypothetical radio propagation channel. With an isotropic receiving antenna, the observed Doppler spectrum at a mobile station is

$$S_{gg}(f) = \begin{cases} \frac{\Omega_p}{200} & , \quad |f| \leq 50 \ Hz \\ 0 & , \quad \text{elsewhere} \end{cases}$$

Moreover, it is noted that plane waves arrive from *all* directions.

a) 2 marks: What is the speed of the mobile station?

b) 4 marks: If the received faded envelope is sampled every T_s seconds, what are the possible values of T_s such that the samples will be uncorrelated?

c) 4 marks: What is the level crossing rate, L_R, in terms of the normalized envelope level $\rho = R/\sqrt{\Omega_p}$?

Extra sheet

Extra sheet

5) Consider a system that uses M-ary orthogonal modulation with non-coherent detection. The error probability on an additive white Gaussian noise (AWGN) channel is known to be

$$P_b = \frac{M}{2(M-1)} \sum_{k=1}^{M-1} \frac{(-1)^{k+1}\binom{M-1}{k}}{k+1} \exp\left\{-\frac{k\gamma_s}{(k+1)}\right\}$$

where $\gamma_s = \alpha^2 E_s/N_o$ is the received *symbol*-energy-to-noise ratio.

a) 6 marks: Derive the corresponding expression for the probability of bit error on a slow flat Rayleigh fading channel. Express your result in terms of the average received *bit*-energy-to-noise ratio, $\bar{\gamma}_b = \mathrm{E}[\alpha^2]E_b/N_o$, and simplify to closed form.

b) 4 marks: Repeat part a) for a slow flat Rician fading channel. Simplify as much as possible.

Extra sheet

Extra sheet