Georgia Institute of Technology
School of Electrical and Computer Engineering

ECE6604 Personal & Mobile Communications

Final Exam

Spring 2009

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

1a) 5 marks: Consider a cellular system with fixed a base station and a moving mobile station. Suppose that an isotropic antenna $G(\theta)$ is used at the mobile station and the propagation environment is characterized by 2-D non-isotropic scattering with the azimuth distribution

$$p(\theta) = \begin{cases} \frac{\pi}{4|\theta_m|} \cos\left(\frac{\pi}{2} \cdot \frac{\theta}{\theta_m}\right) & , \ |\theta| \leq \theta_m \leq \frac{\pi}{2} \\ 0 & , \ \text{elsewhere} \end{cases} .$$

The parameter θ_m controls the angle-of-arrival spread of the incoming waves. Find the Doppler power spectrum $S_{gg}(f)$.

1b) 5 marks: Now suppose that the propagation environment is characterized by 2-D isotropic scattering. However, the mobile station has a vertical loop antenna in the plane perpendicular to vehicle motion, such that $G(\theta) = \frac{3}{2}\sin^2\theta$. Find the Doppler power spectrum $S_{gg}(f)$.

2) A receiver is affected by 3 log-normally shadowed co-channel signals having the power sum

$$I = \sum_{k=1}^{3} I_k$$

where

$$\begin{aligned} I_{1(\mathrm{dB})} &\sim N(-10 \text{ dBm}, \sigma_\Omega^2) \\ I_{2(\mathrm{dB})} &\sim N(-15 \text{ dBm}, \sigma_\Omega^2) \\ I_{3(\mathrm{dB})} &\sim N(-20 \text{ dBm}, \sigma_\Omega^2) \end{aligned}$$

where, $\sigma_\Omega = 8$ dB, and $N(\mu, \sigma_\Omega^2)$ refers a Gaussian random variable with mean μ and variance σ_Ω^2. The sum I is to be approximated as another log-normal random variable, Z, by using the Fenton-Wilkinson method.

a) 6 marks: Find the mean and variance of $Z_{(\mathrm{dB})}$.

b) 4 marks: Suppose that the received carrier power $C_{(\mathrm{dB})}$ has the distribution

$$C_{(\mathrm{dB})} \sim N(0 \text{ dBm}, \sigma_\Omega^2)$$

where $\sigma_\Omega = 8$ dB. Using your result from part a), what is the distribution of the carrier-to-interference ratio $(C/I)_{(\mathrm{dB})}$?

3) Cellular CDMA systems use soft handoff, where the transmissions to/from multiple base stations are combined to give a *macro-diversity.*

Here we consider the effects of path loss and shadowing and ignore multipath-fading. Suppose that the received signal power corresponding to the link with the ith base-station, Ω_{p_i}, has the probability density function

$$p_{\Omega_{p_i}\ (\mathrm{dBm})}(x) = \frac{1}{\sqrt{2\pi}\sigma_\Omega} \exp\left\{ -\frac{(x - \mu_{\Omega_{p_i}\ (\mathrm{dBm})})^2}{2\sigma_\Omega^2} \right\} \quad .$$

where

$$\mu_{\Omega_{p_i}\ (\mathrm{dBm})} = \mathrm{E}[\Omega_{p_i\ (\mathrm{dBm})}]$$

The Ω_{p_i} are assumed to be statistically independent.

a) 5 marks: The reverse link uses selection combining such that the best base-station is always selected. In this case,

$$\Omega^{\mathrm{s}}_{p\ (\mathrm{dBm})} = \max\left\{ \Omega_{p_1\ (\mathrm{dBm})}, \ldots, \Omega_{p_L\ (\mathrm{dBm})} \right\}$$

An outage occurs if $\Omega^{\mathrm{s}}_{p\ (\mathrm{dBm})} \leq \Omega_{\mathrm{th}\ (\mathrm{dBm})}$. What is the probability of outage?

b) 5 marks: The forward link uses coherent combining such that

$$\Omega^{\mathrm{mr}}_{p\ (\mathrm{dBm})} = \Omega_{p_1\ (\mathrm{dBm})} + \ldots + \Omega_{p_L\ (\mathrm{dBm})}$$

Again, an outage occurs if $\Omega^{\mathrm{mr}}_{p\ (\mathrm{dBm})} \leq \Omega_{\mathrm{th}\ (\mathrm{dBm})}$. What is the probability of outage if

$$\mu_{\Omega_{p_1}\ (\mathrm{dBm})} = \mu_{\Omega_{p_2}\ (\mathrm{dBm})} = \cdots = \mu_{\Omega_{p_L}\ (\mathrm{dBm})}?$$

4) Consider the complex low-pass binary modulated signal

$$\tilde{s}(t) = A \sum_n x_n h_a(t - nT)$$

where $x_n \in \{-1,\ +1\}$. Suppose that the amplitude shaping pulse, $h_a(t)$, has the Fourier transform

$$H_a(f) = \left[\tau e^{-\pi(f\tau)^2}\right]^{1/2}$$

a) 4 marks: If the data sequence $\{x_n\}$ is uncorrelated, what is the transmitted power density spectrum?

b) 2 marks: Find the value of τ so that the power density spectrum in part a) is 20 dB below its peak value at frequency $f = 1/T$, where T is the baud duration.

c) 4 marks: Now suppose that that the data sequence is correlated such that

$$\phi_{xx}(n) = \frac{1}{2}\mathrm{E}[x_k x^*_{k+n}] = \rho^{|n|} \quad .$$

Compute the power density spectrum of $\tilde{s}(t)$.

5) An guard interval consisting of a cyclic prefix or cyclic suffix is used in OFDM systems to mitigate the effects of channel time dispersion.

a) 5 marks: Assess the cost of the cyclic prefix in terms of

i) bandwidth and/or data rate.

ii) transmitter power.

b) 5 marks: Suppose the a guard interval of 500 ns is used. The data rate with 64-QAM modulation is 54 Mb/s. The power penalty due to the guard interval is to be kept less than 1 dB. What is the required value of G (constrained to an integer) and minimum the possible OFDM block size (constrained to 2^k for some k)?