Department of Electrical and Computer Engineering

University of Toronto

ECE1543S - Mobile Communication Systems

Answer all questions. Marks: 1: 15, 2: 15, 3: 10, 4: 10. Total = 50.

If doubt exists as to the interpretation of any question, please state any assumptions made. If there are any unspecified parameters which are required to obtain a numerical solution please state so and make resonable choices. If a numerical solution can not be evaluated please give the answer as an expression.

Begin each question on a new page.

1) Consider a wireless system with 3rd order receiver antenna diversity. Three antenna elements are placed on a circle with radius equal to 7.5 cm and equal angle spacing around the circle where the first element (1) is located at $\theta = 0$ (see the Figure below). The receiver travels in the direction of $\theta = 0$ at a speed of 50 Km/H. There are three arriving plane wave signal components from the directions of 0, $\frac{\pi}{4}$, and $\frac{\pi}{2}$ rad. The signal strengths from these three components are 0 dB, -3 dB, and -3 dB respectively. At time $t = 0$ these three components are in phase at antenna element 1. Assume a transmitted sinusoidal signal with frequency 1 GHz.

a) Plot the signal amplitudes versus time at each of the three antenna elements.

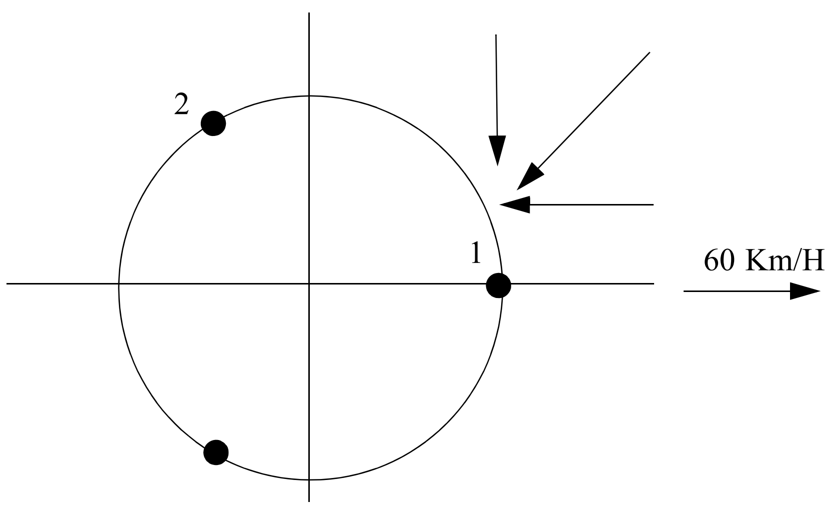
b) Assuming that there is a constant noise level at each antenna element such that considering only the first component the SNR is 10 dB. Plot the SNR versus time for the signals received at each of the elements. $SNR(a, t) = \frac{(E_a(t))^2}{\sigma^2}$.

c) In b) what is the average SNR at each of the antenna elements? What is the minimum SNR? What is the fading margin.

d) Assume maximal ratio combining of the three signals. Plot the SNR of the combined signal versus time.

e) In d) what is the average and minimum SNR? What is the fading margin?

f) Give the improvement in fading margin as a result of the diversity combining in the receiver.



2) A CDMA system utilizes omni-directional antennas. Each cell contains 100 users randomly distributed throughout the cell. A terminal adjusts its transmission power so that the received power at the base station is equal to unity. Write a simplified simulation to determine the expected value of the inter-cell interference, coming from adjacent cells, in the reverse link, under the following assumptions.

a) The propagation power loss law is $\frac{1}{R^4}$, with and without log-normal fading ($\sigma = 6$ dB).

b) The propagation power loss law is $\frac{1}{R^3}$, with and without log-normal fading ($\sigma = 6$ dB).

For each simulation run it 10,000 times and plot a histogram of the interference.

c) Now consider that the signal from each user is a two component multipath signal. Each component is itself made up of many unresolvable componens with the resultant amplitude fading as a Rayleigh random variable and the power fading as an exponential random variable. For the case of an inverse fourth power law, the received signal from one component is $\frac{P_0 L r}{R^4}$, where P_0 is a transmission power constant, L is a log-normal fading variable, r is an exponentially distributed fading variable, and R is the link distance. Note that the fading variables L and r have expected values equal to 1. One of the multi-path components has an average power that is twice of the other component. Run two simulations, one with a one finger Rake receiver locked to the strongest component, and the other with a two-finger Rake receiver. The power at the output of the Rake receiver is used for power control. Plot the corresponding histograms.

Note: In the above simulations model adjacent cells as two circles “touching” at a point.

3a) A CDMA system utilizes a 2-element linear array at the base station. The beamforming is performed by setting one of the combining coefficients equal to 1 and the other equal to -1. Plot the beam pattern in a polar plot versus the azimuth angle, i.e. consider the two antenna elements to be perpendicular to the plane and plot the beam pattern verus signal arrival angle $(0 - 2\pi)$, considering the signal to arrive from a direction that is horizontal to the plane.

b) Now suppose that when the CDMA system is fully loaded with users that are uniformly distributed throughout their cells and when a single element antenna is used, the capacity of the reverse link is equal to C (voice) users per cell. What is the capacity per cell when the above 2-element antenna is used to receive each signal at the base station, where for each user being demodulated we physically orient the 2-element antenna in the optimum manner with respect to the angle of arrival of the signal?

c) Repeat the above for the case where the antenna combining coefficients are both equal to 1. Draw the beam pattern and give the capacity increase relative to the case of an omnidirectional antenna in 2 dimensions.

4) A CDMA system utilizes a modulation scheme DS/BPSK with a data rate of 10 Kbps and a spreading factor equal to 64. Square chip pulses are transmitted. There are 2 interfering signals with the same SS modulation and the following characteristics:

- int 1 - three resolvable multi-path components of powers equal to 0 dB, -2 dB, and -3 dB relative to the received power of the signal of interest.
- int 2 - one resolvable component of power equal to 3 dB relative to signal of interest.

Interferer 1 has a delay relative to the signal of interest as follows 1 μs, 3 μs, and 6 μs, for the three components respectively. Interferer 2 has a delay of 1 μs relative to the signal of interest.

If the interfers are turned off then the signal of interest has an SNR of $\frac{E_b}{N_0} = 16$ dB at the receiver as a result of background noise.

In addition the system is affected by a sinusoidal interfering signal of relative power of 6 dB and frequency equal to $f_c + 320$ KHz, where f_c is the carrier frequency.

a) Assuming a correlator receiver determine the signal to noise ratio for the signal of interest in the presence of background noise and interference.

b) Determine the probability of error for the signal of interest.