EEE 558 – Project 1 – Diversity Techniques over Fading Channels

In this project you will use MATLAB to simulate the performance of different diversity techniques. The fading channel model for this problem is given by

$$x_m = \sqrt{\bar{\gamma}}\, h_m s + v_m \quad m = 1, \ldots, M \tag{1}$$

where x_m is the sampled output, h_m is the complex channel gain, and v_m is the noise sample at the m^{th} diversity branch. As we discussed in class, these diversity branches could come about due to a variety of different scenarios, including a situation that involves M receive antennas. We will assume that both v_m and h_m are circularly symmetric complex-Gaussian random variables. Both have zero-mean and variance one for each m. The transmitted information symbols are assumed to come from a PSK constellation with K elements: $\{\exp(j2\pi(k-1)/K)\}_{k=1}^{K}$ Therefore, everything on the right hand side is normalized so that $\bar{\gamma}$ actually quantifies the average SNR of this system. We will assume that the channel h_m is known.

Generalized Selection Combining: This is a hybrid of selection combining and MRC. You select L antennas ($1 \leq L \leq M$) that have the highest channel gain, and you apply MRC on these subset of antennas. Here L here is a parameter that is fixed (i.e., does not depend on the channel coefficients), and tradeoffs performance with complexity. For a fixed M, you should change L to see how the performance changes. Note that $L = 1$ is selection combining, and $L = M$ is MRC.

Simulate each of these schemes using Monte Carlo simulation and compare your simulation results with your analytical results (that you can get for the MRC and SC special cases for some values of K). So analytical results will not be available for all the cases you are doing the simulations, but some are available, and you should compare with those for a sanity check. You should have at least one plot where L is varied and different Ls are compared with each other for the same value of M. You should also have plots where L is fixed, but the different curves are for different values of M. You should also show plots that study the effect of K and L on performance.

Correlated Channels: In addition to simulating the system for i.i.d. fading where h_m are independent, consider also a correlated fading model. Let $\mathbf{h} = [h_1 \ldots h_M]^T$. Define the correlation matrix as $\mathbf{R} = E[\mathbf{h}\mathbf{h}^H]$ where $(\cdot)^H$ denotes Hermitian (conjugate transpose) of a matrix. Note that $\mathbf{R}$ is an $M \times M$ identity matrix when $\mathbf{h}$ has i.i.d. entries. You will simulate the system under this i.i.d. assumption. You also will simulated correlated fading with the so-called equal-correlation model, which provides a good estimate of the correlation statistics of closely spaced antennas. In this case, the main diagonal elements of $\mathbf{R}$ are 1, and the off-diagonal elements are all given by a correlation value of $0 \leq r \leq 1$. Show the affect of r on performance. Does r affect the diversity gain?

Prepare a (typed) write-up that includes all these results (analytical expressions for symbol error rate, plots, and simulations). There should be a short introduction describing what the report is about. The plots will illustrate how these schemes rank in terms of symbol error rate performance as a function of $\bar{\gamma}$ (in dB) where the y axis should be plotted on a log scale. The write-up should also comment on how these schemes will rank in terms of *implementation complexity.* The whole write-up should not be more than 6-7 pages, which includes the figures, but excludes the MATLAB code that you should also print and attach at the end. Please make sure you pay attention to the following:

1. Your report should be self-contained. This means anyone in the world that is in the wireless area can read and understand it. Suppose you put this report online for all the world to see. It should be the case that anyone downloading it and reading it should follow what you did, how you got your Monte Carlo curves, and which equations you are plotting. You can use the terminology "analysis" for plots that are obtained from formulas, and "simulation" for plots obtained from Monte Carlo simulations. You will be graded in the completeness of your report, your English, and general common sense things that you have been told since your undergraduate about how to write a report (label of axes, captions, always using defined terminology, etc.....)

2. There are many parameters to try. To give you some concrete guidelines, try $M = 1, 2, 3$, $K = 2, 4, 8$, and all values of $L \leq M$.

3. The above was for $r = 0$. *For only a few of the above combinations*, try $r = 0.5$ and $r = 0.9$.

4. Your Matlab code should be appended to the end of the report. The variables in the Matlab code should be defined as they are in this document. For example, $\bar{\gamma}$ should be `gammabar`, etc. Similarly for all other variables. If you do not follow this convention, I cannot understand your code, and will take off points.

5. If you are plotting an analytical result (i.e., a formula), this formula should be in your report, and should be labeled in your simulation what formula it is.

6. Did you label everything? It should be clear what the axes are, what M is used, which scheme is which just by looking at the figure and the caption.

7. Do the Monte Carlo simulation results completely agree with the analytical ones? You should make sure you run enough iterations so that this is the case. A good trick to get reliable curves is to run the Monte Carlo simulation until you have a certain fixed number of errors, say, 100 errors. You would do this for each average SNR value $\bar{\gamma}$. Yes, it is true that if you wait for 100 errors, when the average SNR $\bar{\gamma}$ is large, this will take some time. This is why sometimes you might have to have the simulations run

overnight. Curves having zigzags are a sign that you did not run the simulation long enough, and a reason for me to take off points.

8. Are you considering an appropriate SNR range (for $\bar{\gamma}$) so that the diversity order is visible on the plots (i.e., a decrease of as many orders of magnitude as the diversity order in the symbol error rate for every 10 dB increase in SNR). Please see your textbook to determine what is a reasonable range for $\bar{\gamma}$. Also, choose enough values for $\bar{\gamma}$ for your curves to look smooth.

9. The plots should be clearly labeled. If you want to compare two plots (for example the Monte Carlo simulation and analytical results), they should be on the same plot. Note that color is not often visible when printed, so you should distinguish the curves as dash, dash-dot etc.

Please contact me if you have any questions.