Homework 8 submission

ECET 512 — Wireless Systems

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1 Submitted files

For this assignment, this report and the archives outlined below were created or added to and submitted.

1.1 SRC Folder

/ *"mainMU.m"*: This MATLAB scripts conducts the experiment of plotting BER and SNR vs user distance based on a non-trivial trajectory throughout a single cell system with the added ability of simulated various MIMO schemes

1.2 DOC Folder

+ *"mimo_simulation.avi":* This is a video that shows the mobile user moving through the single cell space within the area.

+ "*SNRvsPosition.png*": This photo shows the plot of the signal to noise ratio for each frame of the mobile user moving through the single cell system.

+ "*BERvsPosition.png*": This photo shows the plot of the bit error rate for each frame of the mobile user moving through the single cell system for the SISO mode and all MIMO modes.

+ "*SNRvsBER.png*": This plot shows BER vs SNR for a particular case of sample Rayleigh fading envelopes for decoding a 4-QAM modulated sequence of random bits for the SISO mode and all MIMO modes.

2 Code execution

The MATLAB programming language was used to create the simulations for this homework. To run the simulations, simply run the *"main*.m"* scripts. The scripts showcase the calculation of various envelope parameters in one script and shows an application of this in a mobile setting in the next script.

3 Homework Solution

3.X All in One

For this homework I decided to smush all of the report requirements into one big answer that reflects them all since in my implementation, all MIMO schemes and the SISO scheme were implemented into the simulation from the get-go. In this homework assignment we were asked to expand upon the single input single output (SISO) simulation that we set up last week that determined the bit error rate (BER) for a four-point quadrature amplitude modulation (4-QAM) symbol transmission scheme. Essentially, QAM works by assigning certain bit sequences to points in a complex plane mapping on what's known as a constellation map. In my case I implemented it so that each permutation of two bits mapped to a different quadrant of the complex-real plane. The angle from each axis was kept at a nice 45-degrees (with variation brought about by random frequency modulation and fading) and the radius from the center was the power of that signal received at the base station. The simulation works by first creating one or two bit streams, converting them to their corresponding symbols, and transforming those symbols on their way from the transmitting mobile user to the receiving base station. Each symbol was attenuated corresponding to the distance from the base station and complexly adjusted based on the realized Rayleigh fading envelope specified for the recovery scheme as well as some random Gaussian white noise corresponding to the noise characteristics of the cell system (which remained mostly constant, but still varied slightly with distance).

Last week's homework accounted for just the basic scheme where signals were recovered by a single antenna at the base station and results were plotted for the SISO scheme. This week we worked on various MIMO schemes that modified the BER of the system as the mobile user moved around. The first method was that for using four receiving antennas to receive four realizations of the transmitted symbol stream. Using spectral diversity, the simulated logic controller determined which antenna experienced a signal with the corresponding lowest noise, or highest signal to noise ratio (SNR) and used that symbol as the one to decode for the bit stream. The maximal ratio combining technique used a least-squares mathematical method to combine the inputs of all four antennas in such a way as to maximize the total gain of the combined symbols. Usually this method would be accomplished by weighting each antenna input by a certain weight factor that would achieve the greatest result. This method is computationally intensive, so the least-squares approach was adopted to combine the symbol streams before converting it back to a bit representation. Finally, a two-by-two spatial multiplexing scheme was developed to take advantage of the spread of antennas to simultaneous decode two transmitted streams of symbols. It used a similar method to that of the SISO scheme computationally, but with vectors and matrices that were of a higher degree than the original. The plots for BER vs SNR, BER vs Mobile Position and SNR vs Mobile Position are shown below and results were explained for each plot.

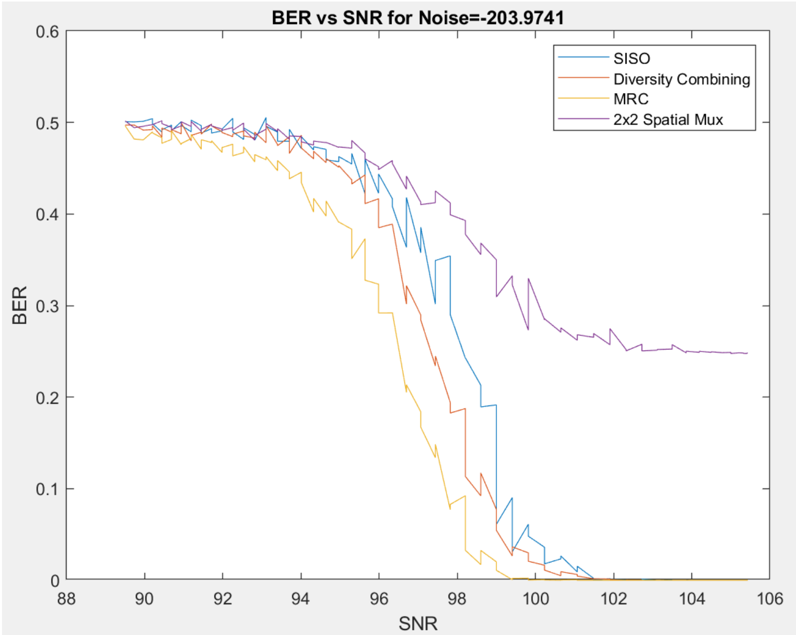

Figure 1: Plot of SNR vs BER for a number Rayleigh fading envelope realizations. The graph shows the results for all four cases specified in the homework assignment write-up. Figure generated using MATLAB.

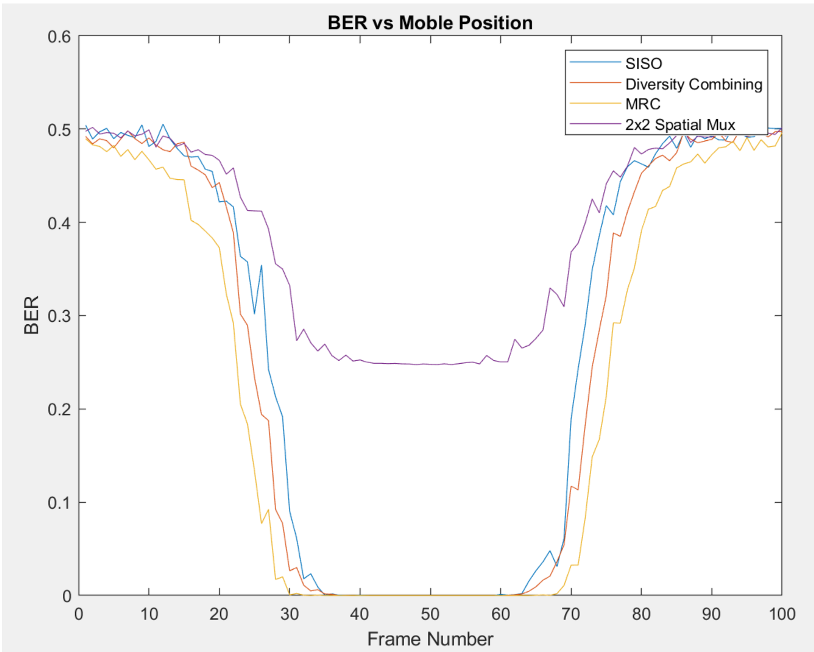

Figure 2: Plot of the bit error rate as the mobile user moves passed the base station. When the signal to noise ratio is greater near the base station, the bit error rate is lowest. The graph shows the results for all four cases specified in the homework assignment write-up. Figure generated using MATLAB.

The plot shows that for all cases, the higher the signal to noise ratio was for the mobile user position, the lower the bit error rate was experience by the base station. Naturally, the SNR was lower the closer the user was to the base station which explains the dip in the middle of the second plot. It seems that for each MIMO case except for spatial multiplexing, the bit error rate was lower than that for a SISO system. Spatial diversity accounts for a small drop in BER compared to SISO because it utilizes knowledge of the fading envelope and leverages that fact that there are four realizations of the transmitted symbol to pick the one corresponding to the greatest SNR. Naturally the less noise for a symbol, or the greater the strength of it, means that there is probably less modification of the symbol. Visually this corresponds to less shifting of the symbol point in the constellation. An error in recovery happens in my case when a symbol is shifted so much that it shifts into a different quadrant than it was generated in.

Maximal ratio combining shows the greatest decrease in BER and this would be even greater if another algorithm (possibly utilizing machine learning techniques) chose proper weights for the antennas. Either way, the least-squares technique was enough to show the improvement over the spectral diversity method. MRC provides a greater improvement over spectral diversity since it is more computationally intensive. The trade off for each one is that MRC is much better and more complex, algorithmically speaking, and spectral diversity is only a little better since it is a simpler algorithm.

It seemed that for the spatial diversity multiplexing, the BER rate actually suffered compared to the other methods. I believe this to be brought about for the following reasons. In the other MIMO cases, there were four antennas per symbol stream that were utilized to decode the bit stream and in this case there were two antennas per symbol stream since two were being decoded. Even though each antenna was working to decode the entire stream, I think this effective ratio is what caused the BER to suffer. It may also be because of the fact that there were indeed two symbol streams making the BER drop because there were naturally more bits to get wrong, twice as much actually! Perhaps a solution to this would be to of course add more antennas, but what the relative improvement of that would be is unknown at this time.

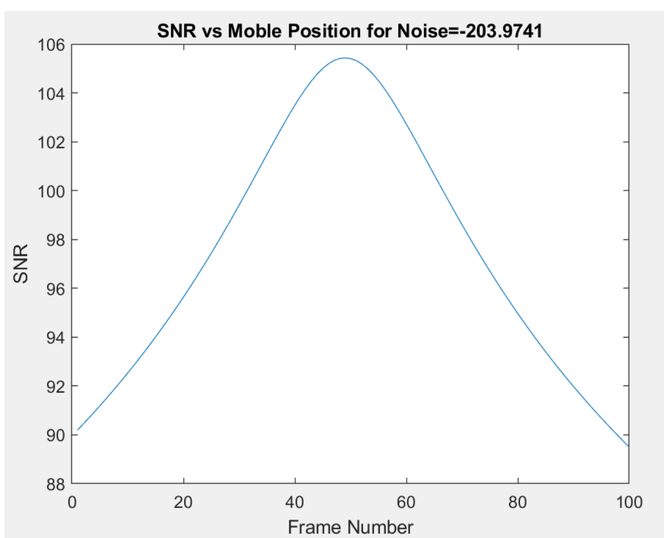

Figure 3: Plot of signal to noise ratio as the mobile user moves passed the base station. It is greater the closer the mobile user gets since the received power is greater at this point. Figure generated using MATLAB.

Naturally, as was experienced in the previous assignment, the signal to noise ratio was much higher near the base station than farther away from it. This is due to the fact that, at least in this simulated system, the noise was pretty consistent throughout, but the received signal power was greater the shorter the distance was between the mobile user and the base station.

3.Y MATLAB Movies

To view the movie illustrating the movement of the mobile user, refer to the flicks found in the DOC archive.