Homework 5 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

+ *"mainHandoff.m"*: The MATLAB script will run a simulation that accomplishes the goal of Problem B. It simulates a single mobile user moving directly from one base station to another, modeling power received by both with and without shadowing effects. It plots this received power with all combinations of fading and shadowing effects.

+ *"mainMultiFading.m"*: This MATLAB script follows the block diagram shown in the assignment sheet to create a Rayleigh-fading envelope for maximum Doppler shift frequencies of 20 Hz and 200 Hz.

1.2 DOC Folder

+ *"handoff_video.avi":* This is a video that shows the results for Problem B. It showcases a single mobile user moving between cell base stations A and B within a single cell cluster. The line drawn indicates the users traveled, and to-be-traveled path.

+ *"RayleighFadingEnvelope.png":* This image shows four plots of the Rayleigh fading envelope. The leftmost plots show results for 20 Hz max shift and the rightmost plots show results for 200 Hz max shift. The top plots are zoomed in images of the bottom ones to better see the peaks and troughs.

+ *" Case1Regular.png":* This picture shows the received signal power as a function of time for the traveling mobile user with no effects of shadowing or fading included.

+ *" Case2Shadowing.png":* This picture shows the received signal power as a function of time for the traveling mobile user with only the effects of shadowing included.

+ *" Case3Fading.png":* This picture shows the received signal power as a function of time for the traveling mobile user with only the effects of fading included.

+ *"Case4ShadowingFading.png":* This picture shows the received signal power as a function of time for the traveling mobile user with both effects of shadowing and fading included.

2 Code execution

The MATLAB programming language was used to create the simulations for this homework. To run the simulations, simply run the "*mainMultiPath.m"* script for problem 4.A and the "*mainHandoff.m"* script for problem 4.B. The first script creates expressions and plots a simulated

Rayleigh fading envelop. The second script shows the handoff simulation of a previous homework this time including the potential effects of shadowing and fading.

3 Homework Solution

3.A Plotting a Simulated Rayleigh Fading Envelope

This problem asked to follow the steps of a block diagram showing how to create a simulated Rayleigh fading envelope that shows the effects of small-scale fading for a mobile user moving through an environment with various IOs. Imaginary Gaussian random variables were taken at 8192 points twice, once for the in-phase arm of the noise and one for the quadrature arm of the noise. The variables were multiplied by the corresponding magnitude of the Doppler spectrum for the maximum Doppler shifts of 20 Hz and 200 Hz. The final envelope was developed by adding the squares of each arm and square-rooting them. The final result for the fading envelope is shown below in Figure 1.

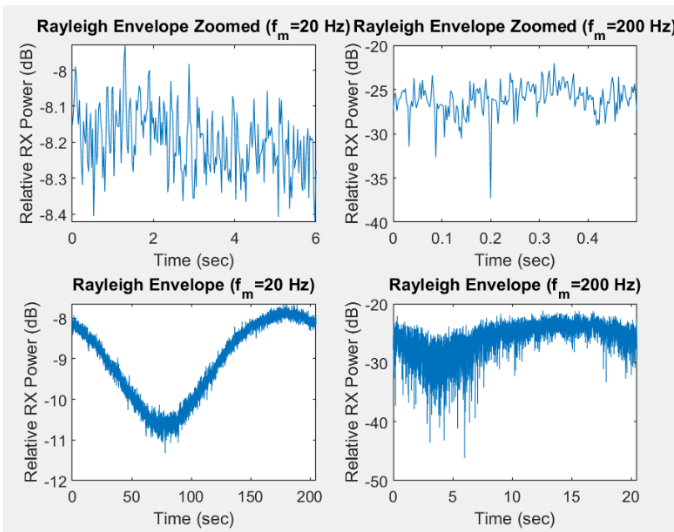

Figure 1: The plots of the simulated Rayleigh fading envelope for two different max Doppler shifts. The top plots show a zoomed in version of the plot directly below it to better see features. Figure generated in MATLAB R2019a.

The plots show that with even small variations in time, which for a moving user means small changes in spatial position, large variations in fading magnitude exist. This may manifest as a mobile user receiving a better signal with the antenna slightly farther from the ear or face. It is also clear that both on the zoomed and non-zoomed images, clear troughs and peaks can be seen.

Note that as the maximum Doppler frequency is increased there is naturally a shortening in the number of samples and time-series duration. More importantly though the waveform's variation becomes greater the potential drop in power jumps more sporadically for smaller distances.

3.B Handoff Procedure with Various Shadowing and Fading Effects

This problem asks to simulate a mobile user traveling directly between two base stations. The setup deems that the mobile user is traveling at about 50 MPH, so the speed of the frames was made equal to one second meaning that it took the mobile user about 90 frames (seconds) to get from one base station to the other. A snapshot of the animation video can be found below in Figure 2. Note that for this case the maximum doppler shift is the speed divided by the wavelength of a 2.4Ghz signal which garnered a max shift of about 178 Hz.

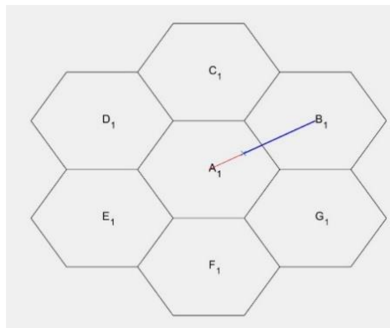

Figure 2: Figure showing one of the mid-frames of the video illustrating handoff procedure for a mobile user. Figure generated in MATLAB R2019a.

In addition to what was done in the previous homework three, this time we are plotting the received power of the mobile user from both base stations under four distinct cases that include every combination of fading and shadowing. The outputs of both simulations in graph form are included below in Figure 3 - Figure 6.

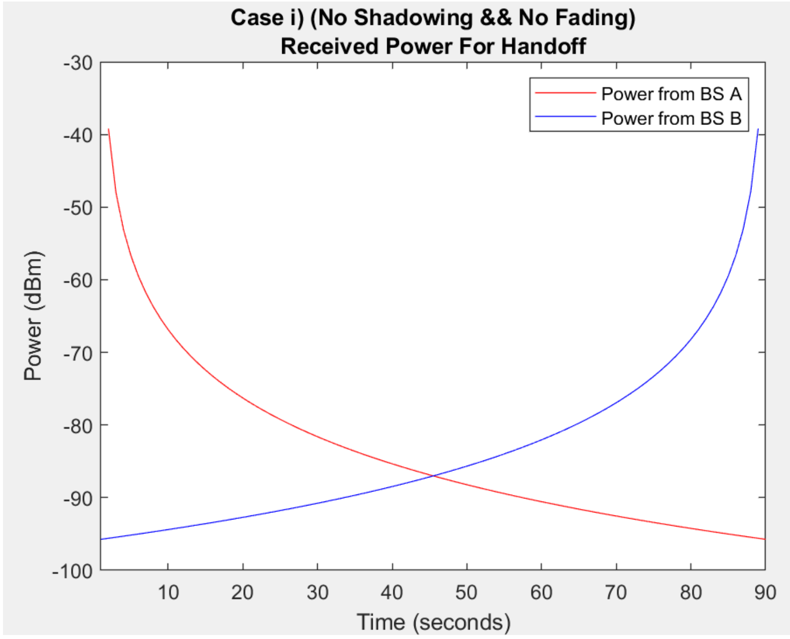

Figure 3: Plot showing the received signal power of the mobile user from both base stations over time. Figure generated in MATLAB R2019a.

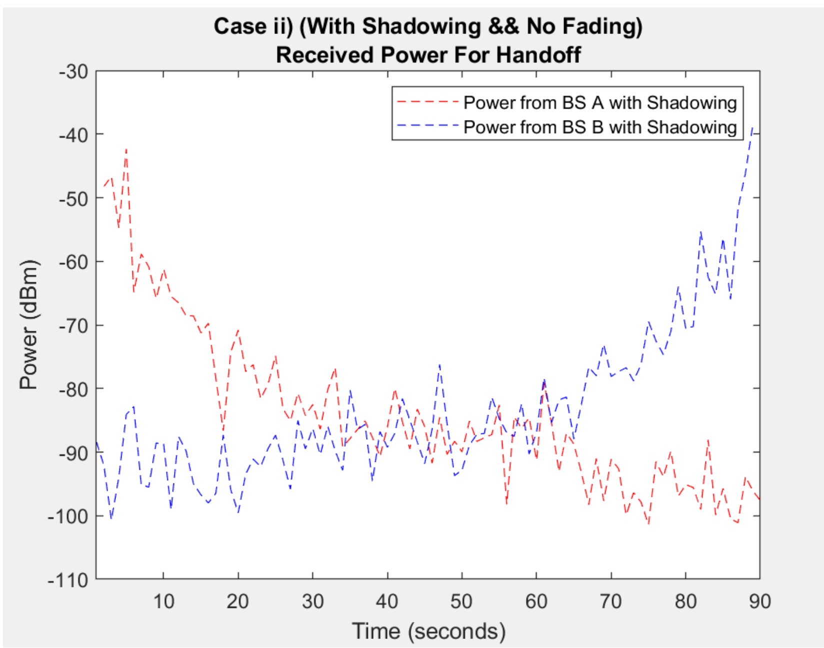

Figure 4: Plot showing the received signal power of the mobile user from both base stations over time with shadowing effects included. Figure generated in MATLAB R2019a.

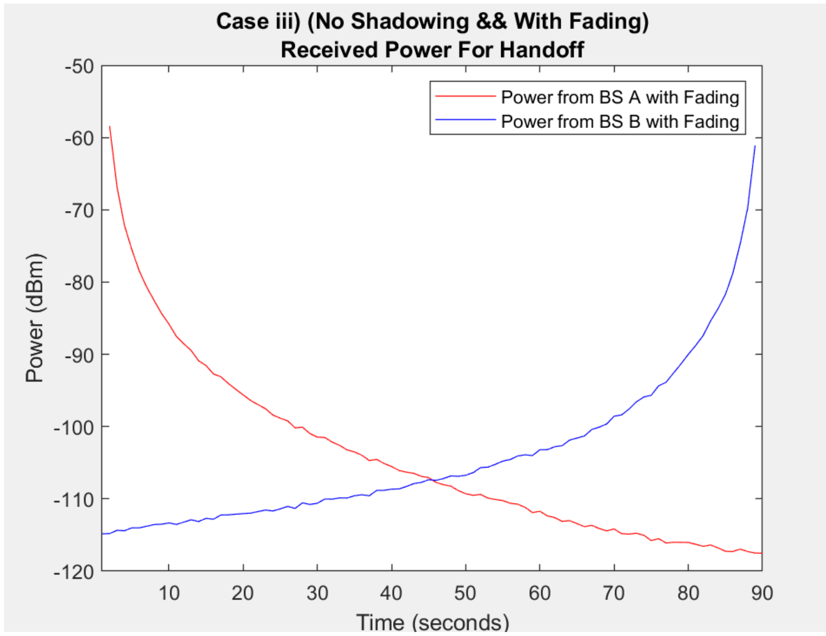

Figure 5: Plot showing the received signal power of the mobile user from both base stations over time with fading effects included. Figure generated in MATLAB R2019a.

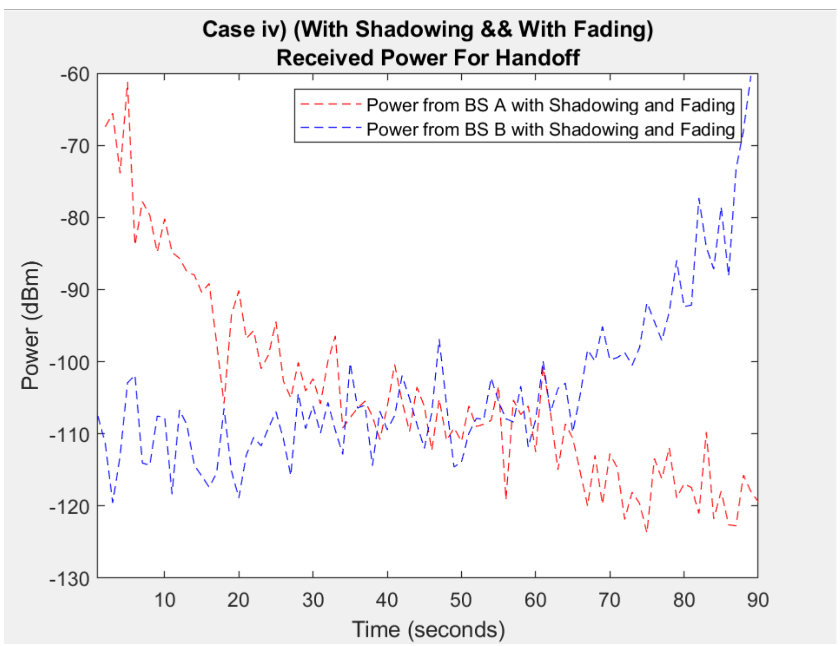

Figure 6: Plot showing the received signal power of the mobile user from both base stations over time with shadowing and fading effects included. Figure generated in MATLAB R2019a.

In the first case it follows a regularly expected path loss calculated using the reference path loss equation with a specified loss coefficient. Signal power decreases exponentially with the square of the distance. The second plot shows what was also garnered in the previous assignment as the shadowing produces large fluctuations in the receive power in situations where the mobile user may be passing through points without a line-of-sight connection to the base station. The signal power decreases with the square of the distance with the great fluctuations of the shadowing simulation.

The third case shows the relatively small magnitude effects caused by the mobile user moving through potential areas where multipath fading occurs. As the user moves through the fading area the effect on the received power may be of a great magnitude or a small one as if varies about the local mean of the main pathloss. Notice how in Figure 5, the received power from the destination base station has smaller visible minimum than in Figure 3 at t=0 seconds. Though the variation may be small from location to location, the magnitude drop from the base case to case three is very visible. Naturally when combining shadowing and fading for case four, the drop in magnitude from fading is visible and the great fluctuation in magnitude from point to point is also evident. As a result the plot show lower magnitude signal values that are very jagged in nature.

For a more composite model for shadowing and fading, most commonly the Nakagami-lognormal distribution is used. This information was garnered from an IEEE Explore paper by Atapattu, Tellambura and Jiang. A link to this paper is provided here for reference. Others include the Rayleigh-lognormal and Rice-lognormal distributions as also mentioned by the article.

3.C MATLAB Movies

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