EITN85: Wireless Communication Channels
Assignment 1

Course Lecturer: Harsh Tataria
Handed Out: Lecture time, 28 January 2020
Due Date: 5 pm, 7 February 2020

Aim

The aim of this assignment is to characterize large scale fading and small scale fading characteristics based on *measured* data from a radio channel measurement campaign.

Preparation

As a preparation for this assignment, it is strongly recommended to go over the material from the lectures thus far, as well as the corresponding chapters and sections in the course textbook by Prof. Andreas F. Molisch. Another optional, but rather useful exercise is to do the computer simulation in section 5.4.1 of the book, and to regenerate figures 5.7 to 5.14.

Outdoor Propagation Measurement Campaign

For this assignment, You will be using data from an outdoor measurement campaign performed here in Lund. The measurement was performed using the so called RUSK Lund channel sounder (channel measurement system), at the carrier frequency of 2.6 GHz. The measurement took place at the Faculty of Engineering at Lund University, in an area which can be best characterized/described as a *semi-urban* microcellular environment. The chosen setup consists of one base station (BS), which is equipped with a single vertically polarized antenna element. The transmit antenna was placed outside of a window at the second floor of the Study center, at a height of about 6 m above the ground level. During the measurement, the receiver was moved in a predefined route circulating the lake, with a total length of 490 m, as shown in Fig. 1.

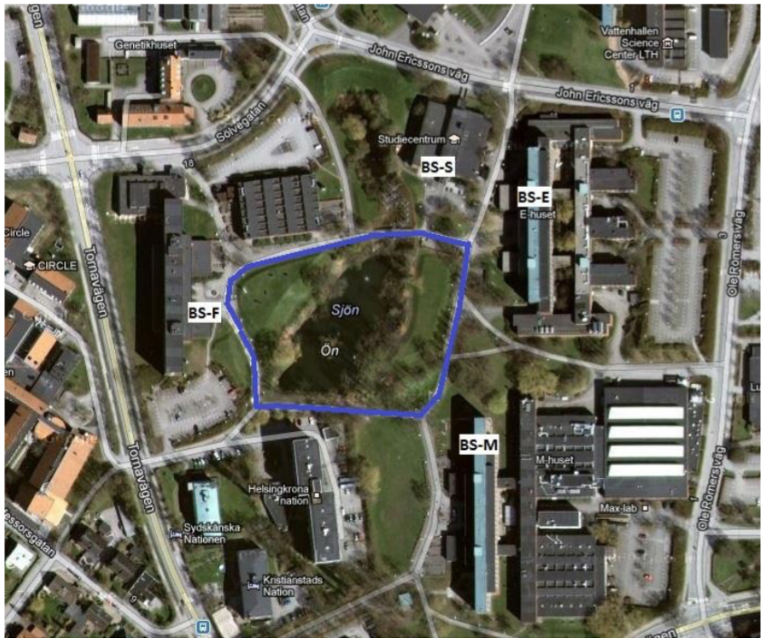

Figure 1: Birds eye view of the measurement environment. The blue line indicates the measurement route for the receiver (Rx), i.e., the user equipment (UE). Even though there are several BSs present in this measurement campaign, **for this assignment, we shall only consider the BS located at the study center (BS-S)**.

Measurement Data Files and Implementation Code

You have been provided with MATLAB data files to be used for the evaluations in this assignment. These data files contain two vectors: The first is named *RxSignal*, and contains the complex amplitudes that were measured and recorded at the receiver. The second is called *Dist*, and contains the Tx-Rx separation distances in meters, that is associated with each amplitude measurement. Note that the TX is the BS, in our case BS-S, and the RX is the UE. On purpose, you have **also** been provided with incomplete implementation code. **Your task is it to complete it, and answer the questions below in a report format:**

Tasks

A1

Run the code and identify the instantaneous channel gain, the small-scale *averaged* channel gain and the theoretical free space gain. Based on the results you observe, how would you characterize the propagation conditions in this measurement? For instance, is the channel behavior line-of-sight (LOS), non-line-of-sight (NLOS) propagation, or obstructed line-of-sight (OLOS)?

A2

We here assume that the small-scale averaged channel gain obeys the log-distance power law which we have discussed in the lectures. That is, the average channel gain as a function of Tx-Rx separation distance, d, is given by

$$\bar{P}(d) = P(d_0) - 10n\log_{10}\left(\frac{d}{d_0}\right), \tag{1}$$

where $P(d_0)$ is the average received power (in dB) at a reference distance of $d_0 = 1$ m, and n is the pathloss exponent. Use ordinary least squares method from curve fitting in mathematics/statistics to find estimates of the parameters $P(d_0)$ and n. Note: If you are not sure about what the least squares method is, please read about it first and make sure you understand it before attempting to answer this question.

A3

Use the parameters You found for the model of equation (1) to subtract the distance dependent average channel gain from the measured small scale averaged power, P_{SSA}. This gives an estimate of the large-scale fading, as:

$$\widehat{LSF}|_{\mathrm{dB}} = P_{SSA} - \bar{P}(d) \tag{2}$$

Plot the empirical cumulative distribution function (CDF) in Matlab, using `cdfplot(LSF)`.

In units of dB, the large-scale fading can often be modelled by a Gaussian distribution, as we discussed in the lectures. Therefore, use the following maximum-likelihood equations to find estimates for the mean, μ_{LSF} and variance, σ^2_{LSF}, of a normal distribution:

$$\hat{\mu} = \frac{1}{N}\sum_{i=1}^{N} LSF(i) \tag{3}$$

$$\hat{\sigma}^2_{LSF} = \frac{1}{N}\sum_{i=1}^{N}(LSF(i) - \hat{\mu})^2. \tag{4}$$

Here, N is the number of samples in the LSF vector. Then, use the values You have obtained to plot the CDF of the normal distribution for the large-scale fading model. The CDF of the normal distribution is given by

$$\frac{1}{2}\left[1 + \mathrm{erf}\left(\frac{x-\mu}{\sigma\sqrt{2}}\right)\right] \tag{5}$$

- Do You think that the modelled CDF agrees well with the empirical CDF? IF yes, why, or if no, why not?

- Based on the measurements, what is the probability that you have a large-scale fading more than 8 dB above the mean?

- Based on the model you have extracted, what is the probability that you have a large-scale fading more than 8 dB above the mean? Are the two results comparable?

A4

Plot the empirical CDF of the small-scale fading amplitude, SSF_{amp}. Then use the following to find an estimate of the square of the scale parameter, σ_R, for the Rayleigh distribution, based on the measured small-scale fading:

$$\hat{\sigma_R^2} = \frac{1}{2N} \sum_{i=1}^{N} SSF_{amp}(i)^2. \tag{6}$$

Now, plot the CDF for the Rayleigh distribution, using the estimate you have found. The Rayleigh CDF is given by:

$$1 - \exp\left(-x^2/(2\sigma_R^2)\right). \tag{7}$$

- Do you think that the modelled CDF has a good fit with the empirical CDF for the small scale fading? If yes, why or if no, why not?

A5

If there is a dominant component present in the measurement, then a Ricean distribution could perhaps be a more valid model for the small scale fading. Here, You are given estimates for the Rice distribution, which are based on this data set. These estimates are: $\hat{\nu} = 0.84185$ and $\hat{\sigma}_{Rice} = 0.489$. Plot the CDF for the Rice distribution with these parameters. The CDF of the Rice distribution is given by:

$$1 - Q\left(\frac{\nu}{\sigma_{Rice}}, \frac{x}{\sigma_{Rice}}\right), \tag{8}$$

where Q is the Marcum Q-function (not to be confused with the Q-function that is also used in statistics). Hint: Type "help marcumq" in MATLAB.

- Compare the CDFs for the Rice and the Rayleigh distribution: Which one has the best fit? Is the difference large between these two models?

Assignment Submission

Submit Your assignment no later than 5 pm, 7 February. Your submission should include the following:

- A technical document/report, where you address ALL the questions posed in this assignment. Note that emphasis needs to be placed on the motivation/justification for your answers. As such, the report should include a detailed discussion around the different questions, in which you should provide and motivate the values for the different parameters that you derive.
- Include plots of your results. Those plots should be clear and visible with labels on the axes and appropriate units. Note that jpeg-files may NOT produce clear MATLAB plots, jpeg is good for photographs, but not for scentific graphs and plots.
- Submit your code. This should be added as an appendix in the technical document that You provide. It is NOT necessary to submit the MATLAB m-files.

Submit your complete assignment as a pdf-file to harsh.tataria@eit.lth.se. Name your file EITN085-ASSIGN1-Lastname.pdf, where you replace "Lastname" with your own last name. The subject of your e-mail should be EITN085-ASSIGN1-Lastname.

WARNING: If you discuss ANY part of the assignment with anyone else in the class, you need to declare this upfront on the report document. Failing to do this will motivate me to seek further action.

Good Luck!