ETIN10 - Channel Modeling for Wireless Communications - Assignment 1

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Aim

The aim of this assignment is to characterize the pathloss, 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 recommended to go over the material from the third lecture as well as the corresponding chapters and sections in the course textbook by Andreas F. Molisch. Another optional (but very useful) exercise is to do the computer experiment 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, at LTH. The measurement was performed using the RUSK Lund channel sounder, using a 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 as a semi-urban microcell environment. For this assignment, 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.

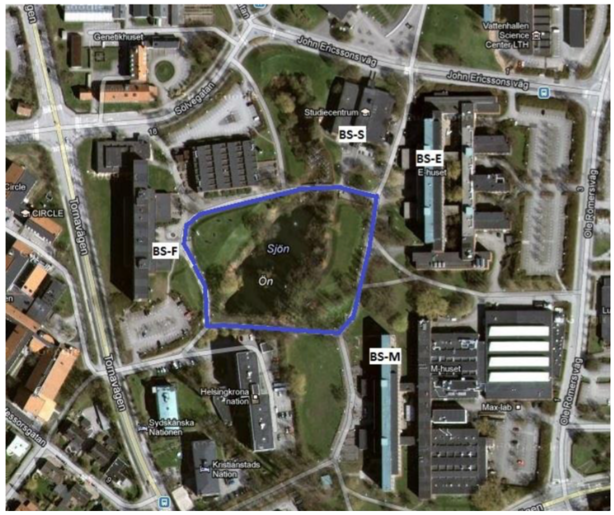

Figure 1: Aerial photo of the measurement environment. The blue line indicates the measurement route for the receiver (Rx), i.e., the user equipment (UE). There are several base-stations present in this measurement campaign. However, **for this assignment, we shall only consider the BS located at the study center (BS-S)**.

Measurement data files and Code

You have been provided with Matlab data files to be used in this assignment. These data files contain two vectors. The first one is named *RxSignal*, and contains the complex amplitudes that were recorded at the receiver. The second vector is called *Dist*, and contains the Tx-Rx separation distances in meters, that is associated with each amplitude mesurement.

You have also been provided with an unfinished code. You task it to complete it and answer the questions below:

Tasks

A1

Run the code and check the results shown in figure 1. Identify the channel gain, the small-scale averaged channel gain and the theoretical free space channel gain. How would You characterize the propagation condition in this measurement: Is it line-of-sight (LOS) propagation, non-line-of-sight (NLOS) propagation, or obstructed line-of-sight (OLOS) propagation?

A2

We here assume that the small-scale averaged channel gain obeys the log-distance power law, i.e., that the average channel gain, as a function of Tx-Rx separation distance, d, is given by

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

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 to find estimates of the parameters $P(d_0)$ and n.

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 normal distribution. 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

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

- Do You think that the modelled CDF agrees well with the empirical CDF?
- Based on your measurement, what is the probability that you have a large-scale fading more than 8 dB above the mean?
- Based on the model you 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?

A5

If there is a dominant component present in the measurement, then a Rician 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 on Feb. 1st. Your submission should include the following:

- Three figures, showing the channel gain, large-scale fading and small-scale fading plots.

- A technical document, where You adress the questions posed in this assignment. This should include a discussion around the different questions, and You should provide numbers for the different parameters that You derive.

- Submit Your code. This should be added as an appendix in the technical document that You provide. It is not neccessary to submit m-files.

Submit Your results to `carl.gustafson@eit.lth.se` before the deadline.