Mobile Communication
Summer term 2020
Exercise Sheet # 1

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- Release date: **April 24, 2020**
- The exercise sheet must be solved in groups of two or three students, and you must register your group beforehand. Registration process:
  - **Not later than May 04, 2020 23:59 CEST.**
  - Registration is done via PECAS: `https://pecas.net.cs.uni-bonn.de`
  - To register in PECAS, you need a valid computer science account.
  - After registering with PECAS, you will be added to a corresponding exercise group in GitLab: `https://git.cs.uni-bonn.de`
- Submission of solutions:
  - **No later than May 11, 2020 23:59 CEST.**
  - Submission is done online via the corresponding GitLab project. If you never used Git before, make sure to get some familiarity with Git before the deadline. Submissions using other media (e-mail, ...) **are not acceptable**.
  - A complete solution must contain:
    - **All scripts/source files** used for solving the programming exercises
    - **A single PDF file** containing your documentation/explanations for all exercise tasks as well as **all relevant plots**.
  - You may update your solution using Git before the deadline as often as you want. Only the final submission made before the deadline will count.
  - In order to get admitted to the exam, you need to hand in solutions and achieve at least 200 out of 400 total points (50%).
- Presentation of solutions:
  - **On May 12, 2020 16:00-17:30 CEST.**
  - Voluntary presentation and discussion will be held online via **BigBlueButton**. URL and access code for the meeting can be found on the MoCo web page.

Exercise 1: Free Space and Two-Ray Ground propagation [20 Points]

In lecture section 2.1 the *Free Space Propagation Model* (FSP) and the *Two-Ray Ground Propagation Model* (TRG) have been introduced. If we ignore the optional gain values, both models can be defined as follows:

$$FSP : P_r = \frac{P_t \cdot \lambda^2}{d^2 \cdot (4\pi)^2}$$

$$TRG : P_r = \frac{P_t \cdot h_t^2 \cdot h_r^2}{d^4}$$

Variable definitions: P_t – Transmitted power, P_r – Received power, λ – Wavelength, d – Distance, h_t – Transmitter antenna height, h_r – Receiver antenna height

1. In the study of wireless communication it is often desirable to express the attenuation independently of the absolute power levels. Instead we use the *Path loss*, which is defined as:

   $$PL[dB] = 10 \cdot log_{10} \frac{P_t}{P_r}$$

   Using the definitions of FSP and TRG given above, derive a formula to calculate the path loss PL_{FSP} and PL_{TRG} independently of a specific P_t and P_r value.
2. TRG does not provide meaningful results for small distances. Therefore it is a common practice to define a *crossover distance* d_c and use FSP for distances $d \leq d_c$, TRG for $d > d_c$. For this exercise sheet, we assume:

   $$d_c = \frac{4\pi \cdot h_t \cdot h_r}{\lambda}$$

   Prove that there is a smooth transition between the two models at the crossover distance, i.e. prove that both models yield equal results at d_c.

Exercise 2: Comparing two path loss models [40 Points]

The MoCo lecture also defines a path loss model based on a known reference loss and an environment-dependent path loss exponent. For this exercise sheet we use a specific variant of this model, the *Three Log Distance Model* (TLD), which defines three different distance fields and their corresponding exponents. Specifically, TLD is defined as:

$$PL_{TLD} = \begin{cases} 0 & d < d_0 \\ L_0 + 10 \cdot n_0 \log_{10}(\frac{d}{d_0}) & d_0 \leq d < d_1 \\ L_0 + 10 \cdot n_0 \log_{10}(\frac{d_1}{d_0}) + 10 \cdot n_1 \log_{10}(\frac{d}{d_1}) & d_1 \leq d < d_2 \\ L_0 + 10 \cdot n_0 \log_{10}(\frac{d_1}{d_0}) + 10 \cdot n_1 \log_{10}(\frac{d_2}{d_1}) + 10 \cdot n_2 \log_{10}(\frac{d}{d_2}) & d_2 \leq d \end{cases}$$

Variable definitions: d – Distance, d_0, d_1, d_2 – Three distance fields, n_0, n_1, n_2 –path loss distance exponent for each field, L_0 – path loss at reference distance d_0

1. Write a program that implements the path loss calculation using the combined FSP and TRG models with crossover distance d_c. In addition, the program should be able to calculate the path loss according to the TLD model.
2. Using your program, generate a plot of the calculated path loss of both FSP/TRG and TLD for the distance range from 0 meters up to 10000 meters. Use the following parameters for your calculations and plots:
   - $\lambda : 1.35m$
   - $h_t : 50m$
   - $h_r : 2m$
   - $d_0, d_1, d_2 : 1m, 200m, 500m$
   - $n_0, n_1, n_2 : 2.0, 3.0, 3.0$
   - $L_0 : 19.377dB$
3. Give a brief description of your implementation and the resulting plot.

Hint: You may check your implementation for correctness using the following reference results.

Distance	**FSP/TRG**	**TLD**
1000m	80.00	86.37
5000m	107.96	107.34
10000m	120.00	116.37

Exercise 3: Reality check [40 Points]

On the MoCo web page we provide the file *ex01.csv* containing a set of real world measurements conducted inside of a moving car. Each line of the file contains a *timestamp*, the *receiver geo-coordinates* and the *relative signal strength* (a unitless value between 0 – no signal reception, and 1 – perfect signal reception). The transmitter is a fixed antenna located at $50°42'25.96"N, 7°5'49.13"E$.

1. Extend your program so that it can calculate the path loss based on two geographic coordinates.
2. Compute the expected path loss for the moving car using both of the models defined before. Produce a plot which shows the expected path loss for both models in comparison to the conducted measurements.
3. Do the path loss models correctly represent the real world signal propagation? Give reasons why this might (not) be the case.