ELEC-H415 Communication channels
Channel modeling for 5G small cells

1. Objectives

5G small cells will be soon deployed to provide very high data rates, at street level. They will complement the usual urban cells whose base stations are located on rooftops, typically. Small cell base stations (BS) will be installed on urban furniture, at height comparable to user equipment (UE). They will communicate at frequencies around 26GHz (in Europe), with very large bandwidths, up to 200MHz in Belgium.
The goal of this project is to numerically model small cell channels, by using ray-tracing and image theory to simulate propagation.

2. Scenario

You are asked to model the downlink channel from a 5G small cell BS towards a mobile UE on the Grand Place/Grote Markt in Brussels and its surrounding streets, shown in Figure 1. The BS is located in the western corner of the square, as marked by the red dot.

Communication parameters

- Vertical half-wave dipoles as transmit and receive antennas
- Carrier frequency: 26 GHz
- BS and UE at the same height (2 m)
- Maximum EIRP: 0.25 W
- Target SNR at UE: 5 dB
- Receiver noise figure: 12 dB

Ray-tracing parameters

- Ground and buildings have relative permittivities between 3 and 5.
- Consider up to double reflections off buildings as well as the ground reflection.
- Consider diffraction, wherever a LOS is not present.
- Square and streets are divided in local areas of 1 m^2. All local parameters are calculated at the center of each local area only.
- Minimal distance to the base station: 10 m.

Due to the simplified scenario, the deduced propagation model won't be based on the usual three scales of analysis (path loss, shadowing, small scale fading) but on two scales only: path loss and global fading. This global fading will be assumed log-normally distributed (which is only approximate in this calculation).

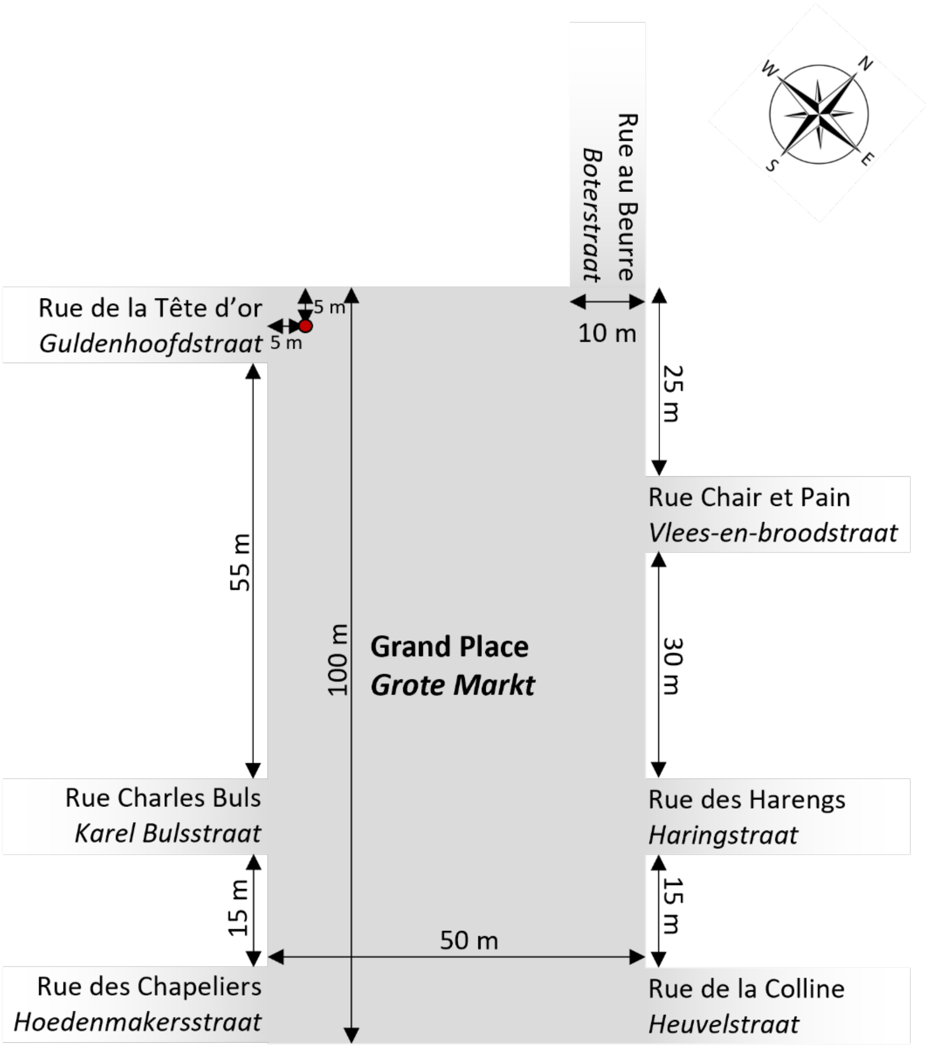

Figure 1: Approximate geometry of Grand Place / Grote Markt in Brussels

3. Minimal Requirements

Discuss the following properties, based on (i) a 2D plot (e.g. heatmap) covering the full map, and (ii) a 1D plot from the BS position to the eastern (i.e. bottom right) corner of the square:

- Received power
- Signal-to-noise ratio at UE, for a 200 MHz bandwidth
- Delay spread
- Rice factor

At the center of the square and in the eastern corner, visualize the rays between the BS and UE and discuss:

- Physical impulse response
- Tapped delay line (TDL) impulse response (as a function of bandwidth, from narrowband until 200MHz at least)

Based on your results, a propagation model for the square should be built. It should include:

- Path loss model
- Fading variability
- Cell range as a function of connection probability at cell edge

Going beyond these minimal requirements is encouraged to maximize your grade, for example:

- Comparing the uncorrelated scattering TDL impulse response with the TDL impulse response.
- Deriving the penetration depth in the streets adjacent to the square.
- Deriving the whole cell connection probability as a function of cell range.
- Investigating beamforming at the base station.
- Deriving a propagation model for the Rue de la Tête d'Or/Guldenhoofdstraat, and comparing the results with those obtained on Grand Place/Grote Markt.
- Designing a BS deployment strategy that minimizes the number of base stations or base station density, while maximizing the probability of connection on Grand Place/Grote Markt and its adjacent streets.
- ...

4. Report

Evaluation will be done based on a written report of max. 15 pages, that should include at least:

- The theoretical foundations for your software. Specifically, the induced voltage should be derived for the following scenarios at least:
    i. Line-of-sight ray
    ii. Single reflection of a building
    iii. Ground reflection
    iv. Diffracted ray
- Validation of your simulation and calculations
- Analyses and physical interpretations of the results from section 3.

The report (as a single PDF file) and code source files (in a zip file) should be submitted by email (philippe.dedoncker@ulb.be) by May 29 2022 for the June session and August 14 for the August session.