Université libre de Bruxelles

École polytechnique de Bruxelles

ELEC-H415

Communication channels
Project

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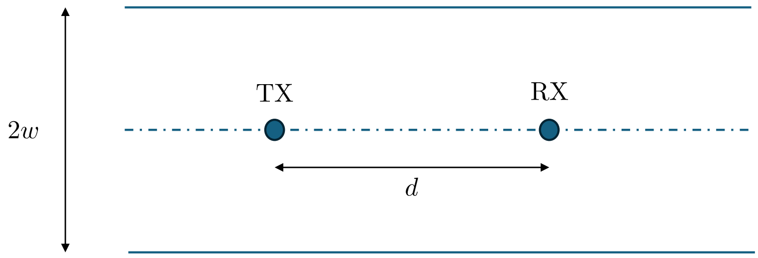
Modeling the Vehicle-to-Vehicle (V2V) communication channel

We propose to develop step-by-step a full channel model for V2V communications in a urban area.

Let's consider two vehicles driving in the middle of a street of width $2w = 20\,\text{m}$ surrounded by two raws of buildings as depicted in the figure below. The two vehicles are driving at the same speed, at a distance $d < 1\,\text{km}$ from each other.



The communication parameters are the following:

- Carrier frequency: $f_c = 5.9\,\text{GHz}$
- RF Bandwidth: $B_{RF} = 100\,\text{MHz}$
- Receiver sensitivity: -70 dBm
- TX and RX antennas: vertical $\lambda/2$ dipoles.
- Transmit power: $P_{TX} = 0.1\,\text{W}$.
- Received power: P_{RX}.
- Signal to be transmitted: $\underline{V}_{TX}$
- Current injected on TX antenna: $\underline{I}_a$
- Open-circuit voltage induced at RX: $\underline{V}_{oc}$
- Received signal: $\underline{V}_{RX}$
- The transmitter and receiver electronics are supposed to be perfectly matched to the antennas.

The buildings have a relative permittivity $\varepsilon_r = 4$. The local areas required to analyze the channel are straight segments of length = 5m.

Step 1: Theoretical preliminaries

1. Draw the equivalent electric circuit at TX and RX. At TX make $\underline{V}_{TX}$ and $\underline{I}_a$ appear on the drawing. At RX, make $\underline{V}_{oc}$ and $\underline{V}_{RX}$ appear.
2. Write the transverse part of the equivalent heights of the antennas, in the horizontal plane.
3. Derive the emitted electric field in free-space in the horizontal plane. Make appear in the expression $\underline{V}_{TX}$, Z_0, f_c and τ (the propagation delay).
4. Deduce $\underline{V}_{RX}$ as a function of $\underline{V}_{TX}$ in this free-space case.

Step 2: LOS channel

Let us suppose that communication takes place via a LOS ray only. Let τ_1 be the propagation delay and d_1 the propagation distance of the LOS.

1. Find $h(\tau)$ as a function of d_1.
2. Deduce $H(f)$.
3. Derive the narrowband transfert function h_{NB}.
4. Find the received power P_{RX} as a function of P_{TX} and compare to the Friis' formula.
5. Explain and interpret as much as you can all results.

Step 3: Full channel, narrowband analysis

We take now into account reflections off buildings, in the narrowband case. We limit our calculations to maximum triple reflections off buildings. We neglect reflection off the ground.

1. Compute the propagation delay and angle of reflection of every MPC for, at least, 1, 2 and 3 reflections off the buildings.
2. Derive, separately for every MPC, the received voltage. Deduce the total received voltage.
3. Find the received power P_{RX} as a function of P_{TX} and compare again to the Friis' formula. Plot the result.
4. Derive the theoretical expression of the Rician K factor. Plot the result.
5. Compute the average received power in every local area (5m segments). Fit a path loss model. Plot the result.
6. Compute the variability σ_L around the path loss model.
7. By supposing that power variations around the path loss model is log-normal (which is not exactly the case due to simplistic geometry), find the fade margin required to reach 50%, 95% and 99% communication reliability. Deduce the cell range in each case.
8. Explain and interpret as much as you can all results.

Step 4: LOS channel, wideband analysis

We go now to the wideband case, but for LOS only communication.

1. Consider again from Step 2 $h(\tau)$ and $H(f)$ in this case. Plot the results (amplitude plots).
2. Deduce from Step 2 $h_{\text{TDL}}(\tau)$ in this case. Plot the result (amplitude plot).
3. Explain and interpret as much as you can all results.

Step 5: Full channel, wideband analysis

We consider again all MPCs.

1. Write the physical impulse response $h(\tau)$. Plot the result (amplitude plot).
2. Deduce $H(f)$. Plot the result (amplitude plot).
3. Deduce $h_{\text{TDL}}(\tau)$. Plot the result (amplitude plot).
4. Explain and interpret as much as you can all results.

Step 6: Further analyses

Be creative and go beyond those minimal requirements to analyze further the channel.