Tutorial 3: Digital Communication
Modern Radio Systems Engineering

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Digital Communication

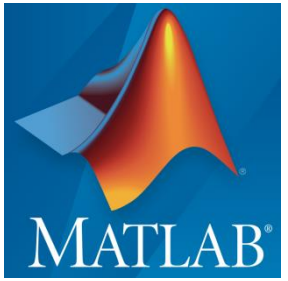
- Simulating a communication system on an abstract level
- Focus on digital signal processing and signal theory
- Quality analysis of the communications link
- Simulation in equivalent baseband representation
- Independent of RF frontend components

Simplified Digital Communication Link

- Digital Signal Processing
  - Source coding
  - Channel coding
  - TX/RX Filter
  - Digital Modulation
  - Add header (frame based transmission)
  - …
- RF Frontend
  - Amplifier (LNA/PA)
  - Filter
  - Mixer
  - Local oscillator
  - Phase shifter
  - Coupler
  - Frequency multiplier
  - …
- Channel
  - Free Space Path Loss
  - Atmospheric attenuation
  - Multipath propagation
  - Fading
  - Interference
  - …

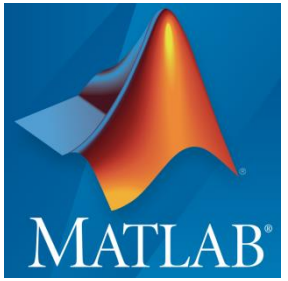
Introduction to MATLAB

- MATLAB documentation
  - Type *doc* into the command line and press ‘enter’
  - Mark with your curser the unknown function and press ‘F1’
- Get started with MATLAB
  - https://www.mathworks.com/help/pdf_doc/matlab/getstart.pdf
- MATLAB description on Wikipedia
  - https://en.wikipedia.org/wiki/MATLAB



Further Help and Beyond

- MATLAB at home
  - As a KIT-Student you can download MATLAB for free from the software shop: https://rzunika.asknet.de (you just have to register yourself and sign in with your KIT account)
  - You can find a bunch of online tutorials at: mathwoks.com (create an account at mathworks.com with your KIT student email address).



- Python
  - There is also an open source programming language widely used called Python for doing calculations like in MATLAB.
  - The development environment, compiler and many libraries can be downloaded for free from the internet.
  - Increasing popularity due to the avoidance of license fees.

Goal 1
Understanding Digital Communication Systems

- Open the m-File *digital_communication.mat* and try to understand the MATLAB code and run the simulation.

Tasks:

- Draw the basic block diagram out of the MATLAB code.
- At which point can you observe the constellation diagram? Make a plot.
- Where can you see the eye diagram ? Make a plot.

Hint: Code to create a simple graph in MATLAB: figure; plot(x,y,'.');

Questions:

- What is the function of the gray encoder?
- What are the two basic tasks of the pulseshaping filter?
- What is the drawback of using a high filter length?
- What does the eye diagram tell you?
- How are E_b/N_0 and SNR connected? Give a formula.

Goal 2
Impacts of I/Q-Imbalances on Signal Quality

Tasks:

- Change the simulation to investigate the influences of I/Q-Imbalances in amplitude and phase.
  - Insert your code after the AWGN channel block. The I/Q-Imbalances in amplitude and phase should be implemented separately.
    - The amplitude imbalance parameter should be insert in **dBm**.
    - The phase imbalance parameter should be insert in **degree**.
  - Plot the resulting changes in the constellation diagram and make a sketch of the characteristic picture for your protocol (use 16-QAM).

Questions:

- Where at a common transceiver architecture can I/Q-Imbalances occur? Name the critical components and their influences.

Goal 3
Frame Detection and Data Recovery

- Open the m-File *frame_detection.mat*
  - In this program a received signal and a training sequence is loaded from a .mat file which should exist in your folder.
  - Afterwards the received signal is processed by a matched filter and a demodulator.

Tasks:

- Find out which modulation format and order is used for the transmitted data and change the parameters for the decoder appropriate.
- Define the start of the frame by using the known training sequence from file (Variable: *training*)
  - Enter the start index of the frame regarding the received bit sequence (Variable: *rx_signal*) as *offset.*
  - What is the start index and what can you see on the image?

rx_signal