Physical Communication

Construcation of OFDM Transceiver

Michalopoulos Angelos
Vlad-Eusebiu Baciu
Boya Zhang

January 14, 2021

VRIJE
UNIVERSITEIT
BRUSSEL

CONTENT

1. Introduction
2. Transmitter
3. Channel
4. Receiver
5. Results
6. Conclusions and Discussion

1. Introduction
2. Transmitter
3. Channel
4. Receiver
5. Results
6. Conclusions and Discussion

INTRODUCTION

1. **Goal of the project:** Make a transmit/receive simulation model for a generic OFDM simulation.
2. **Future work:** Compliant with the IEEE 802.11p standard.

MODEL STRUCTURE

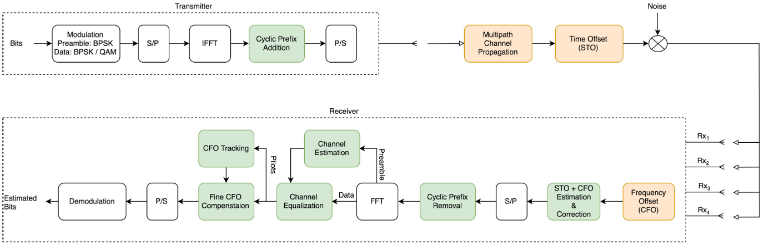


Figure: OFDM Model Structure.

TRANSMITER OVERVIEW

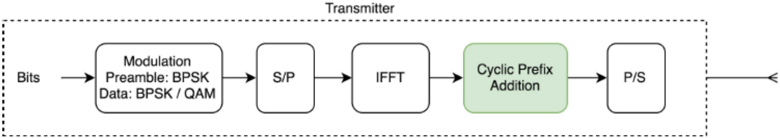


Figure: Transmitter Structure.

MODULATOR

QAM: amplitude modulation with two orthogonal carriers.
Gray Code: two successive values differ in only one bit.

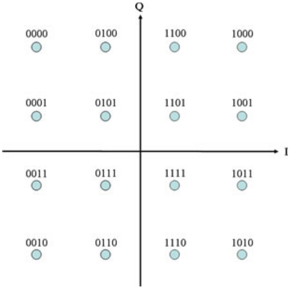


Figure: 16-QAM Signal Constellation with Gray Coding.

S-P/P-S CONVERTER

Serial to Parallel during modulation: The input data is formatted into 4 bits/symbol(16-QAM), 10 symbols/subcarrier and with 90 subcarriers. The goal is to perform IFFT calculation on each subcarrier at the same time.

Parallel to Serial after adding cyclic prefix and before transmission: Transmit the serial data with one antenna.

IFFT/FFT

IFFT on transmitter: multi-carrier modulation.
FFT on receiver: multi-carrier demodulation.

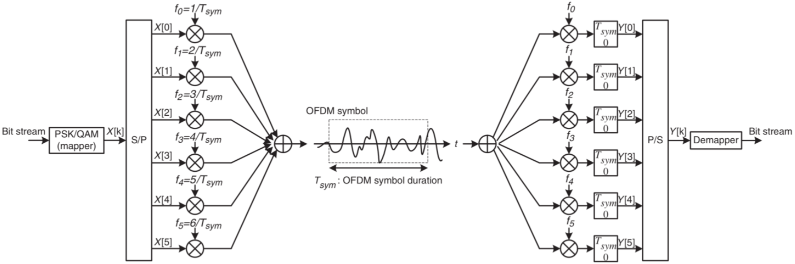


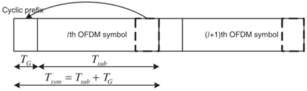
Figure: IFFT and FFT at transmitter and receiver side.

PILOT SYMBOLS

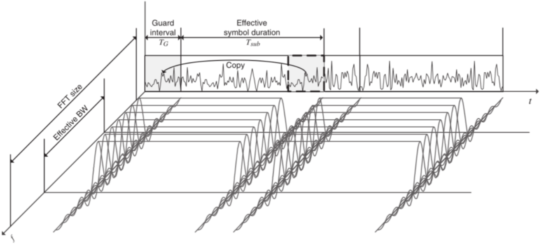
A pilot symbol is a complete OFDM symbol where the value of each subcarrier is predefined and known in transmitter and receiver. It is repeated with a certain rate that depends on how fast the channel changes. The received signal is correlated with the pilot symbol to detect the OFDM symbol start. It can also be used for channel estimation. In our experiment, the pilot frequency is $5 + 5i$ and there are 6 groups of pilot tones.

CYCLIC PREFIX

Cyclic Prefix: OFDM guard interval.



(a) OFDM symbols with CP



(b) Time/frequency-domain description of OFDM symbols with CP

Figure: Cyclic Prefix Illustration.

Channel

Multipath fading

VRIJE
UNIVERSITEIT
BRUSSEL

MULTIPATH FADING

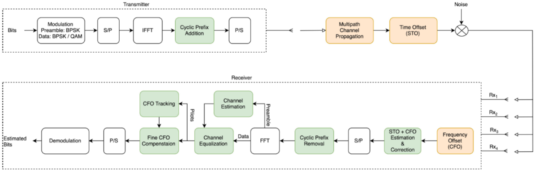


Figure: Block Diagram of OFDM System

The idea is that we need to .....

Channel
General Idea (Transfer function)

VRIJE UNIVERSITEIT BRUSSEL

TRANSFER FUNCTION

THE MAIN IDEA IS TO

red as the a good ca

1. Introduction
2. Transmitter
3. Channel
4. Receiver
5. Results
6. Conclusions and Discussion

SYNCHRONIZATION FOR OFDM

HOW CAN WE CORRELATE THE SIGNAL TO THE REAL ONE

red as the a good ca[1]

Receiver

Symbol Time Offset (STO)

VRIJE
UNIVERSITEIT
BRUSSEL

red as the a good ca

Receiver

Carrier Frequency Offset (CFO)

VRIJE
UNIVERSITEIT
BRUSSEL

CFO

HOW ONE

red as the a good ca

Receiver

Channel estimation

VRIJE
UNIVERSITEIT
BRUSSEL

RECEIVER

CHANNEL ESTIMATION

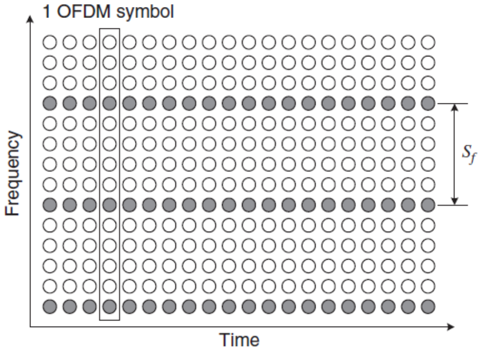


Figure: Comb-type pilot arrangement

- $S_f \leq \frac{1}{\sigma_{max}}$

- Suitable for fast-fading channels, but not for frequency-selective channels

- LS Channel Estimation

The least-square (LS) channel estimation method finds the channel estimate H in such a way that the following cost function is minimized:

$$
\begin{aligned}
J(\hat{\mathbf{H}}) &= \left\|\mathbf{Y}-\mathbf{X}\hat{\mathbf{H}}\right\|^2 \\
&= (\mathbf{Y}-\mathbf{X}\hat{\mathbf{H}})^H(\mathbf{Y}-\mathbf{X}\hat{\mathbf{H}}) \\
&= \mathbf{Y}^H\mathbf{Y}-\mathbf{Y}^H\mathbf{X}\hat{\mathbf{H}}-\hat{\mathbf{H}}^H\mathbf{X}^H\mathbf{Y}+\hat{\mathbf{H}}^H\mathbf{X}^H\mathbf{X}\hat{\mathbf{H}}
\end{aligned}
$$

$$\hat{\mathbf{H}}_{LS} = (\mathbf{X}^H\mathbf{X})^{-1}\mathbf{X}^H\mathbf{Y} = \mathbf{X}^{-1}\mathbf{Y}$$

CHANNEL ESTIMATION

- Data interpolation

```
if pilot_loc(1)>1
slope = (H(2)-H_est(1))/(pilot_loc(2)-pilot_loc(1));
H = [H(1)-slope*(pilot_loc(1)-1) H];
pilot_loc = [1 pilot_loc];
end

if pilot_loc(end) <n_subcarriers
slope = (H(end)-H(end-1))/(pilot_loc(end)-pilot_loc(end-1));
H = [H H(end)+slope*(n_subcarriers-pilot_loc(end))];
pilot_loc = [pilot_loc n_subcarriers];
end
H_interpolated=interp1(pilot_loc,H,(1:n_subcarriers));
```

1. Introduction
2. Transmitter
3. Channel
4. Receiver
5. Results
6. Conclusions and Discussion

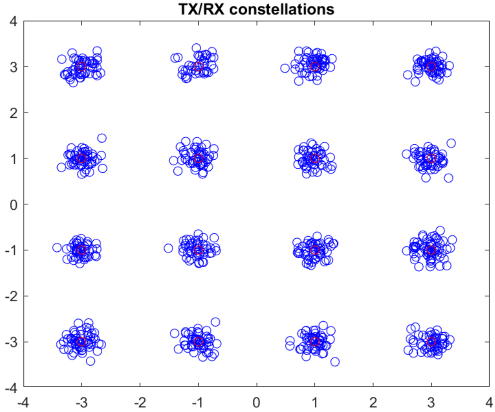
Results

Transmitter side

VRIJE
UNIVERSITEIT
BRUSSEL

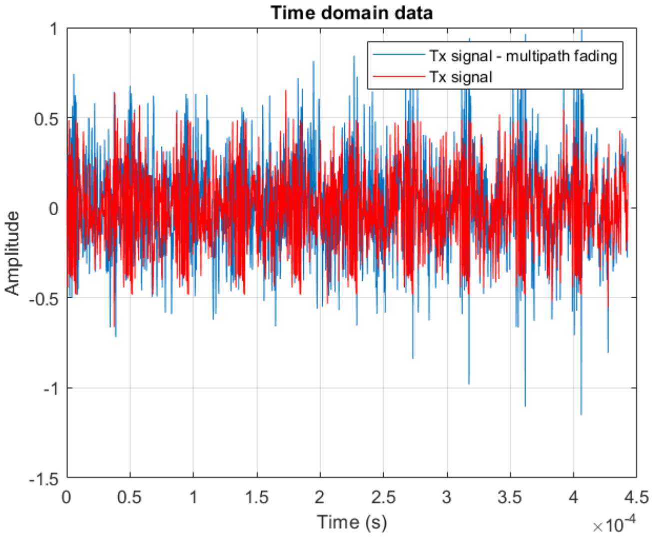
RESULTS

TRANSMITTER SIDE - TX CONSTELLATIONS



RESULTS

TRANSMITTER SIDE - TIME DOMAIN SIGNAL

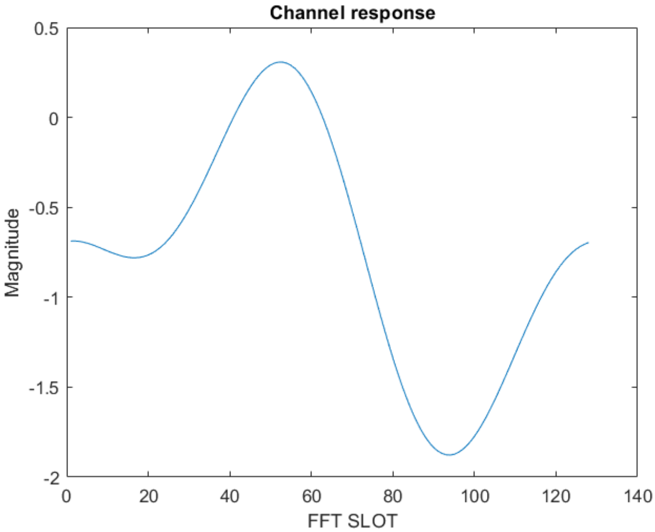


Results

Channel transfer function

RESULTS

CHANNEL TRANSFER FUNCTION



Results
Compensation

VRIJE
UNIVERSITEIT
BRUSSEL

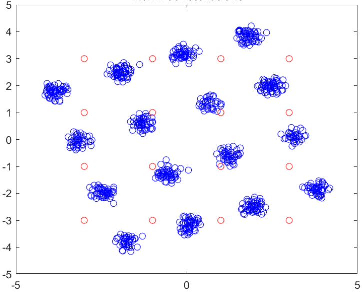
RESULTS

PHASE COMPENSATION

FREQUENCY OFFSET = 0; PHASE OFFSET = 20

WITHOUT PHASE TRACKING

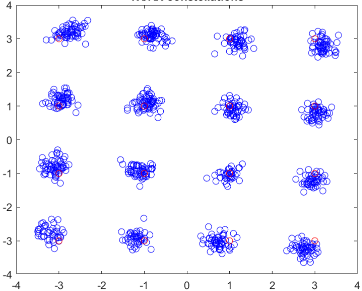
TX/RX constellations




```
tx data != rx data
>> main
```

WITH PHASE TRACKING

TX/RX constellations

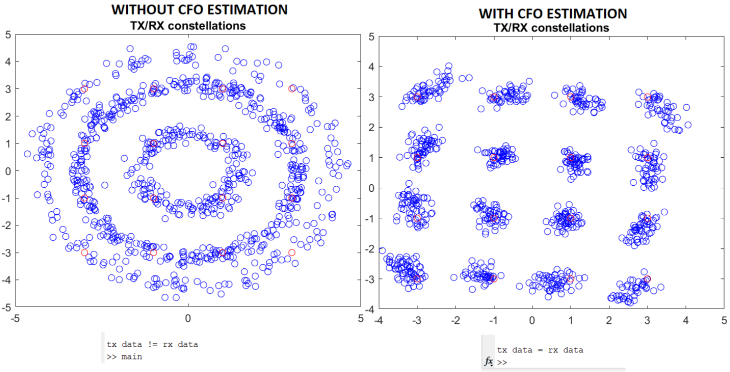



```
tx data = rx data
fx >>
```

RESULTS

FREQUENCY COMPENSATION

FREQUENCY OFFSET = 7000; PHASE OFFSET = 0;

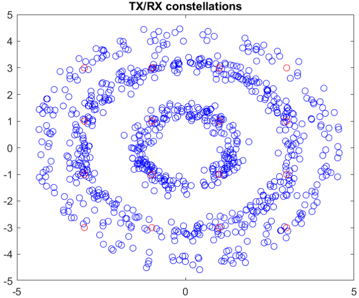


RESULTS

FREQUENCY AND PHASE COMPENSATION

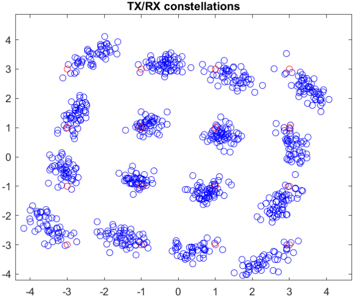
FREQUENCY OFFSET = 7000, PHASE OFFSET = 20

NO PHASE AND CFO ESTIMATION




```
tx data != rx data
>> main
```

WITH PHASE AND CFO ESTIMATION




```
tx data = rx data
>>
```

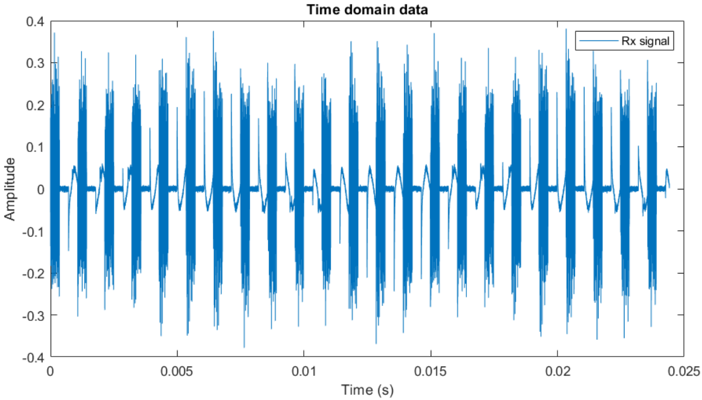
Results

Real world - TX signal

VRIJE
UNIVERSITEIT
BRUSSEL

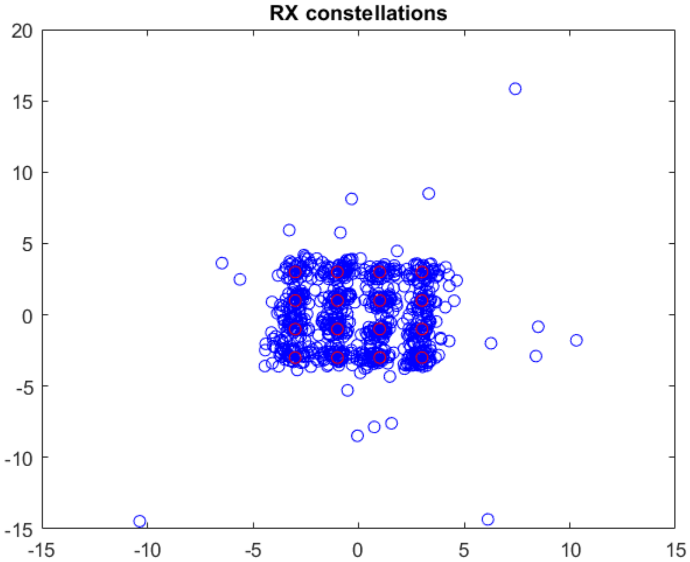
RESULTS

REAL WORLD - TX SIGNAL - SCENARIO 1



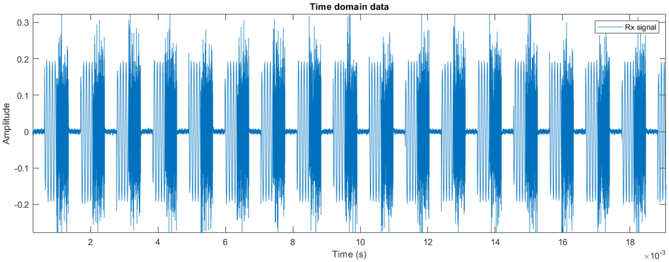
RESULTS

REAL WORLD - RX SIGNAL - SCENARIO 1



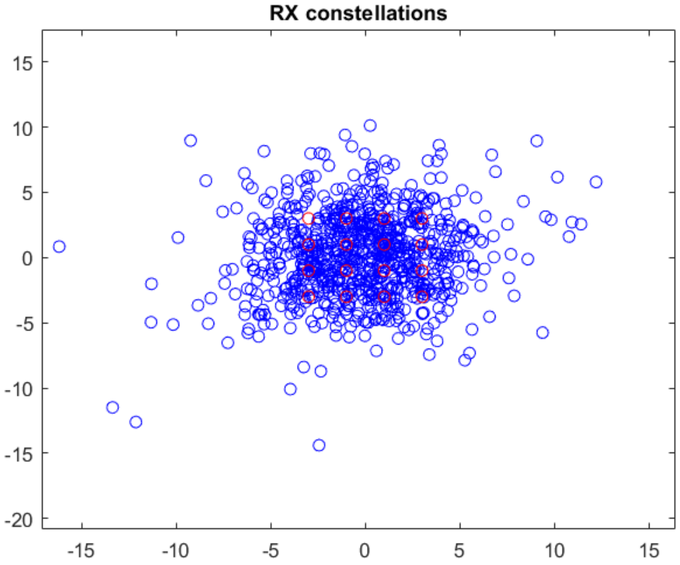
RESULTS

REAL WORLD - TX SIGNAL - SCENARIO 2



RESULTS

REAL WORLD - TRX SIGNAL - SCENARIO 2

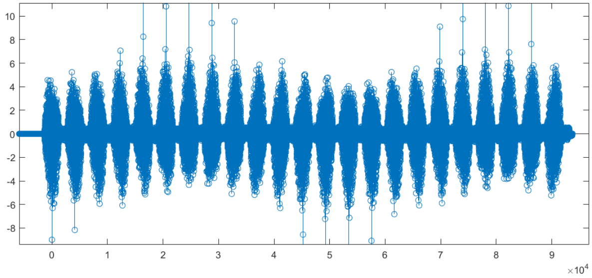


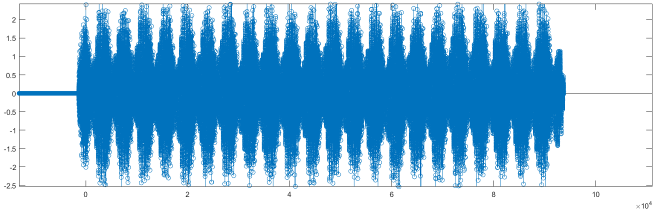
Results

Intepretation

VRIJE
UNIVERSITEIT
BRUSSEL

RESULTS
INTEPRETATION





Results

Tried but not worked

VRIJE
UNIVERSITEIT
BRUSSEL

MORE

TRIED BUT NOT WORKED

- Data coding (only TX part implemented but not used)
- Use preamble for channel estimation (not used in real world scenario)
- Get the real channel transfer function
- Use MMSE for channel estimation

REPOSITORY LINK

https://github.com/vladBaciu/SW_2020_Matlab_OFDM_simulation